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Uncontrolled Propagation of a Transplanted Aquaculture Catfish in Cuba and Its Utilization for Human Food

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Abstract

The effective utilization of invasive African catfish introduced for aquaculture and local promotion of Zapata swamp area, Cuba were discussed. The ecological traits of the catfish, mainly growth, age, sex ratio, maturity and food habits at Zapata swamp were investigated. To determine whether the catfish meat product was acceptable to Cuban people, a fish preference survey and tasting of some fish products were conducted. In addition, we observed the situations of fishing, processing and serving at a restaurant and operated a small-scale practice for this production. Together with the results, it demonstrated the high potential of the catfish in the Zapata swamp as a human food, but there are still plenty of problems to be addressed. To elaborate an active plan for promotion of the project, a scientific approach to many different fields - 'especially natural conservation, aquaculture and food science, and education for the workers about food hygiene and processing techniques -' is essential.

Keywords: catfish, *Clarias gariepinus*, Cuba, local promotion, Zapata Swamp

1. Introduction

The Republic of Cuba is one of the Central American countries located in the northern Caribbean Sea beside the Gulf of Mexico. The economy of Cuba used to rely on the socialist countries. However, because of the collapse of the Soviet Union and dissolution of the COMECON (Community for Economic Cooperation) in 1991, Cuban society was suddenly depressed resulting in a severe shortage of food. Subsequent U. S. legislation on the Cuban embargo further depressed the Cuban economy. The government being particularly concerned with the minimum safety net, adopted the policies of a food program, and then distributed the food ration cards, particularly targeting socially vulnerable groups in society. Furthermore the government promoted an urban agriculture to produce vegetables and tubers without using chemical fertilizers and pesticides

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but using natural insecticides and compost, because of the policy of no chemicals used in the modern agriculture available in Cuba (Pfeiffer, 2010). The urban agriculture so-called "the organopónicos" carried out by the people living in cities has supplied the products directly to the people in cities with minimum transportation related costs. The successful transition towards a sustainable society in Cuba has been an attraction for several decades and is introduced by many related webpages and books including those in Japan (Yoshida, 2002).

The graduate school and research division of "Kuroshio science" were established in Kochi University in 2004. "Kuroshio", one of the great currents in the world, greatly influences on the human culture of people, climate, natural resources, and the community of plants and animals in the many Southeast Asian countries. The aim of Kuroshio science is to study the sustainability mechanism of nature with people in the Kuroshio region through analyses of literature and field observations, and to look for new aspects of sustainable natural and human society for the future.

The Cuban society has been selected as a model towards a sustainable society in progress, and the first field observations were made there in 2005. We found there were several problems including an uncontrolled propagation of transplanted aquaculture of catfish (*Clarias* spp.). This caused a critical disappearance of endemic fish species such as Cuban gar (Manjarí, *Atractosteus tristoechus*) in natural water environments. Since then, we have focused on the invasive catfishes and looked for a possible solution.

In contrast to the success of agriculture mentioned above, animal protein production did not recover until the mid-2000, because no effective system was developed, such as the organopónicos (Pfeiffer, 2010). In 1999, a plan was drawn to introduce the catfish as a candidate for animal protein for human beings. At first, approximately 2,000 of African catfish *Clarias gariepinus* were received for scientific investigation from Malaysia. This species has advantages over other catfish species in aquaculture, because of its high growth rate and large weight of mature fish (reaching up to 60 kg). In the same year, 14 millions juveniles of two species of catfish, *C. gariepinus* and a macrocephalic Asian catfish, were imported from Thailand for commercial use (García and del Valle, 2006).

Over the last a few decades, four catfish species including *C. gariepinus* have been cultured commercially. In the Clara Villa province, in the center of the main island, there are three aquaculture farms for catfish, tilapia and the other fish. Technological developments for culture of catfish were implemented until 2004, and commercial production was started in 2007. The total production of catfish in these farms reached about 500 t in 2008 (Pinera, 2009). In connection with these activities, a national aquaculture center was established in Santa Clara, the main municipality of Clara Villa Province in 2009 (Rvta.ACPA, 2009).

On the other hand, catfish (mainly *C. gariepinus*) which have escaped from aquaculture facilities have now been found in a large number in natural environments throughout the country. Reasons for the possible escape of *C. gariepinus* might be due to heavy rains prepared by hurricanes Michelle, Isidore and Lily in 2001 and 2002 (Grogg, 2009). The uncontrolled propagation is caused by the various characteristics of catfish such as omnivorous feeding, fast growth and highly tolerance for meteorological conditions (Medero and Campbel, 2008). In some fresh and brackish water areas in Cuba, *C. gariepinus* has already become the major top predator and the biodiversity has been threatened by voracious catfish species. "Ciénaga de Zapata National Park", one of the Ramsar sites, has also been affected by this problem (García and del Valle, 2006).

2. Invasion of alien catfish in the Zapata swamp

The Zapata Biosphere Reserve, one of the nature reserve sites established by the federal government and recognized under the UNESCO's Man and the Biosphere (MAB) Programme, encompasses the entire peninsula of Zapata and the near coast lying the south of the Matanzas Province (Fig. 1). This is a National Park area mostly composed of marsh and mangrove regions (4,520 km^2) which is the largest protected area in the Caribbean. Many species of plants and animals, including some fish species such as Manjuarí (Cuban gar *A. tristoechus*) inhabit this region (Kirkconnell et al, 2005). In 2001, a catfish species, possibly *C.*

gariepinus, was first observed in the Lagoon of Treasure (Laguna del Tesoro) and Hatiguanico River of the Zapata swamp. Within several years, it has dispersed over the entire protected area (Grogg, 2009). Actually, numerous individuals of catfish were confirmed by our diving observations into the canal near the Lagoon of Treasure in 2005. At the same time, some fish and blind shrimp inhabiting the swamp decreased their number concomitantly. Yamamoto et al. (2012a) tried to clarify the basic ecological characteristics of the catfish in the Zapata swamp for two years after 2007.

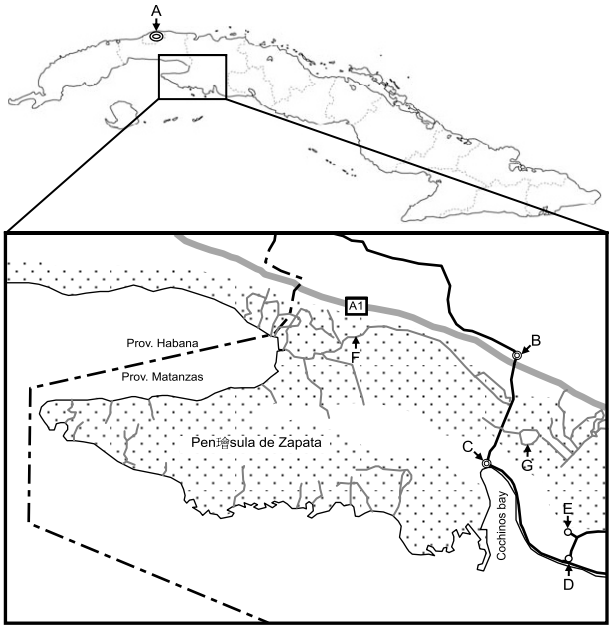

Fig.1. Location of Zapata Peninsula and the places mentioned in the project

A: Habana (capital), B: Jagüey Grande, C: Playa Larga, D: Playa Girón, E: Cayo Ramona, F: Hatiguanico River, G: Laguna del Tesoro

: highway (A1), : swamps, : rivers and canals

Based upon field observations from the end of October, 2007 to the middle of November, 2008 at the irrigation canal located at the east of Lagoon of Treasure using a gill net (mesh size: 55-90mm), longlines, and fishing, it was observed that the sexual ratio (male individuals/ female individuals) of 2.16 was obtained with a highest of 5.94 (October - November, 2007) and the lowest at 1.39 (June, 2008) using the total catch of 401 individuals. The maximum total lengths were 112 cm for male and 109 cm for female, and the minimum of 24.5 cm for male and 19.5 cm for female, although there was no significant difference in the total length (TL) between males and females at the 5% meaningful error using the Student's t-test. Approximate relationships between the TL and the body weight (TW) were $TW = 0.0091TL^{2.9153}$ for male (R^2 (coefficient of determination) = 0.9722, N = 274) and $TW = 0.0068TL^{2.9948}$ for female (R^2 = 0.9825, N = 127). Age structure varied from 0 to 8 years of age (Fig. 2), showing the highest share in four years for males (24.4%) and three years for females (20.8%). The growth of total length approximated by the logistic and the von Bertalanffy equations gave a better fitting in the logistic equation as follow.

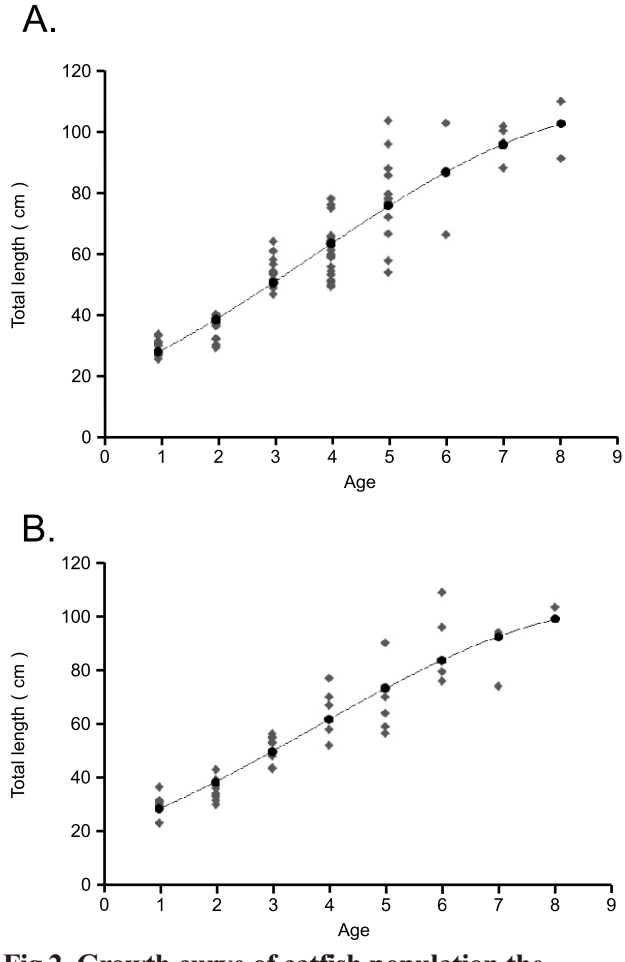

Fig.2. Growth curve of catfish population the caught in Zapata swamp (Yamamoto *et al*., 2012a). A: male, B: female. Diamond spots show the total length of each individual.

Male: $Lt = 113.9 / \{1 + exp [-0.45 (t - 3.47)] \}$
Female: $Lt = 121.6 / \{1 + exp [-0.38 (t - 4.01)] \}$
t , age in year; Lt, total length (cm) at t years

The estimated maximum total length using the above mentioned equations was obtained as 113.9 cm for males and 121.6 cm for females.

Both male and female catfish gave the highest GSI values ((weight of reproductive organ)/(total body weight - weight of reproductive organ)) in June (male: GSI = 0.14 ± 0.19, N = 63, female: GSI = 2.19 ± 2.58, N = 46), compared with two months of March and November (Fig. 3).

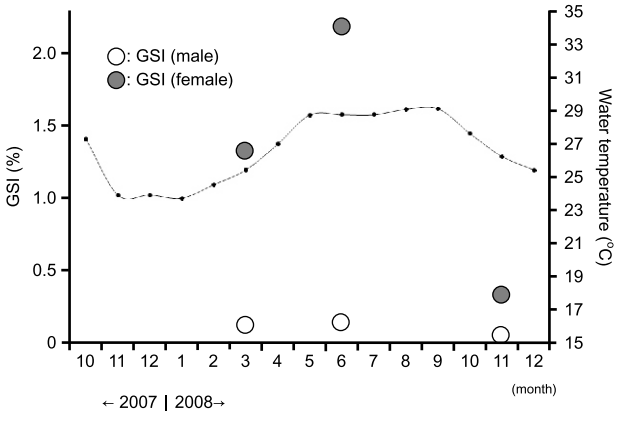

Fig.3. Seasonal changes in gonad-somatic index (GSI) of the catfish caught in Zapata swamp (Yamamoto *et al*., 2012a).
Solid line shows changes in water temperature.

According to the criteria for ovary maturation by Yalçin *et al*. (2001), the proportions of female catfish with ripe ovaries (stage 3- stage 6) were 34.4% in March, 59.1% in June and 8.1% in November. These results suggest that the gonad maturation occurs in the mid rainy season in the Zapata swamp. Among the captured catfish (N = 308), 67.9% of individuals had nothing in their stomach (N = 209). In the others (N = 99), the stomach contents were quite different depending on the fish sizes (Fig. 4). In the stomachs of small size catfish (N = 15, TL < 50cm), detritus (46.7%), plants (40.0%) and mollusks (20.0%) were found. The proportion of detritus in stomach content drastically decreased in the large size catfish (TL = 50-80cm: 8.3%, TL > 80cm: 0%). On the other hand, fish and turtles were found in the stomachs of middle and large size catfish. In some cases, Cuban killifish *Cubanichthys cubensis* and plastron of Cuban slider *Trachemys decussate,* endemic animals and juvenile catfish were found in the stomach.

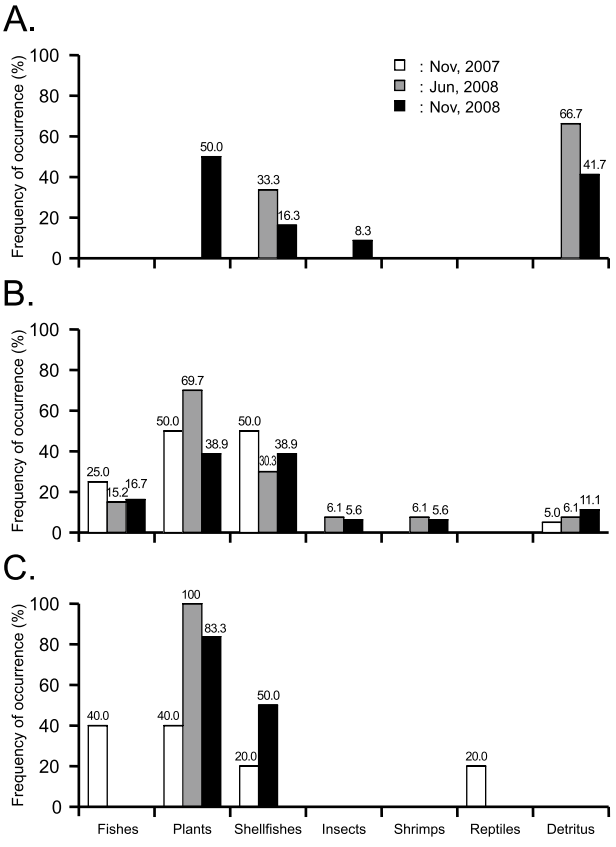

Fig.4. Occurrence frequency of prey items found in the stomach of the catfish caught in Zapata swamp (Yamamoto *et al.,* 2012a).
A: small (< 50 cm in TL, N = 12), B: middle (50 < x < 80cm in TL, N = 18), C: large (> 80 cm, N = 6)

The mean total lengths of 6 year old catfish, possibly *C. gariepinus,* were 85.1 cm for male and 88.8 cm for female in the Zapata Swamp. These are obviously larger than the ones found in the other areas, those ranging from 52.2 cm - 72.6 cm for males and from 53.0 cm - 72.8 cm for females (Buruton and Allnson, 1980, can der Waal and Schoonbee, 1975, Yalçin et al, 2002). These results suggest that the growth rate of catfish in the Zapata Swamp is relatively high. Together with its omnivorous feeding habits, the catfish is no doubt a threat animal in the aquatic ecosystem of the Zapata Swamp. Kirkconnell *et al.* (2005) have pointed out various ecological threats in the Zapata Swamp, and proposed necessary protections and managements, but they have not mentioned the species

names other than "clarias" possibly due to poor information on the invaded alien animals.

The production of catfish in dry season is much higher than that in rainy season (unpublished data, described more in detail in the section 4). In addition, many of the catfish captured in the dry season were not mature individuals. These facts load us to expect a possible effective management of catfish in the Zapata Swamp by removing them by promoting fishery, although it seems to be difficult to eliminate them completely from the Zapata Swamp because of their high vitality. According to the concept of the Zapata Swamp as "Biosphere Reserve" promoting a sustainable development by the local community efforts and sound science, we have proposed an appropriate fishery and the utilization of the catfish products.

3. Potential of catfish as foodstuffs in Cuba

In the first half of the 20th century (between the Independence of Cuba in 1898 and Cuban Revolution in 1959), the Cuban traditional old-fashioned Creole cuisine was characterized by the following: a high proportion of sugar and fat, few vegetables, the presence of bananas, sweet potato, yucca, rice, corn and beans, and a preference for pork meat over fish (Figueroa and Lama, 2010). At that time, the scale of the industrial fisheries in Cuba was relatively small and the products were mainly directed into the local domestic markets in the cities (Adams, 2000).

In the period of the post Cuban Revolution, four kinds of representative commercial fishery fleets were developed. Among them, "The Flota Cubana de Pesca (FCP)", a distant-water fleet mainly harvested low-valued pelagic fish such as mackerel and herring, and the products were intended for domestic consumption (Adams, 2000). Although the operational cost was considerably high, Cuba continued the FCP fishery depending on the inexpensive fuel oil supplied by the Soviet Union, but the pelagic fish catch drastically decreased in the 1990s after financial support. Specifically, the five year average of the pelagic fish supply before the Special Period (1986 - 1990) was 9.7 kg / capita / yr, but after the event (1992 - 1996), it became 0.5 kg / capita/ yr (FAOSTAT, 2012). In spite of the economic recovery in the mid-2000s, the supply level was still low (0.9 kg / capita / yr). Together with the historical facts, the latent demand for fish consumption by Cuban people could be expected. We performed the fish preference survey by general questionnaire and included tasting of some fish products including that made of catfish meat in Havana and near the Zapata Swamp (Yamamoto *et al*., 2012b).

Questions concerning preference for fish, the species names and the ways for cooking, the frequency for the meal, price, and recognition of the catfish were asked to the staff of the University of Havana (Univesidad de la Habana, N = 62) and the residents of Jagüey Grande (N = 22) by questionnaire methods. Fried fish ball and "Satsuma-age" (fried fish ball with vegetables) were prepared from catfish meat. The preference was confirmed by tasting of the products by the same respondents to general questionnaires and the staff of CITMA (Ministerio de Ciencia, Tecnologia y Medio Ambiente) in Zapata Swamp. In addition, preference for the catfish meat products were compared with preference for other kinds of fish meat products including "Kamaboko" (steamed "surimi"), "Chikuwa" (baked "surimi"), "Jako-ten" (fried "surimi"), fish sausages and crab sticks made in Japan.

More than 70 % of respondents preferred the fish and its related products but the frequency of eating fish and related products for a half of the respondents was fewer than 2 times per month. Table 1 shows the preferred fish species for Cuban people. Pargo *Lutjanus analis* was favorite fish species for about 30% of both respondents. In addition, the answers included many kinds of marine fish such as Cherna *Polyprion americanus*, Atun *Katsuwonus pelamis* and Jurel *Caranx crysos* or *Caranx latus*. *Clarias Clarias gariepinus* was listed only as freshwater fish. The popular cooking methods seemed to be Rebozado (fried in batter) and Aporreado (Creole style dish). About 80 % of respondents (asked only in Havana) felt the fish was expensive. The level of recognition of the catfish reached more than 90%. The tasting of fish ball and "Satsuma-age" indicated that most respondents felt these products to be good. On the other hand, the evaluation of Japanese products by some respondents

was relatively low although half of them answered that the products were good.

Many respondents preferred fish and many kinds of marine fish were listed as favorite species by general questionnaire. The results of our survey suggest that fish have a high potential to be used as human food in Cuba, but the high price and insufficient distribution seems to be a barrier to popularization. On the hearing survey, performed in advance, about the rumor of the catfish as a food, there were opinionsthat Cuban people dislike the fish because of its ugly appearance. However, the catfish was well known to the respondents and a favorite fish for some of them. To promote the utilization of catfish meat as human food, production of fish balls and "Satsuma-age" might be a better candidate rather than the processing similar Japanese products.

4. Preliminary feasibility assessment for catfish meat production in Zapata Swamp

The ecological characteristics such as growth rate, spawning season and feeding habits of the catfish in Zapata Swamp were partially elucidated. In addition, it was confirmed that there are latent demands for various kinds of fish as human foods in Cuba in spite of the low fish consumption until now. These results indicated the potential of the catfish in Zapata Swamp for important local resources as human food. To create a practical catfish usage plan, preliminary feasibility assessments on fishing, processing and cooking of the catfish in Zapata Swamp area were performed (Kubota *et al*., 2012).

Catfish fishing in Zapata Swamp was discussed at the meeting held on Nov, 2009. The actual circumstances at the catfish fishery were asked to the fisherman. To know the manufacturing process for preparation of fillet from catfish captured in Zapata Swamp, we visited the processing factory at Playa Larga. The style of serving the catfish fillet has been seen at the kitchen of the restaurant near the Laguna del Tesoro. Based on this observation, we have operated the small-scale practice for the preparation of catfish meat products with people concerned.

According to the statistics of catfish production in Zapata Swamp during 2007 - 2009 (until October, unpublished), the maximum monthly production was about 20 t in May, 2008. Generally, the productions in dry season were relatively high and the amounts were around 10 t / m, but dropped to less than 5 t / m in rainy season (July to September). The average weight was about 3 kg and sometimes individuals weighing more than 10 kg were found in the beginning of the dry season. However, the exact total haul from Zapata Swamp was unclear because there seemed to be unauthorized fishing and trading by some residents. The authorized fishing for catfish in Zapata Swamp was carried out by fisherman groups composed of several people. They have small fishing boats and usually go fishing for about a week. The catfish is captured by fishing and using a trap and the catch of fish is kept with ice on the boat until landing and delivered to the processing factory. The catch by unauthorized people can be also received but it is limited to the high quality catfish equivalent to the ice-stored one. We speculated that the heterogeneity of the quality depends on the season, but the seasonal variation in meat quality was not recognized by the fisherman.

A processing factory with a one-story structure had no air-conditioner, refrigerator or freezer. The train freight car, in place of freezer, for storing the fillet was about 10 m apart from the main building. There were two processing rooms provided with a large washing table, several sinks, and two electronic balances for weighing of fillet. Around 20 workers have been dealing with a maximum of 2 t of catfish a day. Any steps of processing such as decapitation, washing and filleting were simultaneously performed on the undistinguished work zone of the washing table. In regard to hygienic safety and efficient operation, it seemed to have many problems that should be dealt with and the important ones are listed as follows:

1. separation of working space between the contaminated area with raw materials and the clean area for processing fillet
2. establishment of processing flow from receiving the raw catfish to sending it out as fillet
3. standardization of the fillet products depending on the quality and sizes
4. thermal management of the processing room and freezer

A roadside restaurant in "Boca de Guama", the main tourist center of the Zapata Swamp, located

in the west of Laguna del Tesoro, was mainly serving cuisine to the foreign tourists. The catfish fillet steak was a representative dish in the restaurant but no other kinds of dishes were found in the menu. In the cooking in the kitchen, many skinless chunks were left with much dripping in the plastic container at room temperature. Developing the hygiene management is required in restaurant.

Small-scale practices for preparation of catfish meat (fish ball and "Satsuma-age") were performed twice in Playa Larga and Cayo Ramona in March 2011 and January 2012, respectively. At the first trial, the catfish captured the day before were kept in stagnant water with sediment. We advised to keep the catfish in freshwater because they had no experience of freshwater acclimatization of the fish before processing. To confirm the effect of the acclimatization, the taste and flavor of fish ball and "Satsuma-age" made of just captured and acclimatized catfish were compared for the second time.

Preparation of fish balls and “Satsuma-age” is described as follows. About 5 kg of skinnedmeat obtained from six catfish was passed through the portable mincer twice. Two point fivepercent of salt and five percent of starch were commonly added to the minced meat. In somecases when making “Satsuma-age”, finely chopped vegetables such as carrot, onion and smallpieces of garlic were mixed. The minced meat was ground and heated in boiling water or friedin oil at about 180-C. After our demonstration, the participants tried to prepare the products by themselves. Except for the simple boiled product including only salt and starch, all otherproducts were preferred by many participants. In particular, “Satsuma-age” with coconuts proposed by some participants appeared to be the best products for them. The disappearance of bad flavor in the products as a result of freshwater acclimatization was recognized by them.

During this preliminary feasibility assessment, we had been discussing about the differentiation strategy of catfish fillet and its product as a high-value regional resource. The freshwater acclimatization was one of the important subjects. In the stagnant swamp, there are many clear water springs which derived from the underground flow of the north mountain area. The captured catfish in the swamp can be kept in the fish tanks in the clear spring for acclimatization.

Other than fish tanks, there was a lack of any kind of infrastructures in Zapata Swamp area. For example, the cooking stove with charcoal heating was used in the restaurant instead of gas appliances. For the small-scale production, it might be applicable as a heat source, because it has strong caloric force and the cooks are able to control the temperature very well. However, a stable gas supply is essential to construct the production system for a guarantee of high quality products. Furthermore, clear water and electricity supplies, a facility for acclimatization and adequate refrigerators and freezers should be also provided for the same purpose.

5. Perspective

In March 2011, construction of a middle-scale factory for production of catfish products was proposed. However, we thought the plan should be fundamentally reconsidered to reduce the size of business, because there was no concrete plan with objective and effective business planning of sales forecasts. The initial demand prediction of catfish meat products was estimated. If it is simultaneously distributed to all children in this area as a school lunch, 150 individuals of 2 kg catfish must be provided daily, which corresponds to 100 kg of skinned meat at most. We concluded, therefore, that construction of a new factory was unnecessary, and that a detailed plan for the production at the handmade industry level needed to be started, because the initial production would require relatively small facility.

For planning this catfish project, regional advantage and diversified utilization of the raw material should also be considered. With respect to the regional advantage, it can be emphasized that possible consumption of catfish supports the conservation of precious ecosystems in Zapata Swamp. To make these products, Zapata Swamp is expected to increase the commercial value of the area as it has a high natural potential for developing ecotourism and social tourism (Martinez, 2012). Regarding the diversification, the abdominal part of the fillet would be a new material for catfish

steak with an elastic texture instead of skinless chunk with regard to the high fat and collagen contents and the ribless feature. Furthermore, there is a possibility that the raw material for extraction of astaxanthin and its related compounds, meat pigments that have antioxidant function, because the meat color of some catfish showed yellowish red.

The purposes of this catfish project are promotion of local Zapata Swamp area with utilization of the invasive catfish and sustainable conservation of natural resources, but not an effective production of catfish meat products only for the food supply in Cuba. To elaborate the active plan, scientific approaches for many different fields especially natural conservation, aquaculture and food science, and education for the workers about food hygiene and processing techniques are essential. Furthermore, development of this project would be supported by organizing an integrated higher education and research system of related fields in Cuba. Together with detailed research in the social system, regarding local promotion politics and preference of people in Cuba. and the use of Japanese technology, experience and view points, creation of the system is expected to bring a new integrated science of fisheries as a case study in Cuba.

Acknowledgments

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Table 1. Fish names and species preferred by Cuban people.

Fish name	Scientific name	(%)		
		Jagüey Grande (n=22)	La Habana (n=62)	Total (n=84)
Pargo	*Lutjanus analis*	31.8	27.4	28.6
Cherna	*Polyprion americanus*		19.4	14.3
Atun	*Katsuwonus pelamis*		17.7	13.1
Jurel	*Caranx crysos*		12.9	9.5
	Caranx latus			
Bonito	*Euthynnus alletteratus*		11.3	8.3
	Sarda sarda			
Claria	*Clarias gariepinus*		6.5	4.8
Pez perro	*Lachnolaimus maximus*	9.1	6.5	7.1
Sardina			6.5	4.8
Sierra	*Scomberomorus cavalla*		6.5	4.8
	Scomberomorus maculatus			
Aguja	*Makaira nigricans*		4.8	3.6
Emperador	*Xiphias gladius*		4.8	3.6
Merluza	*Merluccius gayi gayi*		4.8	3.6
Sobaco	*Balistes capriscus*		4.8	3.6
Salmon	*Elagatis bipinnulata*		3.2	2.4
Cubera	*Lutjanus cyanopterus*	4.5	1.6	2.4
Picua	*Sphyraena barracuda*	9.1		2.4
Biajaca	*Nandopsis tetracanthus*	4.5		1.2
Mojarra	*Diapterus auratus*	4.5		1.2
	Diapterus rhombeus			
	Eucinostomus argenteus			
Robalo	*Centropomus ensiferus*	4.5		1.2
	Centropomus undecimalis			
	Centropomus parallelus			
Sabalo	*Megalops atlanticus*	4.5		1.2
Marine fish		27.3	19.4	21.4
All fish		27.3	21.0	22.6
Fish with white meat			3.2	2.4
Boneless fish			1.6	1.2