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Strategic Study for Sustainable Development of Freshwater Aquaculture in Camagüey

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ABSTRACT

A strategic study of biological-fishing behavior of the main variables determined for extensive freshwater aquaculture was made in facilities of the Camagüey Fishing Company, province of Camagüey, Cuba. The purpose of the study was to evaluate the organizational insertion within the current Cuban social and economic scenario. Several variable sequence graphs were made, and the degree of dependence and ratio among them was determined through the Pearson coefficient. The highest sustainable catch was also calculated, and the state of technical and productive facilities was evaluated as well. Therefore, it was concluded that the current situation of aquaculture does not favor sustainable development, though a number of priority actions were identified: renovation of technical and production facilities, strategic orientation of the fishing efforts in all the water reservoirs, and diversification of fishing productions.

Key words: *extensive culture, fishing management, fishing yields, fishing efforts*

INTRODUCTION

Aquaculture is a food producing activity that depends on ecosystems or managed sites (Knowler, 2008), which is associated to strategic planning and sustainable development. It is one of the fastest growing sectors of food production, with 50% of the world fish supply, and one of the major economic activities of this century (Pérez, 2014).

Cuban freshwater aquaculture was originally linked to the construction of dams and reservoirs, and the introduction of important commercial exotic species. In 1990, Cuba ranked third in fresh water fish production in Latin America (Vilamajó, Vales, Salabarría and Guzmán, 1997). For decades, several development programs were designed to increase quality and quantity; however, these highly centralized strategies lacked comprehensive studies of potential, and business strategy to adjust development policies to real and complex issues of social development (Peña, 2006).

Today, the new economic model laid out by the Guidelines of the Communist Party of Cuba (2016) recommends the application of modern culturing techniques to develop aquaculture, with high technological discipline and genetic breeding. The goal is to re-invigorate the fishing industry and increase supply, variety, and quality of productions in the domestic market.

Likewise, Law No. 118 of Foreign Investment (2014), opens new opportunities oriented to diversification and broadening of export markets, access to state of the art technologies, and import substitutions, particularly of foods.

Development as a reality responds to an array of human demands according to the historic moment, when government and supranational policies modify the scientific and technical relationships of a country, in concert with its internal components (González, 2005).

The development model for the fishing sector has focused on environmental, social, and economic sustainability, encouraging preservation of environmental and natural resources (Álvarez, Tello, Tello and Campos, 2008).

In that sense, research requires information processing on the biology of major resources, whose exploitation could be assessed more accurately for sustainable use and preservation (De León *et al.*, 2015). The aquaculture strategic prospects are based on ecological and environmental variables, and the relationships set among them.

Estimations and predictions in fishing is a complicated art, because their main elements are biological phenomena that take place in a scenario where scientific observation alone is forbidden. Therefore, several mathematical models have been suggested, such as Schaefer´s static model, the most commonly used. It states that under conditions of exploitation, catches are perceived as a dependent variable of fishing effort and population biomass over time, provided the population is balanced (Seijo, 1997).

Population balance lies in the equivalence of individuals that die or are caught, and the ones born or incorporated through artificial repopulation. Therefore, there is a correspondence between biomass and catch. It is expressed by the catching coefficient, which is the fraction of the population caught by an effort unit, and equivalent to yields or productivity of man in water or catch per effort unit (CPEU), the most widely used dependent variable in terms of fishing efficiency. Thus, considering the existence of the standard fishing efforts and repopulation over time for certain effort level, then the catch rate will be equal to the growth rate. Accordingly, every effort level will have a balanced population (Seijo, 1997).

The Fishing Company of Camagüey (PESCACAM), is known for its high productions (more than 5 000 tons of fish for two straight years), and one of the leading companies in Cuba. Nevertheless, it requires a strategy of freshwater aquaculture development to take advantage of the new business opportunities in Cuba. In that sense, the company will have to engage in research, organization, management, control and regulation to achieve sustainable development of freshwater aquaculture resources, and promote processes and actions to identify new prospects and implement them (Parrado, 2012).

PESCACAM freshwater productions are based on two main methods of fishing: intensive and extensive; the latter (96% of total catches) is the object of this study. It is based on polycultures of cyprinid fish which fill several niches in the trophic chain within the same reservoir. Cultures of different species in the same system offer improved production possibilities (Luchini and Panné, 2008), due to optimization of nutrient consumption per water unit, less environmental pollution, and water eutrophication.

Extensive cultures associated to the basic management model known as repopulation and culture, takes place in reservoirs and is linked to traditional fishing practices (Rodríguez and Yánez, 1994). It repopulates cyprinid populations at a rate of 2 500 fries/ha, using passive fishing gears (different mesh lengths and heights), and active gears (nets and combined fishing tackles).

The aim of this paper was to conduct a strategic study of the biological-fishing behavior of the main variables that take part in the extensive aquaculture production in PESCACAM, in order to evaluate the possibilities and obstacles for insertion into the new scenarios.

MATERIALS AND METHODS

This research was based on strategic evaluation of the main variables associated to aquaculture production at PESCACAM, particularly, extensive culture, between 1986 and 2015. The database used was provided by PESCACAM´s production records.

The variables used were total and annual catches (kg), annual repopulation of commercial species (thousands of fries), annual fishing effort (men/fishing days (MFD)), catches per effort or annual productivity per man (kg/M). Each variable was studied individually to monitor time behavior, and the relation and dependence among them were studied. Data subgroups were also set up according to the annual periods and reservoirs, and were analyzed individually.

Additionally, local reservoirs and hatcheries were monitored to make updated inventories in each company branch, of logistics, productive infrastructure, and accessibility to fishing areas, social and economic scenarios, market prospects, and other factors that may influence the quality of production processes in aquaculture. The main results were statistically analyzed.

Every calculation and tabulation were made using Microsoft Office Excel, 2007 (2D graph), to show the sequence of variables along the years. Pearson correlation was determined to check the relation degree among variables.

For better understanding, two annual periods were established, according to the variety of species caught (1986-1997 and 1998-2015), and two subgroups of reservoirs (main reservoirs and secondary reservoirs). Every calculation was repeated in each subgroup.

Lastly, the maximum sustainable catch (MSC) in the province was estimated and compared to the annual curve of total catches. To calculate the maximum sustainable catch (C), optimum effort (F), and optimum fishing yields (CPUE), the independent variable (x) used was fishing effort (HDP); whereas the dependent variable (y) was fishing yields or catch per effort unit (CPUE). Achieving the regression equation between the two variables

The maximum sustainable catch (MSC), optimum effort (OE), and optimum fishing yields

(OFY) were calculated on spreadsheet (Microsoft Excel).

RESULTS AND DISCUSSION

Catch

The catch sequence described cycles of approximately 5-6 years; the high and low years frequently alternated between 3-4 years. Some cycle irregularities were observed in 1997 and 1998, perhaps due to low catches; however, catches were reported high.

That irregularity was caused by the low levels of water in Jimaguayú dam, which forced the company to perform intensive fishing for two years to catch the largest possible amount of biomass from the reservoir. This event evidenced that the graph drawn by the catches in the form of natural cycles may be influenced by anthropogenic factors, or even be oriented by a strategic-productive will.

Species analysis in the catches (Fig. 2) showed the existence of two periods: mostly tilapia (1986-1997), and mostly tench (1998-2015).

Another species, bagres, was extensively caught by 2001, after introduction in Cuba from Malaysia and Thailand for isolated culture at the Mamposton Experimental Station, first, and then in other provinces, including Camagüey. However, this species accidentally spread throughout the country after floods caused by hurricanes Michelle, Isidoro, and Lily, in 2001 and 2002, and also due to malpractice. The Cuban dam system is cascade-like, allowing for inter-dam communication through stream, canals, rivers, etc., especially during the rainy season.

The transition in the composition of caught species in both periods was favored by technological transference, which contributed to the introduction of fishing gears fit for cyprinids, which made larger catches of succeeding artificial repopulation of species in reservoirs. Additionally, the culture of tilapia was abandoned in extensive practices. In that sense, Seijo (1997) acknowledged that increases in the catching power or more technical fishing might cause unbalances in the structure of the fish biomass.

Moreover, total catch was determined by the output of the 13 most productive reservoirs in the province: Jimaguayú, the best in Camagüey (35 %), Santa Ana, Amistad Cubano-Búlgara, Najasa I, Najasa II, Muñoz, Caonao, Hidráulica Cubana, Máximo, Atalaya, Durán, La Jía and Porvenir (Fig. 3). The correlation coefficient accomplished between the two variables was 0.850. This result offered a selection criterion for strategic and productive priorities.

Fishing-catch effort per effort unit

The fishing effort or man/day/fishing (MDF) (Table 1) and the catch index per effort unit (CPUE) accounted for 63 044 t caught in 1986-1997, using1 065 617 men in water; with yields of 59 kg/M, averaging 101 water reservoirs in 12 years. In 1998-2015, 76 911 t were caught using 1 265 048 men/fishing days, 61 kg/M, averaging 57 water reservoirs.

Concerning the catch and fishing effort ratio, the calculation of the correlation coefficient was 0.404 for the two variables. However, individual calculation of Jimaguayú dam produced 0.645, indicating that this reservoir played a major role in the province, in comparison to the rest of main reservoirs, with 0.193. The correlation indexes for the two periods showed that the 1986-1997 catch index was 0.323, whereas in 1998-2015, it was 0.247.

The fishing effort did not correspond to the results of correlation coefficients, though it is the best independent variable, with the highest strategic connotation in fishing, and sensitive to organizational measures to prevent excess catch and fishing effort. It also intends to make sure that freshwater fish populations are cost-effective (Arias and Pezet, 1996). This issue demonstrated that human resource management in the organization, particularly the fishing effort, was not oriented to rational use of aquaculture resources, and may at some point lead to overexploitation of the reservoir that causes depletion of the fishing potential.

Repopulation

The third variable, repopulation of commercial species in the reservoirs, (Table 2), showed remarkable differences in both periods: in 1986-1997, 166.5 million fries were sown, including 101.1 (61%) of tilapia and 65.4 (39%) of cyprinids; in 1998-2015, 457.3 million were sown, including 50.8 (11 %) of tilapia and 406.5 (89 %) of cyprinids. Species composition was inverted favorably in the second period. Tilapia exploitation began in 2007 intensively in floating cages, so repopulation of this species was not made directly in the reservoirs.

After repopulation-catch analysis, the correlation coefficient among cyprinid populations and their catches was 0.549, considering tilapia reproduces naturally, unlike tench.

Calculation of the maximum sustainable catch (MSC) in current freshwater exploitation conditions

To analyze the interaction of the main variables under today´s aquaculture conditions for strategic purposes, the choice was to calculate the maximum sustainable catch (MSC) of the province as a comparative standard of the varying behavior of catches.

Also important was the natural reproduction in tilapia; hence, the growth of its population was continuously fostered by fry repopulation. Tench is not reproduced in Cuban reservoirs, so its population depends on repopulation and the large size of the species.

The maximum sustainable catch was 5 146.5 t. The optimal effort was 89 882 men in water, and the optimal productive yield was 57 kg per men in water.

Considering that MSC was 5 146.5 t, Fig. 4 shows for the two periods that when the catch was near or higher that figure, the succeeding years had lower indexes.

The previous was increased by other variables, like the number of reservoirs used, and climatic variability produced by extreme cyclical events (ENOS, hurricanes, etc.).

These results revealed that the current management of variables that intervene in processes of freshwater aquaculture production does not allow a steady catch increase, which can promote organizational development; on the contrary a decreasing trend was observed.

Another very important aspect is that fish production based on a particular species does not favor sustainable production increases, which has been demonstrated by cyclical fluctuations in the catches of the two periods studied. This situation was different from the studies made by Arias and Pezet (1996), who suggested letting the threatened or extinguished species recover, and make active interventions to reinstate them, when necessary.

Results of territorial monitoring of reservoirs and hatcheries

A total of 60 reservoirs were monitored to acquire a general vision of the current state of their infrastructure for production (Table 3.).

The figures showed that despite the occurrence of a favorable social and economic scenario due to the existence of nearby settlements, the fishing infrastructure and accessibility of fishermen may hinder further development.

Evaluation of the use of hectares for culturing and growing of repopulation fries revealed that only 45.6 ha out of a total 120.1 ha are exploited today; the other 64.5 (54%) need major repair.

It is important to note that working at full capacity, the hatcheries could produce 10 g heavier species, whose survival indexes and development would be higher when released into the reservoirs. The alternative to cover today´s demands (50 million fries) for extensive culture, is to release smaller fries (2.5 g). This situation affects the quality of seeds planted in the reservoirs, thus limiting the availability of replacement biomass needed to increase the productive levels and sustainability of catches.

CONCLUSIONS

The analysis of the main variables involved in the production-collecting process of PESCACAM, catching, fishing effort, and repopulation of commercial species, along with maximum sustainable catch (MSC), optimal effort (OE), and fishing yields (FYD), evidenced the company´s limited capacity under the current production system and management to accomplish sustainable productions of freshwater aquaculture.

The top priority actions to manage development in aquaculture and sustainability were identified: renovation of productive infrastructure, strategic orientation of the fishing efforts in all reservoirs, and diversification of all fishing productions.

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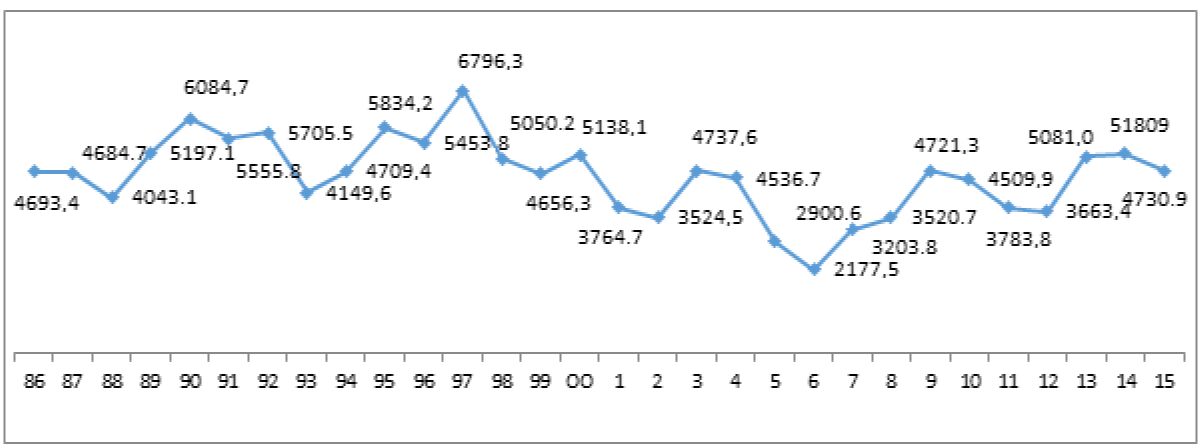

Fig. 1. PESCACAM annual catches (1986-2015).
U/M Ton
Source: Provincial Records Office of Aquaculture Development.

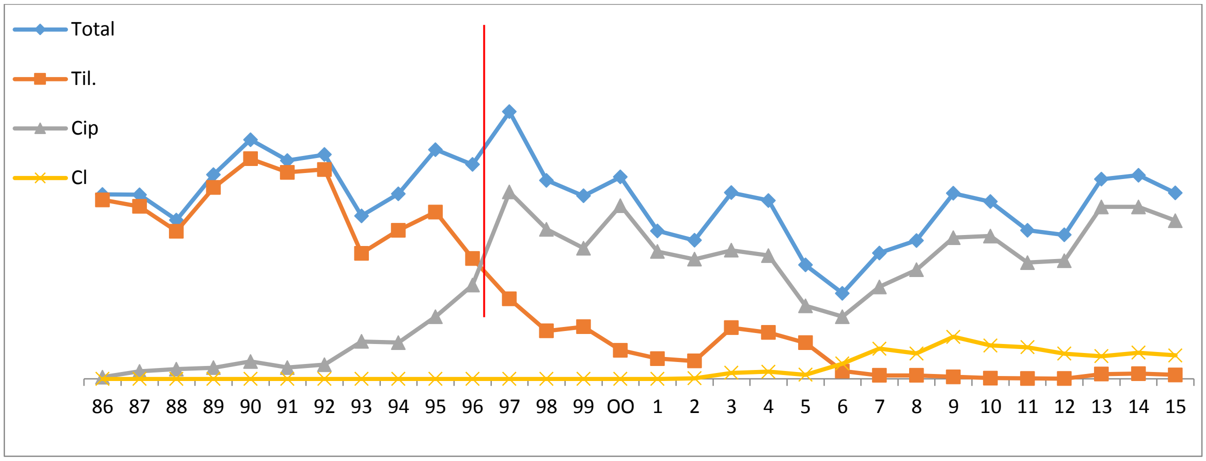

Fig. 2 Fig. Catches of commercial species in the two major periods
U/M Ton Til. (Tilapia), Cip (Tench), Cl (Bagres)
Source: Provincial Records Office of Aquaculture Development.

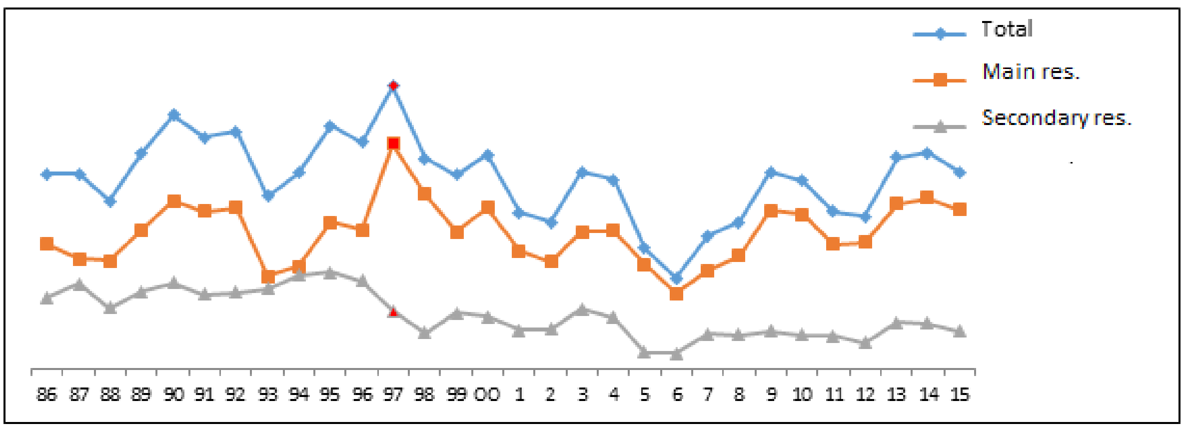

Fig. 3 . Graph comparing the catches: total, main reservoirs, and other reservoirs
U/M Ton
Source: Provincial Records Office of Aquaculture Development.

Table 1.Fishing yields in both major catching periods

	Fishing yields			
Years	Catch (t)	HDP	CUE (kg/men)	Average of reservoirs exploited
1986-1997	63 043	1 065 617	59	101
1998-2015	76 910	1 265 048	61	57
Total	139 953	2 330 665	60	78

Source: Provincial Records Office of Aquaculture Development.

Table 2.Repopulation by species in the two major catching periods Source: Provincial Records Office of Aquaculture Development. (U/M Millions of fries)

Period	Repopulation by species			Total %	
	Tilapia	Ciprinids	Total	Til,	Cip,
1986-1997	101.1	65.4	166.5	61	39
1998-2015	50.8	406.5	457.3	11	89

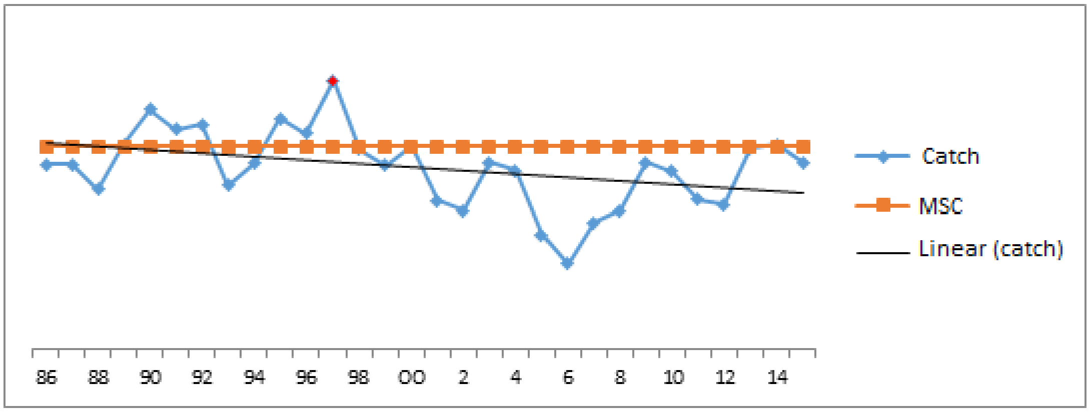

Fig. 4. Comparison of PESCACAM total catches and the maximum sustainable catch calculated as catching timeline. U/M Ton
Source: Provincial Records Office of Aquaculture Development.

Table 3.State of productive infrastructure in the reservoirs and the fishing areas

Monito-red re-servoirs	Location			Conditions of the reservoir								Construction needs		
				Status				Accessibility						
	Nearest settlement	Distance (km)						Road		Dirt road				
		1-10	11-35	B	Weeds	Obs-ta-cles and weeds	Low vol.	Amount	km bad state	Amount	km bad state	Ho-mes	Busines-ses	Free-zers
60	49	49	9	28	11	17	4	19	25.2	41	149.5	56	4	43