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RIVER DAM EFFECTS ON CUBAN FISHERIES AND AQUACULTURE DEVELOPMENT WITH RECOMMENDATIONS FOR MITIGATION

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Abstract

Dam construction in Cuba and their use for freshwater aquaculture development are explained. Some of the environmental impacts of Cuban freshwater reservoirs, particularly in fisheries, the salinization of coastal lands, and effects on marine fisheries, are reviewed and analyzed. Some argumentation and explanations given are in response to remarks on the impact of Cuban dams on species composition of reservoir fishery landings and on coastal marine fisheries. The main impacts of dams are on estuarine and adjacent coastal lagoons. The reduction (85%) of freshwater flow over coastal lagoons had increase salinity in more than 15‰, temperature (about 4-5°C), sedimentation (50-60%), and has decreased nutrient inputs. However, the nutrient concentrations of coastal waters are still at the mesotrophic level and the influence of underground water and increased urban and industrial effluents to more than 160,000 tons/year are suggested as possible additional nutrient sources. The main impact of dams on coastal waters are on coastal lagoons and river deltas, with negative consequences for the fishery of several euryhaline species, although is not the principal cause of the decrease of marine fishery landings. River dams have also accelerated the natural ageing process of coastal lagoons, especially because their sediments are not removed in the absence of river floods. Several practical actions are recommended to mitigate the negative effects of dams and to increase fish production in freshwater reservoirs and coastal lagoons. A polyculture program is recommended, based on the integrated "Vallicoltura" system principles to rehabilitate coastal lagoons, including the use of mechanization to remove bottom sediments.

Keywords: aquaculture, coastal lagoons, dams, environmental impacts, "Vallicoltura"

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1. Introduction

During the past three decades the total world fishery catch yields have been stable at about 90 million tons (FAO, 2012a) and production is expected to decrease in the future (Brugère and Ridler, 2004; Muir, 2005; Pauly, 2010; Pauly and Froese, 2012). While the wild fish landings have steadily declined for about 400 species, now with less than 10% of their historical landings (Pauly and Froese, 2012), world aquatic production has continued increasing, due to the extension of all types of aquaculture methods during the same period (FAO, 2012b; Muir, 2005). Fish production in Latin America and the Caribbean has a similar situation regarding the tendency of the world capture fisheries, although it has been declining since 1994 (Wurmann, 2010), while aquaculture productions have increased about 9.5 times from 200.5 to 1,909.5 thousand tons between 1990 and 2010 (FAO, 2012a).

Cuban aquaculture is mostly based on extensive and semi-intensive production in freshwater reservoirs, built primarily for irrigation and water supply to industries and cities, while showing less than

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half of the growth observed in the region during the same period (FAO, 2012a).

In Cuba, marine fishery landings have declined considerably, from about 250,000 to 24,000 tons between 1986 and 2010 (FAO, 2012a), due to the cessation of operations of the international fleet (between the years 2000 and 2001) and to an important decrease in coastal landings. The coastal fisheries have declined due to multiple factors, including natural as well as human actions. The most important natural factors are the extreme hydro-meteorological events (Houde, 1977; Puga et al., 1992; Salas et al., 2006; Wulff, 1995). Negative human actions include overfishing, inappropriate fishing gears and methods, excessive river damming, illegal fishing, pollution, as well as the construction of several causeways between keys and the main island in more than 200 km of the northern central coast line (Fernández Márquez and Pérez de los Reyes 2009; García, 2012; Serrano-Méndez, 2007) (Fig. 1). However, according to Jackson et al. (2001), ecological extinction caused by overfishing precedes all other pervasive human disturbances to coastal ecosystems, including pollution, degradation of water quality, and anthropogenic climate change.

Annual aquatic food consumption rate in Cuba has been estimated as 8.7 kg per capita, which was half of the world's per capita consumption in 2011 (FAO, 2012b). This figure is even more significant, because Cuba has imported an annual average of 50.8 million USD of seafood between 2007 and 2010 (ONEI, 2011). The above situation is unacceptable, considering that Cuba is an archipelago, with a marine shelf area of nearly 68,000 km^2 (Fernández Márquez and Pérez de los Reyes, 2009), slightly higher than the Cuban total arable land area, which is of about 66,200 km^2 (ONEI, 2011), with a lengthy and rough coast (5,746 km), while also having an area for freshwater reservoirs of 1,450 km^2 at their average water level (INRH, 2005). Cuba is an archipelago located in the Caribbean (19°51' - 23°17' N and 74°8' - 84°56' W), with a total area 19 109,886 km^2, including two main islands, Cuba (107,467 km^2) and the Isle of Youth (2,419 km^2). Furthermore, there are more than 1,600 smaller islands and keys. The length of the main island of Cuba is 1,250 km, with a maximum width of 191 km and a minimum width of 31 km, positioned from East to West, with slow flowing rivers that are short and narrow, which run from inland sites to the northern or southern coasts. (Acevedo, 1980; Fernández Márquez and Pérez de los Reyes, 2009) (Fig. 1). Cuban climate is classified mostly as tropical humid seasonally, with two main seasons, one dry winter (November to April) and another as rainy summer (Fernández Márquez and Pérez de los Reyes, 2009).

The construction of freshwater reservoirs and inter-basin transfer schemes have been required to address the world's growing demands for freshwater resources, often with little regard on their impacts on estuarine and coastal fisheries (Erzini, 2005; Walker, 1985). Environmental impacts of river dams and other barriers have been studied in many countries in the last three decades, and a summary of some of the major impacts are: i) the reduction of the amount of freshwater entering estuaries, coastal lagoons, and coastal waters with negative salinity regimes; ii) reduction of water flow; iii) excessive seaward sedimentation, forming mudflats and sand banks below dams; iv) altering migration patterns of aquatic organisms, mostly fish and invertebrates; v) negative influence on amount, growth, and mortality of most estuarine species, as well as those species that spend part of their life cycle in estuarine and coastal lagoon systems; vi) the reduction of nutrient export from river to coastal lagoons, adjacent salt marshes and mudflats and from these to coastal waters; vii) declines in landings of economically valuable species, especially those showing varying degrees of estuarine dependency (Gillson, 2011; Lindén, 1990; Meybeck, 2003; Rosenberg et al., 2000; Sklar and Browder, 1998; Wadie, 1982; Wells, 1999).

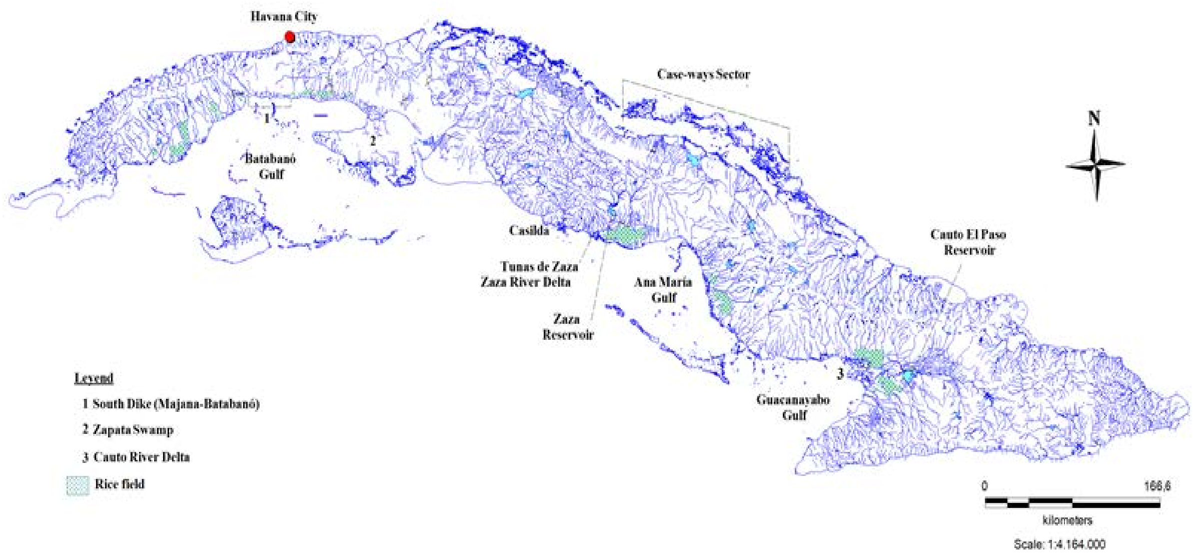

Fig. 1. Cuban archipelago, showing most of the general geographic characteristics, including rivers, dams, as well as the main sites and regions cited in the present review (González Alonso et al., 2012)

The basis of the present study was to analyze the implementation of sustainable activities, including water resources management and utilization, considering national priorities, and the impacts on fisheries and aquaculture. According to the Cuba's environmental policy, the eco-systemic approach must prevail over the sectorial approach (Fernández Márquez and Pérez de los Reyes, 2009). However, the country's damming policy is considered to be mainly sectorial. In the study we adopted the definition of sustainable development as that of FAO (1997), which explains that the management and conservation of natural resources, and the technological and institutional changes, must be carried out in such a way as to assure that human requirements are reached and maintained now and for the future generations.

The objective of the present review is to analyze the negative impacts of dams, as well as their contribution to the ecosystem-based management strategies for fisheries and aquaculture development in Cuba. We especially analyzed and assessed the claims that river damming program is responsible for the change in freshwater reservoir species composition and also the drastic decrease in coastal fisheries by retaining most of the nutrients, thereby limiting their availability in coastal waters. The remarks in this case have produced a distorted picture of the results of Cuba's damming program to high level governmental officials as well in other countries, by distracting their attention and omitting the true main cause of those negative events (Fernández Márquez and Pérez de los Reyes, 2009; Gillson, 2011; Muñoz-Nuñez, 2009; Valle et al., 2011).

2. Cuban dam construction program and freshwater aquaculture development

As Cuban hydraulic resources were limited, an important dam construction program called "Hydraulic will" was established in the early 1960' to mitigate strong and prolonged drought occurring in 1961-1962 as well as devastating floods due to on strong hurricane. This program was based on a national dam construction program, as well as a working principle: "Not a single freshwater drop to the sea" (Caballero Hernández, 2009), a slogan or purpose similar to that expressed thousand years ago by Parakramabahu, the Great Sinhalese King of Sri Lanka (1153–1186) as reported by Gillson (2011). Since then, most of the Cuban rivers have been dammed, building 239 large (more than 3 hm^3) freshwater reservoirs and more than 800 small to medium size reservoirs (INRH, 2010), thereby avoiding flooding as well as using them form irrigation and freshwater supply for urban and industrial purposes. In addition to these three main objectives, freshwater reservoirs are also used for hydropower generation, aquatic sports, and aquaculture practices (Alvarez-Lajonchère, 1983). Cuban river dam program has been very important in agriculture, as a required step for the country's economic and social development, leaving only 11.3% of the hydraulic resources unregulated; in spite of this asset, the limited knowledge and capacity to assess the main interrelationships, have led to sectorial policies instead of integral answers (Fernández Márquez and Pérez de los Reyes, 2009).

The use of these freshwater reservoirs for fish production in Cuba were not considered in their design and construction, and their bottoms were not cleared from obstacles, thus, fishing methods are limited, the fishing gear used in reservoirs must be artisanal, mostly gill nets, set nets, surface seines and in very few areas, beach seines. The main aquaculture practice in Cuba's freshwater reservoirs has been an extensive culture system based on the hatchery production of freshwater juveniles of introduced species, such as tilapias (*Oreochromis* spp.), Chinese carps (mostly silver carp *Hypophthalmichthys molitrix*, and bighead carp *Hypophthhalmichthys nobilis*), and common carp *Cyprinus carpio*). They are stocked in reservoirs, and fishery operations are established after a few years with restocking actions. Starting in the 1980's, semi-intensive and intensive systems have been also applied (Alvarez-Lajonchère, 1983; Díaz et al., 1989). The semi-intensive methods have been carried out in some small reservoirs that are almost completely drained to produce an annual harvest, while applying inorganic and mostly organic fertilizers to increase the natural productivity and stocking densities are high, producing high yields of between 1,500 and 5,000 kg/ha/year (Fonticiella et al., 1995). The intensive systems are being carried out on floating cages in several reservoirs, as well as in some ponds at several hatchery facilities and at especially built pond-farms (Millares Dorado, 2012). The selection of floating cage sites has not been based on detailed studies on suitability, for the best rearing conditions, and the reservoir load capacity has not been estimated. Aquaculture practices in Cuba's reservoirs have been based exclusively on introduced exotic fish species. Since 1923 about 50 species and strains have been introduced, of which less than 10 are being now used (Alvarez-Lajonchère, 1983; FAO, 2012a).

During the 1970's and the 1980's, several studies were carried out on freshwater reservoir limnology (Laíz-Averhoff, 2002; Pérez Eiriz et al., 1990; Quiñones et al 1990). The main objective of one of the FAO funded research projects (UNDP/FAO/CUB/81/004) in 1982-85, was to characterize Cuba's freshwater reservoirs. This project had several consecutive phases, starting with general scope of 74 reservoirs, including the most important, to get a general idea of the reservoir types, that were then chosen to include the most representative soil land types on which the reservoirs were built and their water supply characteristics, as well as those with high and low fishery yields (Henderson and Alvarez-Lajonchère, unpublished). This first phase should have been complemented with an intensive sampling program phase, selecting at least three or four reservoirs on each type (sampling strata), and including bimonthly sampling on limnological parameters and data on fisheries biology, with a final phase of applied fishery management practices on some of the fully studied reservoirs. However, this sampling program was not complemented as planned (Quirós and Marí, 1999).

In 1993, Cuba's extensively exploited medium and large reservoirs reached a mean yield of 212 kg/ha/year, consisting mostly of tilapias (Quirós, 1994; Quirós and Marí, 1999), similar to Sri Lanka reservoirs (De Silva, 1985). Laíz-Averhoff (1999) reported that a mean yield of 189 kg/ha/year was obtained in 54 Cuban reservoirs from 1972 to 1993. Later, Jackson and Marmulla (2001) reported a mean yield of 125 kg/ha/year for Cuban reservoirs, while between 2001 and 2005 Baisre and Arboleya (2006) reported that their average yields were 130 - 150 kg/ha/year.

Several recommendations were given by Marí (1992) to improve the fishery production and efficiency in extensively exploited reservoirs: a) the introduction of new species to cover the vacant trophic levels; b) the control of predator species of tilapia; c) the develop of efficient reservoir fishing gear and method to catch silver carps; d) the mechanic and biological control of aquatic vegetation; e) the increase the limnology and fishery research within a greater number of reservoirs; f) encouraging the participation of fishery scientists in reservoir projects that will be built in the future. However, with the exception of the development of fishing gear and methods to catch silver carps, all other objectives were ignored. Some generalized opinions in the fishery sector on the negative effects of Cuban river dams to fisheries, have been supported through theoretical inferences by Baisre and Arboleya (2006). This report is substantiated by circumstantial evidences and reports from other countries, showing that Cuban dams retain most of the river nutrients, preventing their free flow to estuarine and coastal waters, with two main consequences: i) freshwater reservoirs have become eutrophic with high phytoplankton biomass, causing the displacement of tilapias by silver carps; ii) coastal fisheries have significantly decreased. Furthermore, damming has been reported as the cause of saline intrusion in estuaries and coastal lands, increase salinity in coastal waters and a higher concentration of organic nitrogen in sediments, as well as the reduction of mangrove areas (Piñeiro et al., 2006).

3. Important negative claims referring to Cuban river dam effects

3.1. Changes in composition of freshwater reservoir fish species due to nutrient retention

3.1.1. Dams as nutrient traps: the main cause of tilapia yield decreases

The nutrient retention by river dams has been demonstrated worldwide (Ibáñez et al., 2008; Medeiros et al., 2011). However, the effects of dam nutrient retention in Cuba are not as extreme as those hypothetically considered as a case of a general eutrophic condition according to Baisre and Arboleya (2006), because even after several decades of constructions, many of the freshwater reservoirs do not show eutrophic state. Laíz-Averhoff (2002), Pérez Eiriz et al. (1990), and Quiñones et al. (1990)reported that 50%, 80% and 25% of reservoirs studied by them could be classified as eutrophic. Additionally, Baisre and Arboleya (2006) reported an average fishery yield correspond to a mesotrophic and not to the eutrophic level according to criteria of eutrophic condition applied by Quiñones et al. (1990) (more than 200 kg/ha/year).

Reports by Pérez Eiriz et al. (1990) and Quiñones et al. (1990) of the eutrophic conditions of many Cuban reservoirs correspond to periods within an interval of over 15 years in which maximum tilapia yields and production were reached. Thus, the trophic condition did not negatively affect the tilapia fishery yields.

The effect of nutrient retention by dams can only be detected after several years, as shown by results of the nutrient and chlorophyll "a" content on some Cuban freshwater reservoirs; the nutrient content of these reservoirs can decrease even during the following year, and only increase when measured several years after (Laíz-Averhoff, 2002) (Fig. 2). Nutrient concentrations in Cuban reservoirs had not increased to extreme values, as hypothesized by Baisre and Arboleya (2006), because it remains within the ranges reported for rivers by Meybeck and Helmer (1989). However, reports in some reservoirs show important decreases (about 50%) in nutrient inputs, especially phosphates, which may be due to a lower application of fertilizer by agriculture; this has also lowered the phytoplankton and zooplankton levels and the trophic level of reservoirs have changed from eutrophic to oligotrophic-mesotrophic (Fonticiella García, 1996).

Excess nutrients in reservoir waters are absorbed by bottom's muds, in a similar process to that described for excess nutrients in estuaries (Sin et al., 2007), ponds (Boyd, 2009; Shrestha and Lin, 1996), and in reservoirs (Laíz-Averhoff, 2002), but much slower because of the greater depth of the reservoirs. Freshwater reservoir fishery yields were correlated with important annual variations in reservoir levels, due to the bottom mineralization process occurring in reservoirs on which water level is strongly decreased during the dry season (Song, 1980).

The facts, arguments and reports about Cuban dams becoming nutrient traps as the main cause of decreases in tilapia yield contradict the hypothetical considerations inferred by Baisre and Arboleya (2006), on which the fishery sector's concern on the national river dam program has been based.

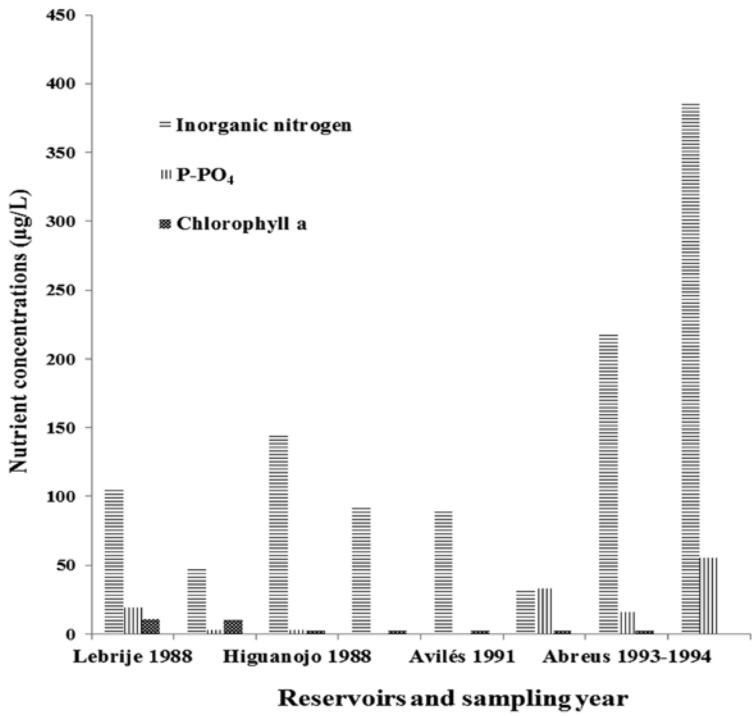

Fig. 2. Inorganic nitrogen ($NO_2 + NO_3$), P-PO_4, and chlorophyll "a" in four freshwater reservoirs at the Cuban central region in consecutive or after several years (updated upon Laíz-Averhoff, 2002)

3.1.2. Claims on the displacement of tilapias by silver carps

Tilapia productions in Cuban freshwater reservoirs reached 18,500 tons in 1990, after which the production has declined to 600 tons in 2011, while Chinese carp landings, mostly silver carps, have increased to about 15,000 - 20,000 tons since 1985 (Fig. 3). The nutrient retention of dams has been blamed for this, since it is said to benefit mostly silver carps by increasing phytoplankton biomass, thereby displacing tilapias (Baisre and Arboleya, 2006). There are several information and facts that are in contradiction with that statement.

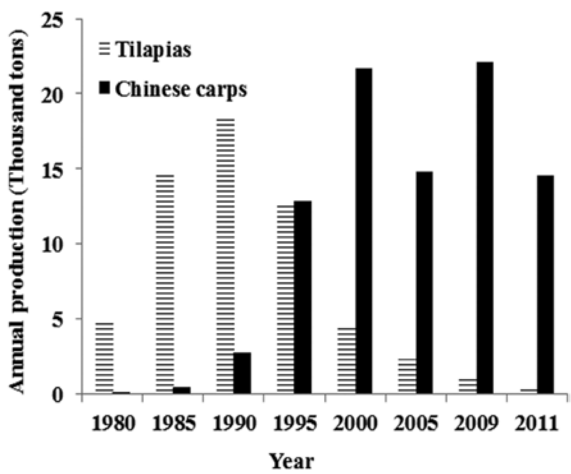

Fig. 3. Cuban reservoir fishery annual landings of tilapias (mostly *Oreochromis* spp.) and Chinese carps (half of them could be estimated as silver carps, *Hypophthalmichthys molitrix*) (Ministry of Fisheries of Cuba, 2012)

Certain data and facts contradict these claims on the displacement of tilapias by silver carps. Some are related to the characteristics of the species: i) tilapias are often reared in polyculture systems, some of them with silver carps, and there are no reports of interference between them (FAO, 2012b; Shepherd and Bromage, 1988; Tal and Ziv, 1978; Welcomme, 1988); ii) tilapias are among the most adaptable and strong species, even though are considered to be invaders in several reports (De Silva et al., 2009; Fonticiella García, 1996; Invasive Species Specialist Group (ISSG), 2009;¸Mendoza et al., 1995); iii) although tilapias are omnivorous species, one of their main food sources is phytoplankton (Froese and Pauly, 2012), thus the possible increase in phytoplankton biomass could have benefit both species, while silver carp also feeds on zooplankton (Stickney, 2000); iv) there are no reports on the displacement of tilapias by non-carnivorous species, such as silver carps (Froese and Pauly, 2012; Welcomme, 1988); v) silver carp not considered to be an invader, but a beneficial species (FAO, 2012c; Welcomme, 1988).

There are two important facts related to juvenile sources: i) there has been significant decrease of tilapia juvenile production by Cuban freshwater hatcheries, and important amounts have been used to stock intensive culture system such as reservoir floating cages and earthen ponds; this significantly produced a 9-fold decrease of their stock in freshwater reservoirs. During the same period, there has been a three-fold increase of Chinese carp juveniles (Fig. 4), which are only used to stock freshwater reservoirs; ii) tilapias have been established and reproduce within the freshwater reservoirs, but this natural recruitment has been seriously affected in recent years by extreme conditions of extended drought during the dry seasons, because important breeding zones at shallow sites of the reservoirs have been lost through a significant reduction in the areas covered by the reservoirs. This situation has not affected the silver carps which do not spawn in reservoirs.

One important aspect that was not analyzed in relation to the thirty-fold decrease of tilapia catches in freshwater reservoir is that reports show overexploitation of tilapia in several important reservoirs (Fonticiella García, 1996), before the silver carp stocking were significantly increased, and even before the introduction of *Clarias* spp.

In reference to fishing gear and practices, it was stated that fishing practices did not change very much during the period (Baisre and Arboleya, 2006), although this argument neglected the fact that: i) a new and very efficient so-called “Chinese fishing gear and method” was introduced and widely applied in the reservoir fisheries, catching mostly silver carps; ii) the distribution of tilapias and Chinese carp to fishing gears and methods is the reservoirs is different: tilapias are mainly found in shallow areas and fished with gill nets, although they try to avoid the nets by adopting a position with one of their sides on the bottom or even by burrowing in the bottom mud to avoid being caught (Fernando and Holcik, 1982; Laíz-Averhoff, 1999) in contrast, silver carps are usually near the water surface layers, and since the early 1990’ the usual gear and fishing method used to catch them in Cuban reservoirs are the Chinese fishing gear and method, which acts as a surface seine and usually do not catch tilapias. Thus, the type of fishing gear and method defines which species are to be captured, and if the main fishing gear in recent years is the Chinese fishing gear, then the main species caught is silver carp.

Finally, there is another argument concerning predators, which is very important and has not been previously analyzed: silver carps have very few natural predators due to their large size and the fact that they jump out of the water when they are frightened (Cauchon, 2009; Rowan, 2010; Sigurdson, 2010); however, there are numerous reports of active tilapia predation by piscivorous species, including *Clarias* spp. (Abdel-Tawwab, 2005; Fagbenro, 2004; Froese and Pauly, 2012; Milstein et al., 2000; Yi et al., 2002). The fact that between 1999 and 2000, two freshwater catfish species (*Clarias batrachus* and *C. gariepinus*) were introduced in Cuba and distributed to many regions through the country was not mentioned when trying to explain the species change within reservoir fishery landings (Baisre and Arboleya, 2006). *Clarias* spp. found their way to reservoirs, rivers, irrigation channels and coastal lagoons, due to their ability to leave the water and move long distances on land, and also because of poor rearing strategies and the absence of control measures to avoid their escape (Bartley, 2010; Fernández de Alaiza García-Madrigal et al., 2012; Fernández Márquez and Pérez de los Reyes, 2009; González Alonso et al., 2012) which are expressed in international codes (Bartley, 2010; Bartley et al., 2005; FAO, 1995).

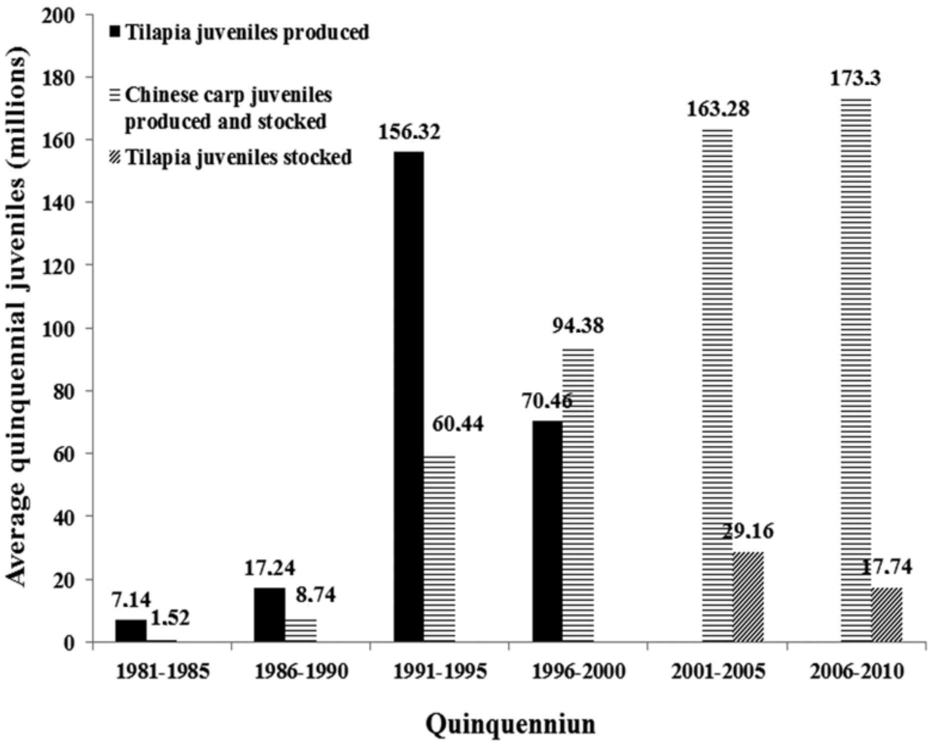

Fig. 4. Cuban freshwater hatchery quinquennial juvenile production and/or stocked of tilapia (mostly *Oreochromis aureus*) and Chinese carp (half of them could be estimated as silver carps, *Hypophthalmichthys molitrix*) (Ministry of Fisheries of Cuba, 2012)

Clarias spp. are considered to be among the most important and successful aquatic invader species, thus becoming a critical environmental problem in regions located outside of their natural distribution throughout the world (Bruton, 1986; Halstead et al., 1990; Invasive Species Specialist Group, ISSG, 2009; Robins et al., 1991; Welcomme, 1988), as well as in Cuba (Fernández Márquez and Pérez de los Reyes, 2009; González Alonso et al., 2012; Larramendi and Viña Dávila, 2011). This is because *Clarias* spp. has all the characteristics of an invader species, including their environmental tolerance to live in the brackish water areas of many coastal lagoons (Beveridge and Haylor, 1998; Bruton, 1986).

In Cuba *Clarias* spp. have moved into many different habitats, including coastal lagoons as those of Tunas de Zaza within the Zaza river delta (Fig. 1), where the species entered through the rice irrigation channel systems that discharge into the lagoons more than 20 years earlier, spreading out to the nearby coastal lagoon areas, such as Casilda (about 50 km from Tunas de Zaza) (Figs. 1 and 5). Within these costal lagoons, *Clarias* spp. feed mostly on one of the most important estuarine species, the striped patao (*Eugerres brasilianus)* (Alvarez-Lajonchère and Beltran Estepe, unpublished). Also, some important *Clarias* spp. have been recently reported within the Cauto River Delta (Fig. 1) the second most important lagoon system in Cuba, located in the southwestern region, which is also next to important rice farms, having mean annual landings of 64 tons between the years 2005 and 2010 (Fernández de Alaiza García-Madrigal et al., 2012).

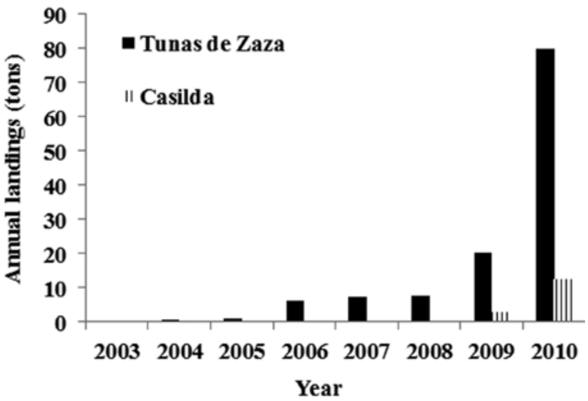

Fig. 5. Annual landings of *Clarias* spp. captured in two coastal lagoon systems of the South central coast of Cuba, Tunas de Zaza and Casilda (Ministry of Fisheries of Cuba, 2012)

The facts and arguments analyzed above contrast with the remarks of Baisre and Arboleya (2006), demonstrating that by hypothetical inference that river dams are the cause of the shift of fishery species from tilapias to silver carps in freshwater reservoirs, and that the later species displaced tilapias as the most numerous and successful freshwater fish species in Cuban reservoirs, are incorrect. This has produced a distorted picture of the fishery sector in high governmental officials on the true causes of those negative events. It is also clear from these facts that the introduction of *Clarias* spp. has resembles the negative ecological impact of the introduction of the Nile perch, *Lates niloticus*, in Lake Victoria, East African (Barel et al., 1985) and other regions (FAO, 2007; Ross et al., 1995). This could be important as an international alert to countries outside the *Clarias* spp. natural distribution areas.

3.2. River dams has caused the saline intrusion in coastal areas

One of the reported effects of river dam effects is saline intrusion, which is increasing salinization of groundwater, as reported by Verkerk and van Rens (2005) for Gambia River, and Arthurton (2005) for several of the African dam river basins, thus affecting estuarine and deltaic agriculture, mangroves, etc. Saltwater intrusion is commonly caused by the decrease of hydrostatic pressure, which is produced by the decrease in ground water level in wells near the coastal areas, or the decline of the flow of rivers, as a result of natural processes such as storms or by human actions. In rivers, the saline intrusion will depend on the river water velocity and flow rate, the length of the saltwater-fresh water wedge, the depth of the saltwater and freshwater layers within the wedge, salinity values along the depth of the wedge, and the frequency and duration of the river flooding while also considering sea tides (Bose et al., 1991); all these factors are favored by river dams.

As river dams reduce or stop the downstream flow of freshwater, the saline front would be inversely proportional to the depth and width of the river mouth, and saline front would penetrate coastal lands sometimes more than 100 m (Yeras Díaz-Vélis et al., 2000). The freshwater moves back toward the dam and a large portion of the old river bed becomes a seawater creek, similar to a shallow fiord (Piñeiro and Valdés, 1994). Also, since one of the river dam effects is to increase particle sedimentations, the river will start losing depth, usually 1.2 – 3 m in a few years (Yeras Díaz-Vélis et al., 2000), and limiting water flow and tide currents, and at the same time the saltwater wedge will be increasingly moving toward the dam, as demonstrated in Zaza River by comparing results by Tápanes (1981) only a few years after the dam was finished, with those reported 16 years after by Piñeiro and Valdés (1994).

Furthermore, saltwater intrusion causes the salinization of arable land surface, which has been estimated to be 10% of the main Cuban riverine catchment area (Fernández Márquez and Pérez de los Reyes, 2009), and 15% of the total Cuban arable land (ONEI, 2011). Also, saltwater intrusion affects coastal aquifers, at given locations and depths, creating serious problems with the ground water in coastal areas (Bose et al., 1991), which have been reported by Cuban dam program at the South coasts of the western region by Piñeiro et al. (2006). These arguments and facts agree with this statement, which has been generalized for the country by Fernández Márquez and Pérez de los Reyes (2009), and is affecting irrigation possibilities of irrigating arable land areas near the coast, as reported by Fernández Márquez and Pérez de los Reyes (2009), Tápanes (1981) and Yera Digat et al. (2010).

3.3. River dam effects on the Cuban marine fisheries

3.3.1. Status of the Cuban coastal fisheries

Cuban coastal fisheries have considerably declined in the last three decades due to many factors that are both natural and anthropogenic. The most important natural factors include extreme hydro-meteorological events such as hurricanes (which have significantly increased in the last 15 years) (Wuff, 1995). The negative human actions that have significantly affected coastal fisheries consist of overfishing (especially recruitment and growth overfishing), inappropriate fishing gear and methods (especially bottom trawls and set nets, the later mostly during spawning seasons), excessive river damming, illegal fishing, pollution (urban, industrial and agricultural), as well as the construction of case-ways between keys and the main island through more than 200 km on the north central coast (Alvarez-Lajonchère, 2013; Alvarez-Lajonchère et al., 2011; Fernández Márquez and Pérez de los Reyes, 2009; García del Barco and Crespo León, 1981).

Without considering the questioned suitability of traditional maximum sustainable yield stock assessment methods (Cury et al., 2005; Frazier, 1997; Garcia et al., 2003; Kempf, 2010; Legović et al., 2010; Mace, 2001) and the recognized low reliability of local catch and effort fishery statistics (Alvarez-Lajonchère, 2013; Baisre, 2000; García del Barco and Crespo León, 1981), the fishery resources within the Cuban coastal and adjacent oceanic waters, have shown a negative evolution in the last three decades. The proportion of underexploited resources have evolved from near 40% in 1980 to 0% in 2005, while resources evaluated as overexploited have increased from less than 20% (Baisre and Páez, 1981) to nearly 70% in 2005 (Baisre, 2012). When simple and easily-understood fishery indicators, as those recommended by Froese (2004), are applied for the assessment of the state of Cuban coastal fisheries, their generalized overfishing situation is evident. This condition is revealed by the high proportion of fish captured at a smaller size than the optimum required for maximum yield (with maximum growth rate and cohort biomass), which are smaller than the length at first maturity, withholding them from spawning at least once, while the concept of optimum capture length has never been applied (Alvarez-Lajonchère, 2014; Claro et al., 2001; Froese, 2004; Froese et al., 2008).

There are several clear indications on the general overexploitation of Cuban coastal fishery resources, which include: a) the decrease of the mean trophic level of capture due to the decline in the amount or even the loss of larger, older and more valued carnivorous species (Fernández Márquez and Pérez de los Reyes, 2009); b) the decrease in the mean size of the Cuban coastal landings during the last five decades (Baisre, 2000), which shows a gradual transition from long-lived, high trophic level, piscivorous demersal fish species, toward short-lived, low trophic level plankton-feeder pelagic fish species, by overfishing the former (Alder and Pauly, 2010), which is in line with the decrease in trophic level reported by Baisre (2000); c) most landings of many important fish species are below the first maturation size (Claro, 1994; Claro et al., 2001), which is consistent with the fact that the average maximum size landing is decreasing, as reported by Baisre (2000); d) increase yields of fish are obtained when fishing effort declines (Obregón López-Silvero, 2003). All of these negative characteristics of the Cuban coastal resources cannot be caused by river dams.

3.3.2. Nutrient levels of coastal water decrease due to river dams

There is an important decrease in freshwater output from dammed rivers, which has been estimated near 80% of original rivers flows (Fernández Márquez and Pérez de los Reyes, 2009); this is especially so on the southern coast of the country were most of the largest rivers discharge. River damming is blamed for being a major factor affecting the Cuban coastal fishery captures, due to the decrease in nutrient retained by the dams (Baisre and Arboleya, 2006). However, there are some facts and arguments clash with this consideration. If the decline in the coastal fisheries were mostly due to river damming, the relationship between the reductions of coastal fishery captures and the increase in the cumulative reservoir water volume capacity would be high (Fig. 6), shown by the fact that the landings declined much earlier than they previously occurred, as observed in several euryhaline species (Fig. 7).

The acceptable state of coastal fishery resources, according to the traditional assessment methods, occurred during the 1980', with landings at about their maximum levels, at which time the cumulative reservoir water volume capacity was approximately the same as their present maximum level, indicating that damming cannot be one of the main causes of the decline in coastal fishery landings, as nutrients are uptake in a short time to increase primary production (Boyd, 2009; Margalef, 1983; Vollenweider, 1969).

The decline of the pelagic fisheries have been correlated to dams in important rivers, as the entire Eastern Mediterranean Sea, which have been traced to nutrient trapping by Lake Nasser reservoir (Halim et al., 1995). Reductions in nutrients due to dams on the Danube, Dnieper, Dniester, and Don rivers in Europe have been associated with reductions in fisheries in the Black Sea and Sea of Azov (Tolmazin, 1979). A similar decline occurred in water quality and fishery production in the Caspian Sea after the construction of a series of dams on the Volga River and elsewhere in the world (Miranda, 2001).

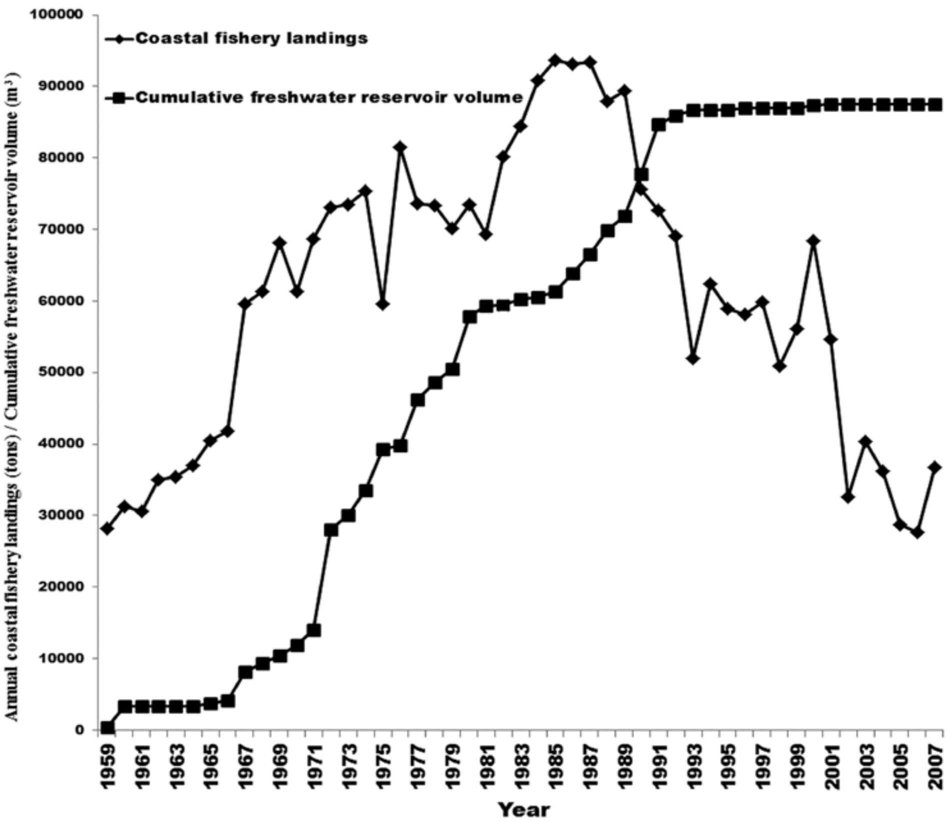

Fig. 6. Annual Cuban coastal fishery landings (FAO, 2012a) and cumulative freshwater reservoir volume capacity (INRH, 2010)

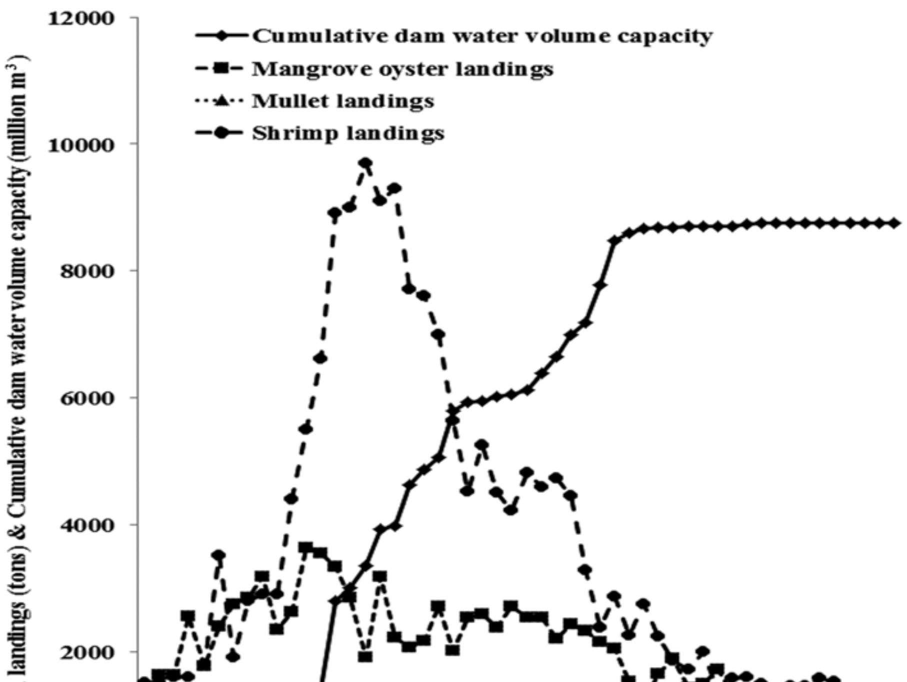

Fig. 7. Shrimp (*Penaeus* spp.), mangrove oyster (*Crassostrea rhizophorae*), mullets (*Mugil* spp.) landings (FAO, 2012a), and cumulative freshwater reservoir water volume (in million m^3) (INRH, 2010)

It is not acceptable the comparison of some of the world main rivers, as Nile, Niger, Mississippi, with the short Cuban rivers, most of them are less than 40 km in length (Fig. 1), and have relatively low discharges, compared to several tens of thousands m^3/s in important world rivers, as Baisre and Arboleya (2006) did to demonstrate generalized effect of river dams on coastal fisheries located far from river deltas and adjacent areas. The main coastal waters of Cuba that should have suffered the greatest environmental impacts of river damming are in the southern central gulfs: Guacanayabo, Ana María, and Batabanó (Fig. 1). The comparison of the inorganic nitrogen (NO_3 + NO_2), phosphates (PO_4), and silica (SiO_3) concentrations on surface water, with reports of 1972-73 (Lluis Viera, 1977) and 1990-2000 (Alvarez-Lajonchère et al., 2011; Perigó et al., 2003), showed that concentrations were increased or at least did not decrease in inorganic nitrogen and phosphate, while silica levels decreased (Fig. 8).

These reports contrast with the theoretical inference of Baisre and Arboleya (2006) on the significant retention of nutrients by freshwater dams. Silicate decreases were in agreement with reports of Harrison et al. (2012) and Humborg et al. (1997) on silica retention by reservoirs. Phosphorous plays the main role in freshwater reservoirs (Schindler, 1977), and has been used by Beveridge (1984) to calculate the carrying capacity of inland waters.

Piñeiro et al. (2006) reported a decrease of phosphorous in the Gulf of Batabanó between 1976 and 1993. This difference could have been caused by the decrease in artificial fertilizers applied by local farmers and the reduction of freshwater runoff, mainly caused by a so-called Southern Dike, built along 42 km of part of the northern boundary of Batabanó Gulf (Fig. 1), and not by river dams.

Turner et al. (2003) considered that restraining P and S could alter the composition of the phytoplankton community and compromise the diatom-zooplankton-zooplankton-feeder fish food webs. Nutrient decrease is the main cause of decrease in phytoplankton productivity that is essential for plankton-feeder species, which include sardines as one of the most important component in tropical coastal waters.

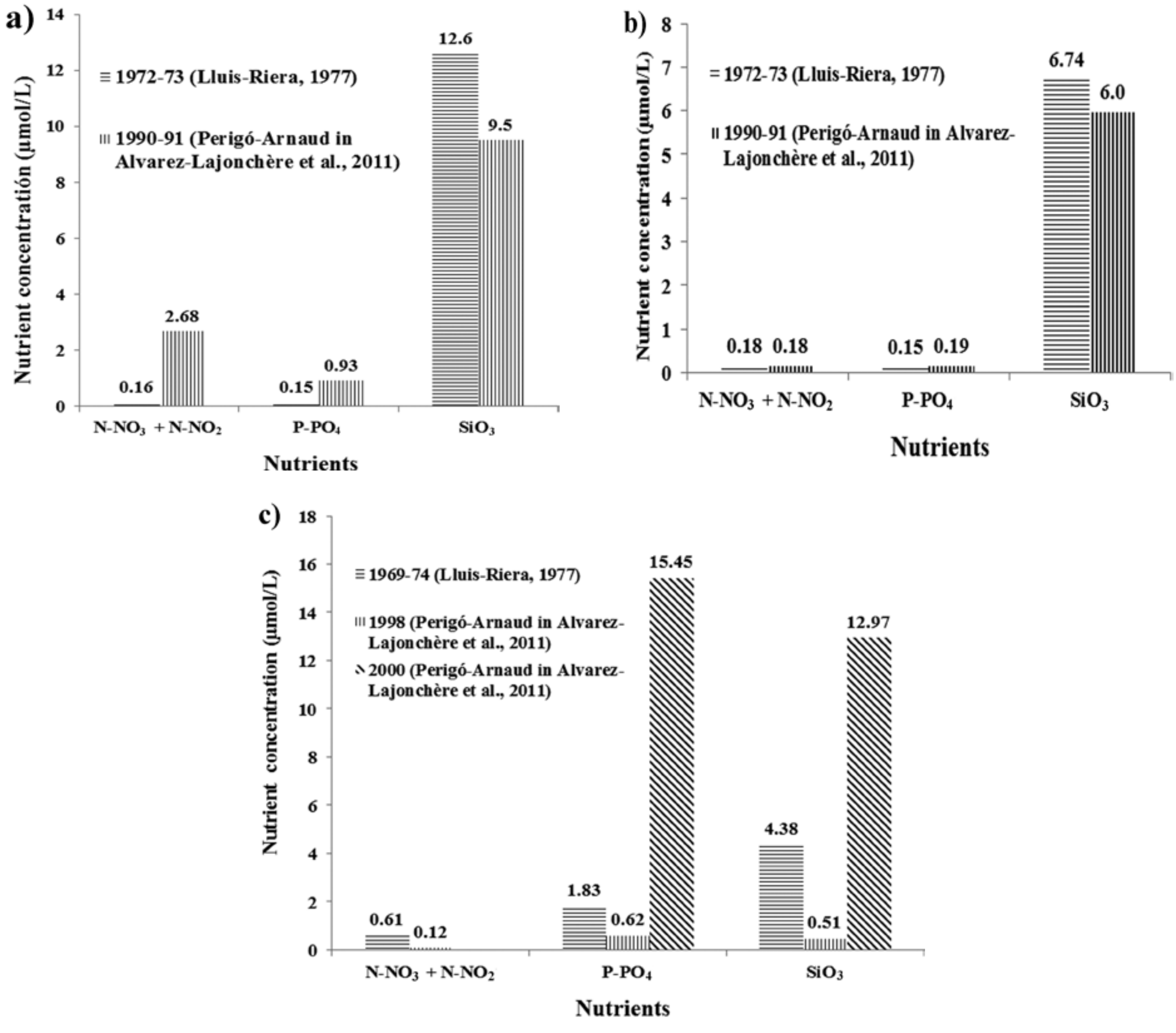

Fig. 8. Nutrient concentration of surface water (µg/L) in three different periods, 1969-74 (Lluis-Riera, 1977), 1998 and 2000 (Perigó et al., 2003; Perigó-Arnaud in Alvarez-Lajonchère et al., 2011), and three coastal areas with greater damming impact in the Southeastern coast of Cuba: a) Guacanayabo Gulf; b) Ana María Gulf; c) Batabanó Gulf

Reports show the decline of pelagic fisheries, due to river dams (Bernacsek, 2001; Halim et al., 1995). However essentially plankton-feeder species, as thread herring, *Opisthonema oglinum* (Peña-Alvarado et al., 2009) and other sardines (Family Clupeidae) have not decreased in abundance as they were considered to be underexploited between 1980 and 2000 (Baisre and Páez, 1981; MIP, 1985; Baisre, 2000; Claro et al., 2001) and have recently become fully exploited (Obregón López-Silvero, 2003). During that period the proportion of plankton-feeder species was increasing, when the fishery landing trophic level was decreasing, thus the decrease in P and S were not significant enough to affect the sardine food web, in contrast to the important nutrient decrease that Baisre and Arboleya (2006) hypothesized. The fact that small pelagic species like sardines and herrings have not been affected by river damming, as reported by Bernacsek (2001), shows that nutrient retention of dams is not that extreme, as pointed out by Baisre and Arboleya (2006).

General trophic levels of Cuban coastal southwestern areas are mesotrophic. This is clearly shown when comparing the mesotrophic level on the inorganic nitrogen, of ≥ 1.14 µmol/L as considered by Wetzel (1983) and the concentrations found in oceanic waters adjacent to the Cuban coast, that are of 0.95-1.06 µmol/L, as reported by Victoria et al. (1990). Although the nutrient levels are about half of those reported for 1972-73 by Lluis-Riera (1977), the coastal water levels are within mesotrophic level limits. Inorganic nitrogen concentrations in Cuban southwestern coastal waters of Cuba during 1990-1991 were between 1.29 and 10.0 µmol/L (Alvarez-Lajonchère et al., 2011; Perigó et al., 2003), which are higher than the lowest mesotrophic level limit, when the cumulative freshwater reservoir volume had reached its current maximum value.

In the case of phosphate concentrations, which according to the definition of the mesotrophic level be of ≥ 0.21 µmol/L (Wetzel, 1983), the concentrations reported in oceanic waters adjacent to the Cuban coast has been of 0.14 µmol/L (Victoria et al., 1990). Thus, according to this information, the coastal water concentration is within the mesotrophic level limits. P-PO_4 concentrations in the southwestern coastal waters of Cuba during 1990-1991 was of between 0.40 and 0.93 µmol/L (Alvarez-Lajonchère et al., 2011; Perigó et al., 2003), much higher than the lowest mesotrophic level limit, when the cumulative volume of reservoir water had reached its current maximum amount, which is not consistent with the report of Baisre and Arboleya (2006).

Montalvo et al. (2010) reported higher mean levels of NO_3 + NO_2 at the Guacanayabo and Batabanó Gulfs, and slightly lower for PO_4 at the Guacanayabo Gulf and greatly lower level at Batabanó Gulf, in almost the same periods than the values reported by Perigó et al. (2003) and Alvarez-Lajonchère et al. (2011) analyzed in the present review.

Betanzos Vega et al. (2012) reported higher inorganic nutrient levels than earlier reports (see Fig. 8) in the rainy season on the southern region of Cuba, mostly on Ana María and Guacanayabo Gulfs, showing low correlation coefficients with salinity levels. These authors suggested that this may be due, among others, to other things, to input sources that are not directly related to the fluvial runoff, as in the case of that transported by sea tide and shrimp ponds water renewal. This recent report strengthens the previously analyzed contradictions with the theoretical inference of Baisre and Arboleya (2006) on the low nutrient levels of costal water due to dam retention.

Although there is no significant coastal upwelling in Cuban waters, and the tidal range is small of 40 cm (Fernández Márquez and Pérez de los Reyes, 2009), there are increasing numbers of extreme hydro-meteorological events affecting Cuba and adjacent waters, as well as frequent cold fronts during the winter that sweep through Cuban territory, from one end to the other, each year. These climate events cause the chlorophyll “a” contents of Cuba’s coastal waters to increase with the entrance of richer nutrient water masses from the deep water, and through the mixing process produced by cold fronts (Cione, 2005), increasing primary productivity (Somoza et al., 2007). Satellite images studied by Somoza et al. (2007) showed that maximum extreme values of the infrared chlorophyll “a” estimated in Cuban waters were much higher than 0.2 mg/m^3, which is the minimum level for sustainable commercial fisheries, as reported by Gower (1972). Thus, the nutrient retention by Cuban river dams could not have severely affected this, in contrast to that expressed by Baisre and Arboleya (2006).

There is growing concern that river damming could lead to severe reductions of nutrient inputs to the sea and this may have dramatic impacts on aquatic food webs in coastal marine environments (Ittekot et al., 2000). However, in the lower Mississippi River, nitrate concentrations have more than doubled while silicate concentration has decreased by 40%; presumably due to deposition in reservoirs behind dams (Turner and Rabalais, 1991). The relative importance of river N inputs have been shown by Carey et al. (2003), reporting that maximum riverine export of N from the watershed to the marine environment is limited and ranging from 15 to 30% or even less than 10%, suggesting that there is a relatively high retention and/or losses of N by denitrification within the watershed.

In addition to river contribution, there are other four main circumstances that positively influence coastal water nutrient contents: a) more than 70% of Cuba’s soil component is limestone that facilitates the effect on coastal areas of underground water (Montalvo et al., 2010), which are almost 5 billion m^3, 33% of all hydraulic resources of the country (INRH, 2007); b) there is a notable orographic slopes toward the northern and southern coasts on the longitudinal axis of the main island facilitating rainwater drainage from the land the coastal waters; c) an important increase of untreated or partially treated urban and industrial effluents (Montalvo et al., 2010), to more than 160,000 tons/year (Fernández Márquez and Pérez de los Reyes, 2009); d) an increase in fertilizer and irrigation in rice paddies has augmented nutrients, particularly in the main estuarine areas; e) the runoff of coastal swamps, which in the Batabanó Gulf region is greatly influence by Zapata Swamp, the biggest wetland in the Caribbean islands (Fernández Márquez and Pérez de los Reyes, 2009; Montalvo et al., 2010). This is consistent with the report of Galloway et al. (1995) stating that the anthropogenic introduction of fixed nitrogen compounds in the environment was estimated to be equal to the natural flux. Thus, the influence of the domestic and industrial effluents as well as the underground water resources is important to compensating the decrease in nutrient supply to coastal waters by river dams.

3.4. River dam effects on the estuarine and coastal lagoon systems

Tropical coastal lagoons are shallow water bodies connected to the sea and their shores are mainly covered by mangrove. These are considered to be the world’s most productive ecosystems, especially due to mangrove and aquatic vegetation (Flores-Verdugo, 1989; Gopalakrishnan, 1977; Martinho et al., 2012; Odum and Heald, 1975). Kapetsky (1984) reported that fishery yields from coastal lagoons average about 100 kg/ha/year, and are two to four times greater than the maximum yields from other systems. The high natural productivity of these ecosystems is due to nutrients available in rivers and terrestrial runoff as well as the effective recycling processes of microbial mineralization and freshwater inputs from rivers (Flores-Verdugo et al., 1993; Gopalakrishnan, 1977; Olsen, 1984). It must be considered that most of the world fisheries come from estuaries of from organisms that spend part of their life cycle in coastal lagoons and estuarine environment (McHugh, 1976).

Coastal lagoon and mangrove areas are the natural nursery grounds for many important commercial species in tropical regions (Menéndez Carrera and Guzmán Menéndez, 2002), as shrimps (Kapetsky, 1981), lobsters (Acosta and Butler, 1997; Witham et al., 1964), and many finfish species (Kapetsky, 1981; Martinho et al., 2012), which are usually caught as adults at open coastal waters. Also, these are the usual habitats of permanent species populations sustained by their high natural productivity and object of important artisanal coastal fisheries (Menéndez Carrera and Guzmán Menéndez, 2002), considered the richest in the world (Miranda, 2001). In Florida, as in other tropical and sub-tropical regions, the main food web on most muddy estuaries and coastal lagoons is based on detritus (Odum, 1970; Odum and de la Cruz, 1963; Odum and Heald, 1975; Quignard, 1984), and according to González-Sansón and Lalana Rueda (1982) macrophytobenthos and the mangroves are the main source for detritus on Zaza River coastal lagoon system in the southern-central coast of Cuba (Fig. 1). Large quantities of detritus are exported from mangrove areas into the coastal zone (Christensen, 1978; Odum and Heald, 1975) in non-dammed rivers; it has been found that there is a positive correlation between the areal extent of mangroves and fishery yields from adjacent waters, and if there is inference, catches will decline in proportion to the degree of mangrove destruction (Macintosh, 1982).

Mangroves are euryhaline species, but grow best when salinity do not exceed that of normal seawater (Macnae, 1966), and their leaf production is markedly reduced during dry seasons (Christensen and Wium-Anderson, 1977) when salinity is higher. Berdayes et al. (1990) and Odum and Johannes (1975) reported that extremely high salinity appear to be harmful to mangroves, which do not grow at all in open arid areas. Hypersalinity is a problem for most mangrove species; this can be created by man when water circulation to mangrove stands is cut off or restricted (Berdayes et al., 1990; Menéndez Carrera and Guzmán Menéndez, 2002; Odum and Johannes, 1975;). Also, mangroves are intolerant to situations in which the aerial roots become too heavily coated with fine sediments or particulate matter, and in extreme cases the plants die within a few weeks (Odum and Johannes, 1975). The increase in salinity and sedimentation are two of the main negative impacts of the river dams on coastal lagoons and estuarine areas (Menéndez Carrera and Guzmán Menéndez, 2002).

Coastal lagoons tend to be transformed into swamps and eventually to large dried land areas as their natural ageing process, mostly by sedimentation. Associated river periodic floods usually delay this process, by removing the lagoon bottom sediments (Cervantes Castro, 1984; González-Sansón and Aguilar, 1984; Kapetsky, 1981; Nichols and Allen, 1981). In Cuba, the natural evolution of lagoons to swamps has been accelerated by river dams, and it has been observed in areas near the Zaza and Cauto Rivers, as well as in other important dammed rivers (Fernández Márquez and Pérez de los Reyes, 2009; González-Sansón and Aguilar, 1983). The process can be analyzed comparing what typically occur during the dry and the rainy seasons before damming and after dam construction (Fig. 9). This includes the silting up of lagoon connections with the sea, enhanced by the drastic decrease in the water flow by river dams, accelerating the natural ageing and decreasing aquatic productivity, as described by Kapetsky (1981). Estuarine siltation caused by damming has been reported in African rivers, which now require costly dredging due to the absence of river flood discharges (Arthurton, 2005). The absence of the benefits of natural flooding may be the single most ecologically damaging impact of dams (Duvail and Hamerlynck, 2003; McCully, 1995).

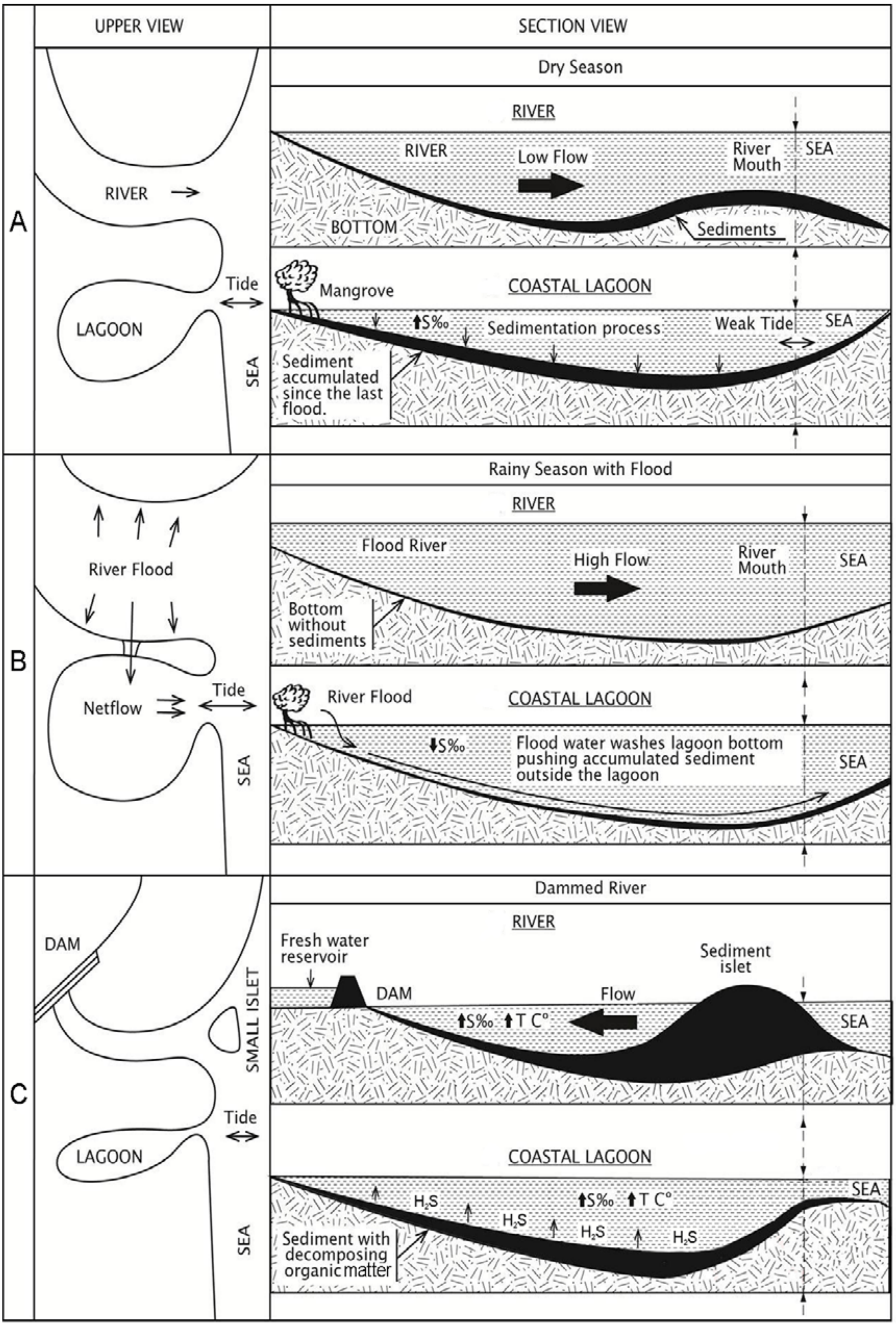

Fig. 9. Schematic diagrams of the main processes taking place on rivers and coastal lagoons: (A) during dry seasons, (B) during rainy seasons with floods; (C) when rivers are dammed (Alvarez-Lajonchère et al., 2011)

River damming is one of the main hydrological alterations that can be defined as an anthropogenic disruption in the magnitude or timing of river natural flows (Rosenberg et al., 2000). An environmental chain of effects is triggered with the natural flow of water and sediments is impeded and when altering natural seasonal patterns of river discharge (Vörösmarty and Sahagian, 2000), including the absence of river floods in coastal areas. This environmental chain starts by the significant reduction of more than 85% of the freshwater flow and water renovation rate below dams, causing an increase salinity (about 15‰) and temperature (about 4-5°C) (Alvarez-Lajonchère and Perigó Arnaud, unpublished; Berdayes et al., 1990; Tápanes, 1981), and sedimentation (50-60%), as well as a decrease of nutrient inputs. Sedimentation decreased water depth, thus increasing salinity, temperature and also augmenting organic matter decomposition at the bottom, which leads to an increase in the production of toxic substances, as hydrogen sulfide (H_2S) gases. During the dry season (Fig. 9A) before rivers are dammed, important sediment amounts are accumulated at their bottoms, while the sedimentation process at coastal lagoons are more significant, due to the weak tide water exchange with the adjacent sea. During the rainy season (Fig. 9B), river flow are higher, floods frequently occur, and the sediments on the river bottom are removed and transported to the sea, thereby maintaining their depth (Berdayes et al., 1990).At coastal lagoons, the river flood water washes the lagoon bottom, pushing accumulated sediment outside the lagoon, restoring the original lagoon depth and lowering salinity. Dams preclude river floods (Fig. 9C), the net flow is from the sea, usually transforming the original river banks into a sea inlet; the salinity, temperature and bottom sediments are significantly increased, lowering the depth and even forming islets at the original river mouth. Without floods, the amount of nutrient exported from coastal lagoons to adjacent coastal areas is significantly reduced, and the lagoons lose depth (more than 2 – 3 m in some originally deep lagoons in 10 years or 1 – 2 m in originally shallow lagoons in 15 years (Alvarez-Lajonchère, unpublished; Yeras Díaz-Velis et al., 2000), their communication with the sea tend to be reduced or even eliminated, the sediments with decomposing organic matter accumulated at their bottom are not transported to the adjacent sea, increasing the production of H_2S and other toxic substances which, together with the increasing salinity and temperature, significantly affect the water quality of coastal lagoons for species that usually use these habitats and nursery grounds, as well as for resident species, including mangroves (García del Barco and Crespo León, 1981; González-Sansón and Lalana Rueda, 1982; González Sansón et al., 1985).

The effects of river dams have been studied in Asia and Africa, and are mostly restricted to river estuaries and adjacent areas (Lindén, 1990). Freshwater flow, per se, may not be as important in determining fishery production, especially in estuarine species, as episodic flow events (Erzini, 2005; Gillson et al., 2009), mostly affecting populations inhabiting lower trophic levels as plankton feeders (Bergeron et al., 2010; Salat et al., 2011), in agreement with Hill and Cichra (2002) review on the significant effects of water level fluctuations on fish production and system productivity in Florida's adjacent southeast area of the USA, and considering water level manipulation as a management tool that may be used to increase fish production.

All these negative environmental impacts significantly decrease the local and adjacent coastal fishery production. One of the first estuarine fish species negatively affected by Cuba's dam program since the beginning of the 1970's were the mullets (*Mugil* spp.), with a highly significant correlation between its annual landings and the increase in the volume of freshwater reservoirs (Alvarez-Lajonchèe, 1998), as well as other estuarine species of commercial importance, such as shrimps (*Penaeus* spp.) and mangrove oyster (*Crassostrea rhyzophorae*) (Fig. 6). The negative effects on mangrove oysters, which are permanent lagoon residents, started during the same period as the mullets, but the effect on shrimp landings was observed several years later, this may be due to the fact that shrimp juveniles migrate from the lagoons to open coastal waters where the adult stages are found. A direct and positive correlation was found between commercial shrimp catches and mangrove swamp areas adjacent to fishing ground (Macintosh, 1982). These facts and arguments are in agreement with the report of Baisre and Arboleya (2006) about the important and negative environmental impact of river dams on coastal lagoons and estuarine areas.

Mangrove oyster normally inhabits waters ranging in salinities from 12 and 45 ppt. Best salinity range for cultivation is 28 – 36 ppt with small freshwater inflows, as well as water movements of about 30 cm/s, which is considered optimal for mangrove oyster (Nikolic et al., 1976). These conditions are affected by river dams (Berdayes et al., 1990; Lindén, 1990; Yeras Díaz-Velis et al., 2000).

3.5. Estuarine and coastal lagoon system modifications

According to Kapetsky (1981) certain engineering procedures and other management actions to restore the coastal lagoon natural environment and productivity include:

a) Channelization to increase productivity by avoiding extreme temperature and the hypersalinity of lagoons;

b) Diversion of freshwater from nearby rivers or streams, to reduce salinity;

c) Predator control;

d) Selective stocking.

Re-establishing the communication with the sea is one of the most important rehabilitation actions carried out in many cases, and has improved the lagoon's productive yield (Cervantes Castro, 1984; Kapetsky, 1981).

Channelization is a solution of utmost importance to restore the environmental conditions and productivity of coastal lagoons (Kapetsky, 1981). Internal channels can be design to reduce sedimentation and promote circulation within coastal lagoons (Cervantes Castro, 1980), while others may be used to restore or increase the coastal lagoon's exchange with the adjacent sea, which can be designed to gather organisms that will be captured during their outward migration (Edwards, 1978; Kapetsky, 1981). However, hydraulic engineering to restore the lagoon's environment should have a positive cost-benefit ratio for economical sustainability, which has been difficult to determine in sites were these actions have been carried out (Kapetsky, 1981) and would probably not positive if these actions are not part of an aquaculture program.

There is a particular aquaculture system developed in Mediterranean countries, which is a polyculture system called "Vallicoltura" in Italy (Ardizzone et al., 1988; De Angelis, 1960). "Vallicoltura" consist of several modifications of costal sites, to retain estuarine fish, allow the juveniles to enter the facility, on which rudimentary ponds, channels, ditches, etc., are prepared for rearing the juveniles up to commercial size (Alvarez-Lajonchère and Cittolin, 2012; Ardizzone et al., 1988; Ravagnan, 1978;). Its general purpose is to modify the secondary production, reducing it to a few commercially important euryhaline species, by improving their rearing conditions, increasing fish density through the stocking programs, and taking advantage of their natural migration behavior for their efficient harvest.

The species integrating the polyculture system must be selected from the most naturally common species in those environments that do not interfere with one another, and could consume the main food sources available. This is considered among the environmentally friendly aquaculture types (Rosenthal, 1994). The most develop "Vallicoltura" type is the one called integrated (combining intensive, semi-intensive and extensive culture areas), that is equipped and uses hydraulic management to control water flow and salinity through seawater and freshwater supply and distribution channels (Alvarez-Lajonchère and Cittolin, 2012; Ghion, 1980; Ravagnan, 1978, 1981). An example of this "Vallicoltura" type is Ittica Valdagri farm, at Policoro, Italy. Kapetsky (1981) considered that hydraulic management is the main modification whereby environmental conditions are managed through varying freshwater and seawater inputs so as to increase aquatic productivity and hence fishery yields.

The equipment used at these integrated "Vallicoltora" farms include an outstanding "hydrocultivator", designed by Eng. Gino Ravagnan (Ravagnan, 1978), which is able to plow the lagoon bottom (Rosenthal, 1994). This piece of equipment consists of a floating tank sustaining a diesel pump that pumps the lagoon water into the tank and by means of a manually controlled hydraulic mechanism the water is jetted through several parallel tubes to the lagoon bottom (with a variable slope angle that can be manually changed by the operator), thereby removing the upper bottom layers where the sediment particles have been deposited, putting them in suspension.

The organic matter that was deposited at the lagoon bottom is now mineralized when re-suspended. The deposition process of the organic matter deposited consumes the dissolved oxygen in the water and produces toxic compounds and hydrogen sulfide. Thus, there are three purposes for removing the upper bottom layers: a) to restore the original depth of the lagoon (reducing the organic matter content); b) to indirectly fertilize the water by organic matter mineralization; c) to improve the water quality. The action of the "hydrocultivator" is similar to tilling the bottom of a pond, which is part of aquaculture practices (Boyd, 2009).

Coastal shrimp ponds usually located near coastal lagoons could form part of these integrated systems by benefitting from their periodic effluent discharges of high nutrient concentrations, which could be diverted toward the modified coastal lagoons, as artificial fertilizations to increase nutrient level of the lagoon, as well as washing out its accumulated bottom sediments.

In Cuba several estimations have been made of the coastal lagoon system area. Menéndez Carrera and Guzmán Menéndez (2002) reported that Cuban mangrove areas represent 4.8% of total country's surface, covering about 450,000 ha (Rollet, 1986). Approximately 30,000 ha is the estimated total coastal lagoon area, of which 14,000 ha are located in the southeastern coast, with a general estimated yield of 100 kg/ha/year (Ministerio de la Agricultura, 1984). An experimental program for "Vallicoltura" development could start with four phases: a) extraction of predator species; b) the stocking of juveniles of the desired species; c) water fertilization, and d) artificial food supply. Rollet (1986) summarized the information on integrated mangrove management. The first steps for the Cuban polyculture of euryhaline fish species research program was started in 1965, studying the coastal lagoons and the biology of mullets and sea breams (Gerreidae), the most important fishes inhabiting the coastal lagoons (Alvarez-Lajonchère, 1978, 1998; Báez Hidalgo and Alvarez-Lajonchère, 1980).

4. Practical recommendations for mitigating the negative environmental effects of dams on aquatic production

4.1. For freshwater reservoirs

Recommendations are to be implemented by the aquaculture sector working in reservoirs, together with the National Institute of Hydraulic Resources as the national authority that regulates and controls all activities concerning the country's hydraulic resources.

- Recommendations made by Mari (1992) to improve the fishery production and efficiency on extensively exploited reservoirs should be applied.
- A systematic monitoring program of limnological characteristics should be carried out from the reservoir tributaries to the coastal waters, as well as their main pollution sources.
- The fishery biology and population dynamic research program of reservoirs species should be restarted, following principles of the

UNDP/FAO/CUB/81/004 project to characterize, properly monitor, and managed reservoir fisheries.

- Allow the sanitary or ecological discharges of the dam to mitigate excess salinity in the estuaries and coastal lagoon systems.
- The bottom gates of the dams should be opened when dams are overflowing due to strong rains, allowing the release of the excess water from the reservoir's bottom toward the former river bank, flowing to the estuarine areas, as demonstrated elsewhere (Kim et al., 2010; McCartney et al., 2001); this water is richer in nutrients than the surface water.
- Facilities for preventing the fish from escaping should be built within the present concrete structures below the reservoir curtain, on the water discharge structures or spillways where the width is relatively narrow and water is shallow, and not in front of the dam curtain where water depth is greater (see Song, 1980). This can be based on steel screens to prevent fish escapement, and at the same time a "V" disposition and sufficient screen area to allow avoiding fish impingement, together with a device such as a mechanized steel mesh seine to catch the fish. Borrego (2012) reported that after consecutive gate openings of Zaza dam due to its high water level caused by strong rains in May and June 2013, more than 100 tons of freshwater fish from the reservoir were caught with seine nets by a few fishermen in about two months in the old river bank.
- Annual artificial flooding events during the rain seasons should be tested, as recommended by Bernacsek (1984) and Duvail and Hamerlynck (2003). This should be carried out while preserving the water for main programmed purposes.
- Studies on sedimentation and the nature of the sediments show that if shallow reservoirs were significantly drained before the rainy season, which would simulate annual flooding towards estuaries and coastal lagoons, large parts of the reservoir bottom will be exposed to the air, leading to the direct oxygenation and mineralization of the organic matter. As a result of this, the reservoir would be fertilized when it is again filled with rain water. This would be a recommendable practice to increase productivity.
- Reservoirs load capacities should be evaluated to manage the juvenile stocking and restocking programs, as well as fishery exploitation and intensive fish culture in them.
- Extensive site selection studies for floating cage farms on reservoirs should be carried out to minimize their negative effects due to artificial food wastes, and to provide adequate and safe conditions for rearing fish.

4.2. For estuarine and coastal lagoons

As the main environmental impacts of dams are on coastal lagoons and estuaries the main mitigating actions should be considered for their application. Therefore, based on the above information, it is recommended that the polyculture development program should be restarted, based on "Vallicoltura" principles, to rehabilitate coastal lagoons, especially the integrated "Vallicoltura", but with the peculiarity that lagoon modifications should allow the shrimp to move freely in order to rehabilitate the open water shrimp fishery resource.

The species combination should be those prevailing and that are most efficient in the brackish water lagoon environment (Table 1), which is similar to the group previously planned (Ministerio de la Agricultura, 1984). "Hydrocultivators" should be used on modified coastal lagoons and their seaward communication channels, to remove sediments and restore their original depths, ensuring the export of nutrient loads to adjacent coastal areas. When possible, brackish river water should be diverted to the modified lagoons on which "Vallicoltura" is being implemented, as well as to the nearby shrimp culture pond farms effluents should be directed, to increase water flow from the lagoons and ensure the nutrient inputs to the adjacent coastal waters. In a first phase, with extensive and well managed systems, the yields could be increased to 200-300 kg/ha/year; in a second phase, including semi-intensive areas, the yields could be raised to 400-500 kg/ha/year, and when intensive areas could be included, the yields could be 600-700 kg/ha/year (Ministerio de la Agricultura, 1984).

5. Conclusions

Coastal waters have increased salinity and decrease nutrient input by the presence of river dams, which significantly reduced river discharges, while also preventing the removal of accumulated coastal lagoon sediments and their transportation to the adjacent coastal areas, which are now deprived of such nutrients, thus affecting their environmental quality.

Table 1. Selected species for integrated polyculture in coastal lagoons

Polyculture system	***Species***		***Feeding habit in coastal lagoons***
	Common name	***Scientific name***	
Extensive and semi-intensive	Striped mullet	*Mugil liza*	Detritus and periphyton
	Striped patao	*Eugerres brasilianus*	Small invertebrates
	Tilapia	*Oreochromis aureus*	Filamentous algae (*Cladophora* spp., *Enteromorpha* spp.) and detritus
	Mangrove oyster	*Crassostrea rhyzophorae*	Phytoplankton
Intensive	Common snook	*Centropomus undecimalis*	Small fishes and crabs

This has affected fisheries of local species and others that use these habitats as nursery grounds, although this is not a major cause of the decreases in coastal fishery, as reported. Also, dramatic changes occurring in species composition at freshwater fishery reservoirs are not caused by river damming, but by several other causes, which were analyzed above.

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References

Abdel-Tawwab M., (2005), Predation Efficiency of Nile Catfish, *Clarias gariepinus* (Burchell, 1822) on fry Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758): Effect of prey density, predator size, feed supplementation and submerged vegetation, *Turkish Journal of Fisheries and Aquatic Sciences*, **5**, 69-74.

Acevedo M., (1980), *Physical Geography of Cuba*, vol. 1 (in Spanish), Editora Pueblo y Educación, Havana, Cuba.

Acosta C., Butler M., (1997), Role of mangrove habitat as a nursery for juvenile spiny lobster, *Panulirus argus*, in Belize, *Marine Freshwater Research*, **48**, 721-727.

Alder J., Pauly D., (2010), *Future of Fisheries*, In: *The Atlas of Global Conservation: Changes, Challenges and Opportunities to Make a Difference*, Molnar J.L. (Ed.), University of California Press, Berkley, 120-121.

Alvarez-Lajonchère L., (1978), Mullet (Pisces: Mugilidae) fishery in Cuba (in Spanish), *Ciencias (Serie 8, Investigaciones Marinas)*, **35**, 1-39.

Alvarez-Lajonchère L., (1983), *Cuban aquaculture*, National reports about acuaculture development in Latin America. Primera Reunión del Grupo de Trabajo de Acuicultura de la Comisión de Pesca de la FAO para América Latina (COPESCAL), Santiago de Veragüas (Panamá), abril de 1983, *FAO Fisheries Report*, **294** suppl., 19-22.

Alvarez-Lajonchère L., (1998), Negative impacts on mullet fisheries (Pisces, Mugilidae) in Cuba from 1971 to 1995, and recomendations to increase their production (in Spanish), *Revista de Investigaciones Marinas*, **19**, 103-113.

Alvarez-Lajonchère L., (2013), Brief analysis of coastal fisheries: the case of Cuba (in Spanish), *Industria Acuícola*, **11**, 12-22.

Alvarez-Lajonchre L., (2014), Fish minimum legal size for fishes on the Cuban costal fisheries (in Spanish), *Revista de Investigaciones Marinas*, **34**, 81-103.

Alvarez-Lajonchère L., Cittolin G., (2012), The Italian "Vallicoltura", a polyculture system for coastal and estuarine areas (in Spanish), *Industria Acuícola*, **9**, 16-26.

Alvarez-Lajonchère L., Laíz Averhoff O., Perigó Arnaud E., (2011), *Reservoirs, Fishery and Fish Culture* (in Spanish), 4th Erosion and Sedimentation Workshop, National Institute of Hydraulic Resources and National Commission of the International Hydrological Program for Latin America and the Caribbean of UNESCO, Havana, Cuba.

Ardizzone G.D., Cataudella S., Rosi R., (1988), Management of coastal lagoon fisheries and aquaculture in Italy, *FAO Fisheries Technical Paper*, **293**, 1-103.

Arthurton R., (2005), LOICZ AfriCat 1-coastal impacts of damming and water abstraction in African catchments, *LOICZ Newsletter*, **34**, 1-4.

Báez Hidalgo M., Alvarez-Lajonchère L., (1980), The sea bream (Pisces, Gerreidae) fishery at Tunas de Zaza, Cuba (in Spanish), *Revista de Investigaciones Marinas*, **1**, 89-134.

Baisre J.A., (2000), Chronicle of Cuban marine fisheries (1935-1995). Trend analysis and fisheries potential, *FAO Fisheries Technical Paper*, **394**, 1-26.

Baisre J.A., (2012), *Marine Fishery. Past, Present and Future* (in Spanish), 1st International Fishing Workshop CONyMA 2012, Fisheries Research Center, May 22 to 24, Havana, Cuba.

Baisre J.A., Arboleya Z., (2006), Going against the flow: Effects of river damming in Cuban fisheries, *Fisheries Research*, **81**, 283-292.

Baisre J.A., Páez J., (1981), Fishery resources of the Cuban Archipelago (in Spanish), *WECAF Studies*, **8**, 1-79.

Barel C.D.N., Dorit R., Greenwood P.H., Fryer G., Hughes N., Jackson P.B.N., Kawanabe R.H., Lowe-McConnell R.H., Nagoshi M., Ribbink A.J., Trewavas E., Witte F., Yamaoka K., (1985), Destruction of fisheries in Africa's lake, *Nature*, **315**, 19-20.

Bartley D., (2010), Codes of practice on species introductions, On line at: http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/introspec/codeesofpractice.htm.

Bartley D.M., Bhujel R.C., Funge-Smith S., Olin P.G., Phillips M.J., (2005), International mechanisms for the control and responsible use of alien species in aquatic ecosystems, Report of an Ad Hoc Expert Consultation. Xishuangbanna, People's Republic of China, 27-30 August 2003. FAO, Rome.

Berdayes J.J., Moya C.E., Hernández R., Valdes J.L., Acosta E., Martínez J., (1990), *Damages to the mangrove on the Southern coast of Sancti Spiritus province, Cuba*, In: *Water Resources Management and Protection in Tropical Climates*, Quesada V., Gutiérrez J., Landner L. (Eds.), First International Symposium, Havana, February 8-12, 1988, Havana, Cuba, 413-420.

Bergeron J.-P., Delmas D., Koueta N., (2010), Do river discharge rates drive the overall functioning of the pelagic ecosystem over the continental shelf of the Bay of Biscay (NE Atlantic)? A comparison of two contrasting years with special reference to anchovy (*Engraulis encrasicolus* L.) nutritional state, *Journal of Oceanography*, **66**, 621-631.

Bernacsek G.M., (1984), Dam design and operation to optimize fish production in impounded river Basins. Based on a review of the ecological effects of large dams in Africa, *CIFA TechnicalPaper*, **11**, 1-98.

Bernacsek G.M., (2001), *Environmental Issues, Capacity and Information Base for Management of Fisheries Affected by Dams*, In: *Dams, Fish and Fisheries. Opportunities, Challenges and Conflict Resolution*, Marmulla G. (Ed.), *FAO Fisheries Technical Paper*, **419**, 139-166.

Beveridge M.C.M., (1984), Cage and pen fish farming. Carrying capacity environmental models and environmental impact, *FAO Fisheries Technical Paper*, **255**, 1-131.

Beveridge M.C.M., Haylor G.S., (1998), *Warm-Water Farmed Species*, In: *Biology of Farmed Fish*, Blanc K.D., Pikering A.D. (Eds.), CRC Press, Sheffield, 783-406.

Betanzos Vega A., Garcés Rodríguez Y., Delgado Miranda G., Pis Ramírez M.A., (2012), *Space-Time Variations and Eutrophic Degree of Nutrient Substances in Waters of the Ana María and Guacanayabo Gulfs* (in Spanish), 1st International Fishing Workshop CONyMA 2012, Fisheries Research Center, May 22 to 24, Havana, Cuba.

Borrego J.A., (2012), Fishermen perform harvest South Zaza, *Granma*, **196**, 2.

Bose A., Ghosh S., Yang C., Mitra A., (1991), *Coastal Aquaculture Engineering*, Chapman and Hall, Inc., New York.

Boyd C.E., (2009), Statistical design and analysis of studies to evaluate fertilizers and other pond amendments. methods for improving water use efficiency, On line at: https://www.was.org/documents/MeetingPresentations/AA2009/AA2009_0029.pdf.

Brugère C., Ridler N., (2004), Global aquaculture outlook in the next decades: an analysis of national aquaculture production forecasts to 2030, *FAO Fisheries Circular*, **1001**, 1-47.

Bruton M.N., (1986), *The Life History Styles of Invasive Fishes in Southern Africa*, In: *The Ecology and Management of Biological Invasions in Southern Africa*, Macdonald I.A.W., Kruger F.J., Ferrar A.A. (Eds.), Oxford University Press, Cape Town, 201-208.

Caballero Hernández R., (2009), Without water there is no development (in Spanish), *Voluntad hidráulica*, **102**, 60-62. On-line at: www.hidro.cu/documentos/Revista_VH/vh102/13c.pdf.

Carey A.E., Nezat C.A., Pennock J.R., Jones T., Lyon W.B., (2003), Nitrogen budget of the Mobile-Alabama River System watershed, *Geochemistry: Exploration, Environment, Analysis*, **3**, 239-244.

Cauchon D., (2009), Invasive carp threatens Great Lakes. *USA TODAY*, On line at: http://www.usatoday.com/news/nation/2009-11-30-asian-carp_N.htm.

Cervantes Castro D., (1980), *Civil Engineering for Coastal Lagoon Adaptation for Aquaculture Works* (in Spanish), Proceedings of the Latin American Aquaculture Symposium, vol. 2, Department of Fisheries, Mexico D.F., 1485-1498.

Cervantes Castro D., (1984), *Coastal Lagoons Improvement: Some Mexican Examples* (in Spanish), In: *Management of Coastal Lagoon Fisheries*, Kapetsky J.M., Lasserre G. (Eds.), *Studies and Reviews*, **61**, 695-708.

Christensen B., (1978), Biomass and primary production of *Rhizophora apiculata* BL in a mangrove in southern Thailand, *Aquatic Botany*, **4**, 43-52.

Christensen B., Wium-Anderson S., (1977), Seasonal growth of mangrove trees in Southern Thailand. I. The phenology of *Rhizophora apiculata* BL, *Aquatic Botany*, **3**, 281-286.

Cione J., (2005), How does the ocean respond to a hurricane and how does this feedback to the storm itself?, On line at: http:// www.aoml.noaa.gov/hrd/tcfaq/H7.html.

Claro R., Baisre J., García-Arteaga J.P., (1994), *Evolution and Management of Fishery Resources* (in Spanish), In: *Cuban Marine Fish Ecology*, Claro R. (Ed.), Institute of Oceanology (ACC) and Research Center of Quintana Roo, Mexico, 435-525.

Claro R., Baisre J.A., Linderman K.C., García-Arteaga J.P., (2001), *Cuban Fisheries: Historical Trends and Current Status*, In: *Ecology of the Marine Fishes of Cuba*, Claro R., Linderman K.C., Parenti L.R. (Eds.), Smithsonian Institution Press, Washington, 194-210.

Cury P.M., Mullon C., Garcia S.M., Shannon L.J., (2005), Viability theory for an ecosystem approach to fisheries, *ICES Journal of Marine Science*, **62**, 577-584.

De Angelis R., (1960), Mediterranean brackish water lagoons and their exploitation, *Studies and Reviews*, **12**, 1-41.

De Silva S.S., (1985), Status of the introduced cichlid *Sarotherodon mossambicus* (Peters) in the reservoir fishery of Sri Lanka: a management strategy and ecological implications, *Agriculture and Fisheries Management*, **16**, 91-102.

De Silva S.S., Nguyen T.T.T., Turchini G.M., Amarasinghe U.S., Abery N.W., (2009), Alien species in aquaculture and biodiversity: A paradox in food production, *Ambio*, **38**, 24-28.

Díaz G., Vázquez J., Marí A., (1989), Aquaculture development in Cuba (in Spanish), *COPESCAL Documento Técnico*, **6**, 1-69.

Duvail S., Hamerlynck O., (2003), Mitigation of negative ecological and socio-economic impacts of the Diana dam on the Senegal River delta wetland (Mauritania), using a model based decision support system, *Hydrology and Earth Systematic Sciences*, **7**, 133-146.

Edwards R.R.C., (1978), The fishery and fisheries biology of penaeid shrimp on the Pacific coast of Mexico, *Oceanography and Marine Biology*, **16**, 145-180.

Erzini K., (2005), Trends in NE Atlantic landings (southern Portugal): identifying the relative importance of fisheries and environmental variables, *Fisheries Oceanography*, **14**, 195–209.

Fagbenro O.A., (2004), Predator control of overpopulation in cultured tilapias and the alternative uses for stunted tilapias in Nigeria, On line at: http://ag.arizona.edu/azaqua/ista/ ista6/ ista6web/pdf/634.pdf.

FAO, (1995), Code of conduct for responsible fisheries, FAO, Rome, On-line at: ftp://ftp.fao.org/docrep/fao/005/v9878e/v9878e00.pdf

FAO, (1997), *Aquaculture Development*, *FAO Technical guidelines for responsible fisheries*, No. **5**, FAO, Rome.

FAO, (2007), A world overview of species of interest to fisheries. *Lates niloticus* SIDP –Species Identification and Data Programme FIGIS Species Fact Sheets FAO – FIGIS Species Fact Sheet, On-line at: http://www.fao.org/fi/website/ FIRetrieveAction.do?dom=species&fid=2275.

FAO, (2012a), FishStatJ: Universal software for fishery statistical time series, Version 1.0.0.

FAO, (2012b), The state of the world fisheries and aquaculture, FAO, Rome.

FAO, (2012c), *Hypophthalmichthys molitrix*. FAO Cultured Aquatic Species Information Programme, On line at: http://www.fao.org/fishery/culturedspecies/*Hypophthalmichthys_molitrix*/en.

Fernández de Alaiza García-Madrigal R., Arencibia Carballo G., Guerra Aznay M., (2012), *Situation of Some Exotic Marine Species in the Guacanayabo Gulf, Cuba* (in Spanish), 1st International Fishing Workshop CONyMA 2012, Fisheries Research Center, May 22 to 24, Havana, Cuba.

Fernández Márquez A., Pérez de los Reyes R., (2009), *Geo Cuba, Cuban environment assessment* (in Spanish), Environmental Agency, Ministry of Science,

Technology and Environment and United Nations Program for the Environment, Havana, Cuba.
Fernando C.H., Holcik J., (1982), The nature of fish communities: a factor influencing the fishery potential and yields of tropical lakes and reservoirs, *Hydrobiologia*, **97**, 127-144.
Flores-Verdugo F.J., (1989), *Some Ecological Aspects, use and Importance of Mangrove Ecosystems*, In: *Mexican Biological Oceanographi* (in Spanish), de la Rosa-Velez J., González-Farias F. (Eds.), Universidad Autónoma de Baja California, 21-56.
Flores-Verdugo F.J., Calvario-Martínez O., Cárdenas-Cárdenas M.A., (1993), Geographic distribution and some Nayarit and Sinaloa wetland environmental characteristics (in Spanish), *Biología de Humedales Costeros de México*, **1**, 11-16.
Fonticiella García D.W., (1996), The fisheries at Alacranes reservoir, *Villa Clara, Cuba*, (in Spanish), MSc Thesis, Center for Marine Research, University of Havana.
Fonticiella D.W., Arboleya Z, Díaz Perez G., (1995), Re-stocking as a way to fishery management in the Cuban aquaculture, *COPESCAL Occasional Documents*, **10**, 1-45.
Frazier J.G., (1997), Sustainable development: modern elixir or sack dress?, *Environmental Conservancy*, **24**, 182-193.
Froese R., (2004), Keep it simple: three indicators to deal with overfishing, *Fish and Fisheries*, **5**, 86–91.
Froese R., Pauly D., (2012), Fish Base World Wide Web electronic publication, On line at: http://www.fishbase.org/.
Froese R., Stern-Pirlot A., Winker H., Gascuel D., (2008), Size matters: how single-species management can contribute to ecosystem-based fisheries management, *Fisheries Research*, **92**, 231-241.
Galloway J.N., Schlesinger W.H., Levy III, H., Michaels A., Schnoor J.L., (1995), Nitrogen fixation: Anthropogenic enhancement-environmental response, *Global Biogeochemical Cycles*, **9**, 235–252.
García E., (2012), *Organization of Fishery Resorces in Cuba* (in Spanish), 1st International Fishing Workshop CONyMA 2012, Fisheries Research Center, May 22 to 24, Havana, Cuba.
García del Barco F., Crespo León J., (1981), Description of the Cuban fish fishery in coastal and estuarine areas (in Spanish), *Revista Cubana de Investigaciones Pesqueras*, **6**, 50-69.
Garcia S.M., Zerbi A., Aliaume C., Do Chi T., Lasserre G., (2003), The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook, *FAO Fisheries Technical Paper*, **443**, 1-71.
Ghion F., (1980), Modern vallicultura and fish feeding experience and development direction (in Italian), *Nova Thalassia*, **4**, 183-193.
Gillson J., (2011), Freshwater flow and fisheries production in estuarine and coastal systems: where a drop of rain is not lost, *Reviews in Fisheries Science*, **19**, 168-186.
Gillson J., Scandol J., Suthers I., (2009), Estuarine gillnet fishery catch rates decline during drought in eastern Australia, *Fisheries Researh*, **99**, 26-37.
González Alonso H., Rodríguez Schettino L., Rodríguez A., Mancina C.A., Ramos García I., (2012), *Red Book of the Cuban Vertebrates* (in Spanish), Editorial Academia, Havana, Cuba.
González Sansón G., Aguilar Bentancourt C., Finalé Gómez E., (1985), Coastal lagoon fisheries at Tunas de Zaza (in Spanish), *Revista de Investigaciones Marinas*, **6**, 52-61.
González-Sansón G., Aguilar Betancourt C., (1983), Comparative study of the fish comunities in the coastal lagoons of the Cuban southwestern region (in Spanish), *Revista de Investigaciones Marinas*, **4**, 91-123.
González-Sansón G., Aguilar Betancourt C., (1984), Ecology of the coastal lagoons at the southern region of Cuba (in Spanish), *Revista de Investigaciones Marinas*, **5**, 127-171.
González-Sansón G., Lalana Rueda R., (1982), Mangrove organic matter imput to the Cuban coastal lagoon aquatic ecosystem (in Spanish), *Revista de Investigaciones Marinas*, **3**, 3-32.
Gopalakrishnan V., (1977), *Management of Estuarine Fisheries – A Coordinated Plan of Research and Development*, Symp. on The Development and utilization of inland fishery resources, Proc. of the Indo-Pacific Fisheries Council, vol. 17, 138-147.
Gower J.F.R., (1972), *A Survey of the Uses of Remote Sensing from Aircraft and Satellite in Oceanography and Hydrography*, Marine Sciences Branch, Pacific Region, Sidney, vol. 72.
Halim Y., Morcos S.A., Rizkall, S., El-Sayed M.K., (1995), The impact of the Nile and the Suez Canal on the living marine resources of the Egyptian Mediterranean waters (1958–1986), *FAO Fisheries Technical Paper*, **349**, 19-50.
Halstead B.W., Auerbach P.S., Campbell D.R., (1990), *A Colour Atlas of Dangerous Marine Animals*, Wolfe Medical Publications Ltd, W.S. Cowell Ltd, Ipswich.
Harrison J.A., Frings P.J., Beusen A.H.W., Conley D.J., McCrackin M.L., (2012), Global importance, patterns, and controls of dissolved silica retention in lakes and reservoirs, *Global Biogeochemical Cycles*, **26**, 1-12.
Hill J.E., Cichra C.E., (2002), Evaluation of the importance of water depth and frequency of water levels/flows on fish population dynamics. Literature review and summary, Special Publication SJ2002-SP1.
Houde E., (1977), Abundnace and potential yield of the Atlantic thread herring, *Opisthonema oglinum*, and aspects of its early life history in the Eastern Gulf of Mexico, *Fishery Bulletin*, **75**, 493-512.
Humborg C., Ittekkot V.E., Cociasu A., Bodungen B.V., (1997), Effect of Danube River dam on Black Sea biogeochemistry and ecosystem structure, *Nature*, **386**, 385-388.
Ibáñez C., Prat N., Duran C., Pardos M., Munné A., Andreu R., Caiola N., Cid N., Hample H., Sánchez R., Trobajo R., (2008), Changes in dissolved nutrients in the lower Ebro River: causes and consequences, *Lumnetica*, **27**, 131-142.
INRH, (2005), Dam water statistics (in Spanish), National Institute of Hydraulic Resources, Havana, Cuba.
INRH, (2007), Annual report 2006 (in Spanish), National Institute of Hydraulic Resources, Havana, Cuba.
INRH, (2010), Annual report 2009 (in Spanish), National Institute of Hydraulic Resources, Havana, Cuba.
ISSG, (2009), Global Invasive Species Database, Invasive Species Specialist Group IUCN, On line at: http://www.issg.org/database/welcome/.
Ittekot V., Humborg C., Schäfer P., (2000), Hydrological alterations and marine biogeochemistry: a silicate issue?, *Bioscience*, **50**, 776-782.
Jackson D.C., Marmulla G., (2001), The influence of dams in river fisheries, *FAO Fisheries Technical Paper*, **419**, 45-90.
Jackson J.B.C., Kirby M.X., Berger W.H., Bjorndal K.A., Botsford L.W., Bourque B.J., Bradbury R.H., Cooke R., Erlandson J., Estes J.A., Hughes T.P., Kidwell S., Lange C.B.X., Lenihan H., Pandolfi J.M., Peterson

C.H., Steneck R.S., Tegner M.J., Warner R.R., (2001), Historical overfishing and the recent collapse of coastal ecosystems, *Science*, **293**, 629-638.

Kapetsky J.M., (1981), Some considerations for the management of coastal lagoon and estuarine fisheries, *FAO Fisheries Technical Paper*, **218**, 1-47.

Kapetsky J.M., (1984), Coastal lagoon fisheries around the world: Some perspectives on fishery yields, and other comparative fishery characteristics, management of coastal lagoon fisheries, *Studies and Reviews*, **61**, 97-139.

Kempf A., (2010), Ecosystem approach to fisheries in the European context – history and future challenges, *Journal of Applied Ichthyology*, **26**, 102-109.

Kim J., Kim J.-S., Kim G., (2010), Nutrient input from submarine groundwater discharge versus intermittent river-water discharge through an artificial dam in the Yeongsan River Estuary, Korea, *Ocean Science Journal*, **45**, 179-186.

Laíz-Averhoff O.R., (1999), Fish yields in Cuban reservoirs and relationships with some morphometric and edaphic parameters, *Lakes & Reservoirs: Research and Management*, **4**, 75-83.

Laíz-Averhoff O., (2002), *Phytoplankton and its interrelationship with the physical and chemical aspects of four reservoirs of the Cuban central region* (in Spanish), MSc Thesis, University of Havana, Cuba.

Larramendi J.A., Viña Dávila N., (2011), *Endangered Faces. Cuban Endangered Species* (in Spanish), Ediciones Polymita S.A., Ciudad Guatemala.

Legović T., Klanjšček J., Geček S., (2010), Maximum sustainable yield and species extinction in ecosystems, *Ecological Modelling*, **221**, 1569-1574.

Lindén O., (1990), *Environmental Threats Against Fish-Producing Tropical Coastal Waters*, In: *Water Resources Management and Protection in Tropical Climates*, Quesada V., Gutiérrez J., Landner L. (Eds.), Selected Papers from the First International Symposium, February 8-12, 1988, Havana, 389-402.

Lluis-Riera M., (1977), Hydrological studies of the Southwestern Cuban platform and adjacent oceanic waters (in Spanish), *Informe Científico-Técnico Instituto de Oceanología*, **16**, 1-29.

Mace P.M., (2001), A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management, *Fish Fisheries*, **2**, 2–32.

Macintosh D.J., (1982), *Fisheries and Aquaculture Significance of Mangrove Swamps, with Special Reference to the Indo-West Pacific Region*, In: *Recent Advances in Aquaculture*, Muir J.F., Roberts R.J. (Eds.), Croom Helm, England, 4-85.

Macnae W., (1966), Mangroves in eastern and southern Australia, *Australian Journal of Botany*, **14**, 67-104.

Marí A., (1992). *Cuban Interior Water Fisheries from Aquaculture*, In: *Management and Aquatic Exploitation of Freshwater Dams in Latin America* (in Spanish), Proyecto GCP/RLA/075/ITA, Documento de Campo, **1**, 72-105.

Margalef R., (1983), *Limnology* (in Spanish), Ediciones Omega S.A., Barcelona.

Martinho F., Cabral H.N., Azeiteiro U.M., Pardal M., (2012), Estuarine nurseries for marine fish: Connecting recruitment variability with sustainable fisheries management, *Management of Environmental Quality: An International Journal*, **23**, 414-433.

McCartney M.P, Sullivan C., Acreman M.C., (2001), Ecosystem Impacts of large dams. International Union for Conservation of Nature and Natural Resources and the United Nations Environmental Programme, On line at: intranet.iucn.org/webfiles/doc/archive/2001/iucn852.pdf.

McCully P., (1995), *Silenced Rivers. The Ecology and Politics of Large Dams*, Zed Books, London.

McHugh J.L., (1976), *Estuarine Fisheries: Are They Doomed?* In: *Estuarine Processes*, Wiley M. (Ed.), vol. 1, Academic Press, New York, 15-27.

Medeiros P.R.P., Knopper B.A., Cavalcante G.H., Landim de Souza W.F., (2011), Changes in nutrient loads (N, P and Si) in the São Francisco estuary after the construction of dams, *Brazilian Archives of Biology and Technology*, **54**, 387-397.

Mendoza E.A., Mendoza A., Galmiche T.A., Meseguer E.R., (1995), *Aquaculture of Native Fishes in Mexico: Challenges and Perspectives* (in Spanish), In: *2nd Seminar on Native Fishes with Aquaculture Potential*, Cardenas, Tabasco, México. 23-26 May 1994, 131-141.

Menéndez Carrera L., Guzmán Menéndez J.M., (2002), *Mangrove Ecosystems in the Cuban Archipelago* (in Spanish), Editorial Academia, La Habana.

Meybeck M., (2003), Global analysis of river systems: from earth system controls to Anthropocene syndromes, *Philosophical Transactions of the Royal Society of London, B*, **358**, 1935-1955.

Meybeck M., Helmer R., (1989), The quality of rivers - from pristine stage to global pollution, *Global and Planetary Change*, **75**, 283-309.

Milstein A., Eran Y., Nitzan E., Zoran M., Joseph D., (2000), Tilapia wild spawning control through predator fishes: Israeli trial with red drum and hybrid bass, *Aquaculture International*, **8**, 31-40.

Millares Dorado M., (2012), *Aquaculture* (in Spanish), 1st International Fishing Workshop CONyMA 2012, Fisheries Research Center, May 22 to 24, Havana, Cuba.

Ministerio de la Agricultura, (1984), Cuban Report. Seminar on Integral Management of Mangrove Ecosystems (in Spanish), Manzanillo, 6-9 November 1984, Ministerio de la Agricultura, La Habana.

Ministry of Fisheries of Cuba, (2012), Fishery Reception Reports, Tunas de Zaza Fishery Unit, Ministry of Fisheries of Cuba, 2012.

MIP, (1985), Report to the Popular Power National Meeting, (in Spanish), Sea and Fishing Workshops, Ministry of the Fishing Industry, Havana, Cuba.

Miranda L.E., (2001), *A Review of Guidance and Criteria for Managing Reservoirs and Associated Riverine Environments to Benefit Fish and Fisheries*, In: *Dams, Fish and Fisheries. Opportunities, Challenges and Conflict Resolution*, Marmulla G. (Ed.), Food and Agriculture Organizations of the United Nations (FAO), Rome, Italy, 91-139.

Montalvo J.F., Perigó E., Martínez M., García I., Esponda S.C., Cesar M.E., García R., López D., García N., Blanco M., (2010), Nitrogen and phosphorous compounds in water surface in three zones of Cuban marine shelf (in Spanish), *Series Oceanológica Instituto de Oceanología de la Academia de Ciencias de Cuba*, **7**, 27-36.

Muir J., (2005), Managing to harvest? Perspectives on the potential of aquaculture, *Philosophical Transactions of the Royal Society of London B*, **360**, 191–218

Muñoz-Nuñez D., (2009), *The Caribbean spiny lobster fishery in Cuba. An approach to sustainable fishery management*, MSc thesis, Nicholas School of the Environment, Duke University.

Nichols M., Allen G., (1981), Suspended sediment transport in coastal lagoons and estuaries, *UNESCO Technical Papers in Marine Science*, **33**, 27-80.

Nikolic N., Bosch A., Alfonso S., (1976), A system for farming the mangrove oyster (*Crassostrea rhizophorae* Guilding, 1828), *Aquaculture*, **9**, 1-18.

Obregón López-Silvero M.H., (2003), *Fish Fisheries Integrated Management at the Cuban Platform* (in Spanish), XIV Science and Technology Forum, Directorate of Fisheries Regulations, Ministry of the Fishing Industry, Havana, Spain.

Odum W.E., (1970), *Utilization of the Direct Grazing and Plant Detritus Food Chain by the Striped Mullet Mugil cephalus*, In: *Marine Food Chains*, Steele J.H. (Ed.), Oliver & Boyd, Edinburgh, 222-240.

Odum E.P., Cruz A.A., (1963), Detritus as a major component of ecosystems, *AIBS Bulletin*, **13**, 39-40.

Odum W.E., Heald E.J., (1975), *Mangrove Forest and Aquatic Productivity*, In: *An Introduction of Land-Water Interaction*, Springer-Verlag Ecological Study series, New York.

Odum W.E., Johannes R.E., (1975), *The Response of Mangroves to Man-Induced Environmental Stress*, In: *Tropical Marine Pollution*, Wood E.J.F., Johannes R.E. (Eds.), Elsevier Oceanography Series, 52-62.

ONEI, (2011), *Selected products imports* (in Spanish), National Bureau of Statistics, Havana, Cuba, On line at http://www.one.cu/.

Olsen H.F., (1984), Lagoon and estuarine fisheries in the broader context of coastal zone management with a review of three case studies in Queensland, Australia, *Studies and Reviews*, **61**, 711-734.

Pauly D., (2010), *The State of Fisheries*, In: *Conservation Biology for All*, Sodhiand S.N.S., Ehrlich P.R. (Eds.), Oxford University Press, Oxford, 118-120.

Pauly D., Froese R., (2012), Comments on FAO’s State of Fisheries and Aquaculture, or ‘SOFIA 2010’, *Marine Policy*, **36**, 746-752.

Peña-Alvarado N., Figuerola-Fernández M., Torres-Ruiz W., (2009), Reproductive biology of three important baitfishes (Clupeidae) in Puerto Rico, *Proc. of the Gulf and Caribbean Fisheries Institute*, **61**, 38-47.

Pérez Eiriz M.C., Pubillones M.A., Romanenko V.I., (1990), *The Primary Productivity of Phytoplankton in Cuban Reservoirs*, In: *Water Resources Management and Protection in Tropical Climates*, Quesada V., Gutiérrez J., Landner L. (Eds.), Selected Papers from the First International Symposium, February 8-12, 1988, Havana, 193-211.

Perigó E., Montalvo J.F., Pérez D.M., (2003), More frequent and extreme values of chemical parameters of environmental quality in costal ecosystems and Cuban marine platform waters (in Spanish), *Contribución a la educación y la protección ambiental*, **4**, 445-455.

Piñeiro R., Valdés R., (1994), Water quality in the Zaza and Najasa River estuaries (in Spanish), *Revista Latinoamericana de Acuicultura*, **43**, 72-90.

Piñeiro R., Puga R., González-Sansón G., (2006), Integrated management basis of lobster (*Panulirus argus*) resource at the south coastal zone of Pinar del Río. I. Environmental factors (in Spanish), *Revista de Investigaciones Marinas*, **27**, 245-251.

Puga R., de León M.E., Cruz R., (1992), Spiny lobster, *Panulirus argus* Cuban fishery assessment (in Spanish), *Revista de Investigaciones Marinas*, **12**, 286-292.

Quignard J.P., (1984), The biological and environmental characteristics of lagoons as the biological basis of fisheries management (in French), *Studies and Reviews*, **61**, 3-38.

Quiñones N., Martínez R., Rodríguez L., Romero C., (1990), *Trophic Classification of Cuban Reservoirs*. In: *Water Resources Management and Protection in Tropical Climates*, Quesada V., Gutiérrez J., Landner L. (Eds.), Selected Papers from the First International Symposium, February 8-12, 1988, Havana, 234-241.

Quirós R., (1994), Fishery intensification on the small water bodies in Latin America and the Caribbean, *COPESCAL Documento Ocasional*, **8**, 1-41.

Quirós R., Marí A., (1999), Factors contributing to the outcoming of stocking programs in Cuban reservoirs, *Fisheries Management and Ecology*, **6**, 241-258.

Ravagnan G., (1978), *Modern Elements of “Vallicoltura”*, (in Italian), Edagricole, Bologna.

Ravagnan G., (1981), Production increase on lagoon areas: available technologies and intervention strategies, (in French), *Studies and Reviews*, **58**, 181- 251.

Robins C.R., Bailey R.M., Bond C.E., Brooker J.R., Lachner E.A., Lea R.N., Scott W.B., (1991), World fishes important to North Americans. Exclusive of species from the continental waters of the United States and Canada, *American Fisheries Society Special Publication*, **21**, 1-243.

Rollet B., (1986), Mangrove integrated organization (in Spanish), Latin American seven national seminar synthesis. FO: MISC/86/4. FAO, Rome.

Rosenberg D.M., McCully P., Pringle C.M., (2000), Global-scale environmental effects of hydrological alterations: introduction, *BioScience*, **50**, 746-751.

Rosenthal H., (1994), Aquaculture and the environment, *World Aquaculture*, **25**, 4-11.

Ross G.L., Beveridge M.C.M., Akester M.J., (1995), *Aquaculture Development and Species Introductions: The Background, the Problems and Current Trends*, 2nd Seminar on Native Fishes with Aquaculture Potential, 23-26 May 1994, H. Cardenas, Tabasco, México, 205-215.

Rowan K., (2010), Why are Asian carp so fearsome?, On line at: http://www.livescience.com/8364-asian-carp-fearsome.html.

Salas S., Mexcano-Cintora G., Cabrera M.A., (2006), To where do the Yucatan fisheries go? Tendencies, challenges and perspectives (in Spanish), CINVESTAV-IPN, Unidad Mérida, Yucatán, México.

Salat J., Palomar I., Lloret J., Solé I., (2011), *Impact of Riverine Contributions on the Anchovy Population Productivity South of Cataluña* (in Spanish), VII Iberian Congress on Water Management and Planning "Ríos Ibéricos + 10. Looking to the future after 10 years of DMA". February 16-19, 2011, Talavera de la Reina, Toledo, Spain.

Serrano-Méndez H., (2007), *Fishery resources sustainable management* (in Spanish), Topics on the Sea, Fisheries, Fishermen and the Environment, CITMA, UNDP Project / GEF Sabana Camagüey - Capacity 21, MIP, CIP, Cuba, 14-17.

Shepherd C.J., Bromage N.R., (1988), *Intensive Fish Farming*, BSP Professional Books, Oxford.

Shrestha M.K., Lin C.K., (1996), Phosphorous fertilization strategy in fish ponds based on sediment phosphorous saturation level, *Aquaculture*, **142**, 207-219.

Sigurdson R., (2010), Silver carp species profile, On line at: http://www.dnr.state.mn.us/minnaqua/speciesprofile/silvercarp.html.

Sin Y., Sigleo A.C., Song E., (2007), Nutrient fluxes in the microalgal-dominated intertidal regions of the Lower Yaquina Estuary, Oregon (USA), *Northwest Science*, **81**, 50-61.

Sklar F.H., Browder J.A., (1998), Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico, *Environmental Management*, **22**, 547-562.

Somoza R.D., Kampel M., Souza R.B., (2007), *Chlorophyll Concentration Variability in the Cuban Platform Adjacent Waters and the Relationship with Lobster (Panulirus argus) Fisheries* (in Spanish), Anais XIII Simp. Brasileiro de Sensoriamento Remoto, 21-26 April 2007, INPE, Florianópolis, Brasil, 4699-4706.

Song Z., (1980), Manual of small-scale reservoir fish culture, *FAO Fisheries Circular*, **727**, 1-18.

Stickney R.R., (2000), *Carp Culture*, In: *Encyclopedia of Aquaculture*, Stickney R.R. (Ed.), John Wiley and Sons, Inc., New York, 147-153.

Tal S., Ziv I., (1978), *Culture of Exotic Fishes in Israel*, In: *Symposium on Culture of Exotic Fishes*, Smitherman R.O., Shelton W.L., Grover J.H. (Eds.), American Fisheries Society, Aquaculture Atlanta'78, Atlanta, 1-42.

Tápanes J.J., (1981), Salinity, temperature and oxygen determinations of the Zaza river water (in Spanish), *Voluntad Hidráulica*, **57**, 33-39.

Tolmazin D., (1979), Black Sea - Dead Sea, *New Scientist*, **84**, 767-769.

Turner R.E., Rabalais N.N., (1991), Changes in Mississippi River water quality this century, *Bioscience*, **41**, 140-147.

Turner R.E., Rabalais N.N., Justic D., Dortch Q., (2003), Future aquatic nutrient limitations, *Marine Pollution Bulletin*, **46**, 1032-1034.

Valle S.V., Sosa M., Puga R., Font L., Duthit R., (2011), *Coastal Fisheries of Cuba*, In: *Coastal Fisheries of Latin America and the Caribbean*, Salas S., Chuenpagdee R., Charles A., Seijo J.C. (Eds.), FAO Fisheries and Aquaculture Technical Paper, 155-174.

Verkerk M.P., van Rens C.P.M., (2005), Saline intrusion in Gambia River after dam construction, Research Report, University of Twente, The Netherlands.

Victoria I., Cabal A., García R. Hernández M., Puentes H., (1990), *Characteristic of the Jagua pit and the Southern Cuba Exclusive Economic* (in Spanish), Final Theme Report, Scientific Archive of the Institute of Oceanology, Academy of Sciences of Cuba, Havana, Cuba.

Vollenweider R.A. (Ed.), (1969), *A Manual on Methods for Measuring Primary Production in Aquatic Environments*, IBP Handbook Nº 12, Blackwell, Oxford and Edinburgh, UK.

Vörösmarty C.J., Sahagian D., (2000), Anthropogenic disturbance of the terrestrial water cycle, *BioScience*, **50**, 753-765.

Wadie W.F., (1982), Observations on the catch of the most important fishes along the Egyptian continental shelf in the South Eastern part of the Mediterranean Sea, *Bulletin of the Institute of Oceanography and Fisheries*, **8**, 212-227.

Walker K.F., (1985), A review of the ecological effects of river regulation in Australia, *Hydrobiologia*, **125**, 111-129.

Welcomme R.L., (1988), International introduction of inland aquatic species, *FAO Fisheries Technical Paper*, **294**, 1-318.

Wells P.G., (1999), Environmental impact of barriers on rivers entering the Bay of Fundy: report of an ad hoc environment Canada working group, Technical Report Series, 1-43, On line at: http://www.publications.gc.ca/site/eng/83340/publication.html.

Wetzel R.G., (1983), *Limnology*, W.B. Saunders Company, Philadelphia, London, Toronto.

Witham R., Ingle R.M., Sims H.W., (1964), Notes on postlarvae of *Panulirus argus*, *Quartery Journal of the Florida Academy of Science*, **27**, 289-297.

Wuff J., (1995), Effects of hurricane on survival and orientation of large erect coral reef sponges, *Coral Reefs*, **14**, 55-61.

Wurmann C.G., (2010), Regional revision of the situation and tendency of the aquaculture development in Latin America and the Caribbean–2010 (in Spanish), *FAO Fisheries and Aquaculture Circular*, **1061**, 1-212.

Yera Digat G., De Migual Fernández C., Fagundo Castillo J.R., (2010), Saline intrusion in the aquifer system at the South coast of Camagüey, Cuba (in Spanish), On line at: http://www.oceandocs.net/handle/ 1834/3636.

Yeras Díaz-Velis J.I., Berdayes Arritola J.J., Pérez Rodríguez A., Hernández Garciarena A., Pérez García, Gómez Pérez A., Valdés Iznaga R., Corbea Cruz N., Guerra Guillermo L., Pérez Ruiz A., (2000), *Environmental impact of anthropic activities on the costal lagoons of the South coast of Sancti* Spiritus (in Spanish), MarCuba 2000, 4-8 December, 2000, Havana, Cuba.

Yi Y., Diana J.S., Shrestha M.K., Lin C.K., (2002), Culture of mixed-sex Nile tilapia with predatory snakehead, Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon: 67-73, On line at: http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/544.pdfhttp://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/544.pdf.