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Ecological Functions and Economic Value of the Neotropic Cormorant (*Phalacrocorax brasilianus*) in Los Olivitos Estuary, Venezuela.

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ABSTRACT

We determined the ecological function and economic value of a colony of piscivorous Neotropic Cormorants at the Los Olivitos Wildlife Refuge and Fisheries Reserve (WRFR), Lake Maracaibo, Venezuela. Colony size increased from 17,000 to approximately 40,000 in two years. Lake Maracaibo supports one of the most productive artesinal fisheries in Venezuela and the cormorant colony comprises 2 km of coastal mangrove. Neotropic Cormorants and fishermen use the same area, but do they compete? What is the ecological role of the Neotropic Cormorant in that area? To study the economic value of Neotropic Cormorants, we established ecological functions in the area of interest. Where, how many and how much do they feed? An ecological study of abundance, distribution and diet of Neotropic Cormorants was undertaken from 1999 to 2001. Abundance and distribution was discerned from monthly censuses and dietary composition was obtained via stomach and pellet analysis. An economic study was developed to estimate the economic impact and value of the Neotropic Cormorant population using four ecological-economic functions 1) Harvesting cormorants for food M(N), 2) Cormorants as contributors to fish diversity FD(N), 3) Cormorants as indicators of presence of fish schools S(N) and 4) Cormorants as contributors to fish biomass due to guano production B(GN). These functions were established after literature review and selection of goods, services, and attributes provided by Neotropic Cormorants in Los Olivitos Estuary and feasible for the study. The economic Total Value of the Neotropic Cormorant Population TV (N) was defined as the value of Cormorants to fishermen; changes in cormorant numbers would imply changes in the fishermen's well-being. Ecological results indicated the population is increasing exponentially. Eighty-three percent of the population fed outside of the WRFR. Diet consisted mostly of 19 fish species in four families (Ariidae, Engraulidae, Gerreidae and Bothidae), and one shrimp. Monthly changes in dietary composition were observed. Average daily consumption was 225g, but before migration, birds may consume 800g/day. Based on the list of 9 commercial species consumed and fish size, no competition occurred. Estimated values of S(N), M(N) and FD(N) were positive, but B(GN) was negative.The Net Value of the Neotropic Cormorant population obtained only from S(N) + B(G,N) was $6,793,871/year. The Neotropical Cormorant population does not presently compete with artisanal fisheries in Lake Maracaibo, but if habitat is not a limiting factor and numbers of birds continue to increase, future conflicts could arise. This relationship offers unique opportunities to develop an integral ecological and economic dynamic model to study different scenarios to establish management policies for Neotropic Cormorants and artesinal fisheries, aquaculture, fish diversity and conservation.

1.INTRODUCTION

Cormorants (23 species) are aquatic birds at the top of food webs in marine or estuarine ecosystems. They are skilled aquatic divers, feeding mainly on fish. Most are strongly migratory and move locally from overnight roosts to feeding areas (Weller 1999).

Nowadays, environmental conflicts are arising between cormorant species and fishery industries. The most documented conflicts are on populations of Double-crested Cormorants (*Phalacrocorax auritus*) and Great Cormorants (*Phalacrocorax carbo*). These species have been studied during the past two decades and are still of increasing concern for commercial aquaculturists, and for commercial and sport fishermen in North America (United States and Canada) and some European countries (Spain, Netherlands, Sweden, Switzerland, Ireland, England). Moreover, conservationists are worried about habitat destruction and impacts to other waterbirds.

Several studies have been done on these birds in different continents, and most show an effort to give these species the status of pest or plague (Duffy, 1995). From another perspective, Suter (1998) revealed from a literature review on impacts of piscivorous birds on freshwater fish populations and fisheries, that few rigorous studies on avian impacts exist or are based on poor scientific data (Warnink and Chifamba 1999).

Some investigations have shown that these birds cause considerable economic losses for different reasons: On commercial fisheries, because they compete for commercial fish (Price and Nockum, 1995, Weseloh, *et al*. 1995, Glahn and Stikley, 1995, Glanh and Brugger 1995); on baits that fishermen use, because they consume fish species used as bait, as well as remove bait from lobster traps, diminishing the capture of these (Price and Nockum, 1995); and on the aquaculture of commercial fish, such as catfish, atlantic and pacific salmon, rainbow trout, crabs, prawn, shrimps, ornamental fish and mussels, because cormorants feed on ponds where resources are concentrated (Price and Nickum, 1995). Cormorants decrease vegetable biomass, because their excrement (guano) dries vegetation. Also, vegetation "whitewashed" with guano may be considered unsightly, impacting vegetation aesthetics, which in turn may reduce tourism to certain areas (Haynes and Goh, 1978). Finally, cormorants damage fishermen's nets (Nettleship and Duffy, 1995).

Other studies, however, indicate that cormorants do not generate economic losses and contribute to the ecosystem in different ways, because they: Perform fish density-dependent regulation (Suter 1994, 1995a,b), allowing fish diversity; are part of bird biodiversity (Barbiert *et al.* 1994); allow bigger captures of fish of commercial sizes (Hustler 1991); extract sick organisms from farms, since these are easier to capture (Nettleship and Duffy, 1995); and indicate quality of the water (Keith, 1995). Maybe the greatest influence of cormorants on wetlands, although less direct, is on nutrient production, because of guano excretion. This organic matter is incorporated into the water column (Odum 1971, Krebs 1994, Miller 1994, Begon *et al.* 1997, Weller 1999). Cormorants are ideal species to study material flow from aquatic ecosystems to terrestrial ecosystems, via stable isotope analysis of their diets (Kameda 1998). Also, due to their high mobility, these birds transport eggs of invertebrates, snails, seeds, vegetable material and algae stuck to their feet, feathers or in their digestive tract (Weller 1999).

In relation to these discrepancies of opinion, the Neotropic Cormorant population and artisan fishery, located in Venezuela, gave the opportunity to develop a study to find our own conclusions about types of conflicts or relationships occurring between artisanal fisheries and Neotropic Cormorants. Are they in competition? Do they have a positive or negative value for artisanal fishermen?

This is the only cormorant species in Venezuela and occurs in high numbers in estuarine areas of Lake Maracaibo, where many artisanal fishermen also occur. The Neotropic Cormorant (*Phalacrocorax brasilianus*) or "Cotua Olivacea", is broadly distributed in the Neotropic, from Texas and Mexico to Patagonia (Stotz *et al.* 1996). Although it is remarkably versatile in its use of habitat, many aspects of its life history remain poorly known and in need of study. Telfair and Morrison (1995) compiled studies on Neotropic Cormorant feeding habits, distribution, habitat, breeding, demography and populations from studies developed mainly in the upper Texas coast. However, from Venezuela and neighboring countries few references are available, and include the short accounts of Phelps and de Schauensee (1978), Hilty and Brown (1986) and Hilty (2003), and feeding habits in Argentina (Regidor and Terraba, 2001) and from Brazil (Branco *et al*., 2002).

For the study area, we selected the Los Olivitos mangrove ecosystem, located northeast of Maracaibo, in western Venezuela. At Los Olivitos, a colony of Neotropic Cormorants established about 1986, at Punta de Java (10° 53' 48" N: 71° 26' 41" W). Since then, the colony has grown, and the birds presently use 2 km of coastal mangrove for roosting and breeding. Fig. 1. At the same time, the Lake Maracaibo area supports one of the most productive artisan fisheries in the country.

In this ecological - economic study, the impact created by the presence of thousands (40,000) of these fish-eating birds is analyzed, using similar methodologies to establish comparisons with studies developed on similar species.

The economic impact of cormorants has been reported in several countries, based on the daily consumption rate of fish, multiplied by the number of cormorants, especially those that affect aquaculture farms. Double-crested cormorants (*Phalacrocorax auritus*) can have a daily consumption of approximately 304 g/day (Glahn and Stickley 1995). The financial impact of a population of 35,000 cormorants to the catfish (*Ictalurus punctatus*) industry in the State of Mississippi, U.S.A, was $3,300,000/year (Glahn and Brugger, 1995).

In this study, number of cormorants, distribution of foraging areas, and daily consumption were key factors in the research.

2. METHODOLOGY

2.1 For Ecological Analysis:

During 1999 and 2001, data on abundance and distribution of Neotropic Cormorants were obtained during monthly censuses from a boat within the Los Olivitos WRFR. Dietary composition was discerned via stomach contents (73 stomachs) and pellets or regurgitation analysis (400) collected in the roosting area. Fish identification was done via a species-specific shape pattern match of 3,465 pairs of otoliths. A catalogue on how to identify otoliths of fishes in Lake Maracaibo was produced, Fig. 2.

We studied the behavior of fishermen in terms of where they fish, amount of fish production in Zulia State, commercial species harvested, number of fishermen/boat, salary, cost of boat maintenance, and price of fish for distribution.

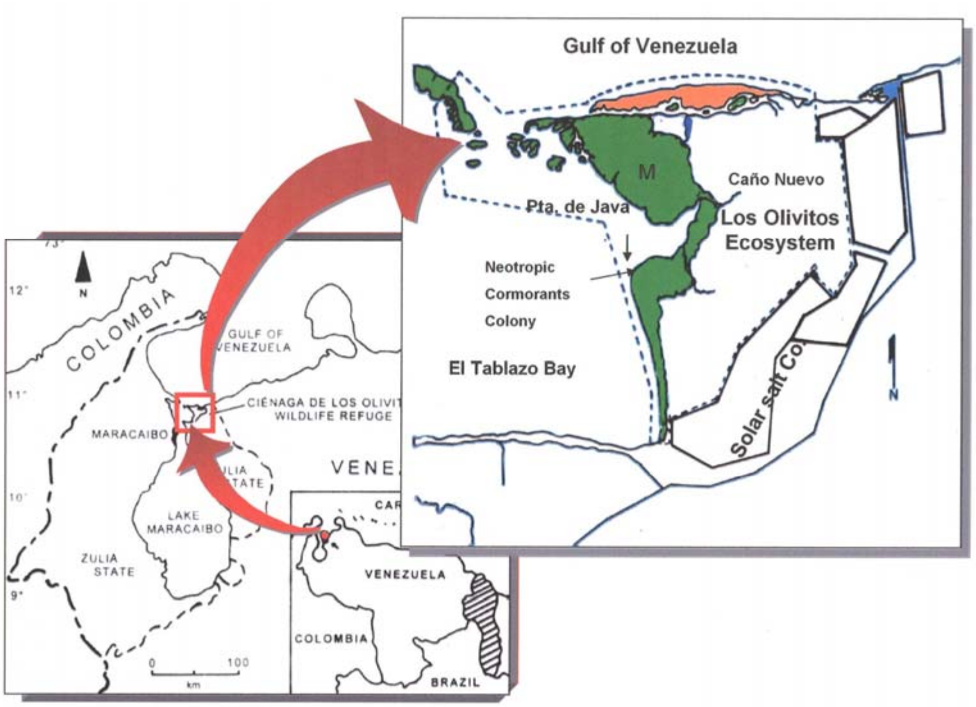

Figure 1. Study Area: Los Olivitos Wildlife Refuge and Fish Reserve (Los Olivitos WRFR) (26,000 Has). Western Venezuela. M = Mangrove forest

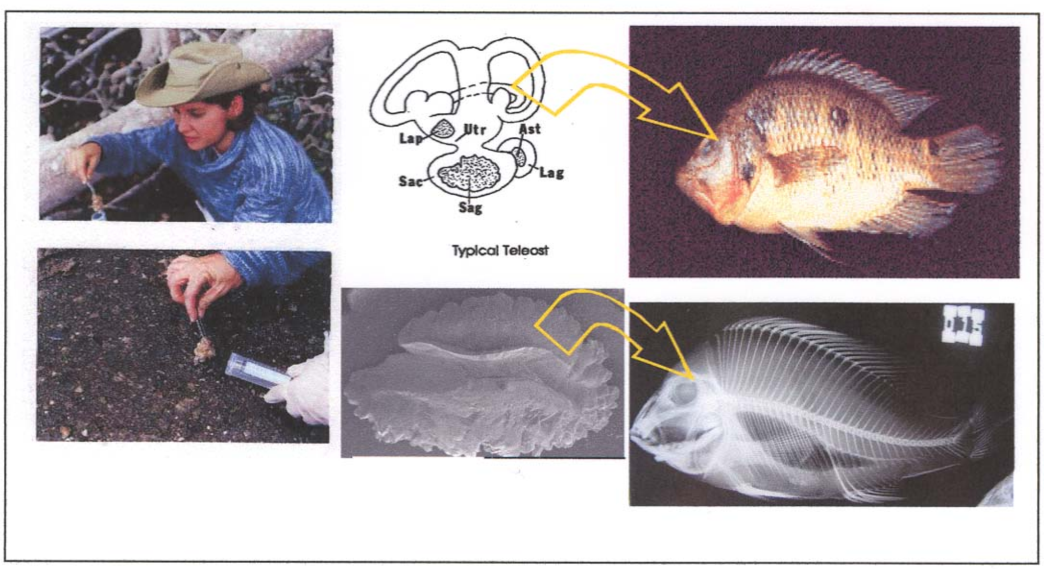

Figure 2. Pellets or regurgitation collection for fish identification in cormorant diet.

2.2 For Economic Analysis:

The analytical study of economic valuation of the Neotropic Cormorant is based on the premise that the economic total value (TV) of the cormorant population (N) is defined as the value of the cormorant species to fishermen. The ecological functions of the species have an impact on the well being of fishermen. Thus, changes in the species would imply changes in the fishermen's well being. This economic valuation aims to identify those changes.

A literature review was done to determine all relationships between fish-cormorant populations, and to analyze these factors in function of importance in location and feasibility.

The study was structured using Barton's methodology (Barton, 1995) and analytical steps. The choice of evaluation criteria, identification and valuation of costs and benefits were based on Bojo *et al.* (1992):

1) Identification of the most significant goods, services and attributes provided by Neotropic Cormorants in Los Olivitos, and
2) Selection of goods, services and attributes to be valued (Table 1).
3) Economic valuation based on ecological information available.
    a. Ecological analysis,
    b. Economic analysis, and
4) Comparison of effects in fisheries: Fishing activities with and without cormorants.

The value of cormorants was estimated via four ecological functions of the population:

1. M(N) = Harvesting cormorants for food
2. FD(N) = As contributors to fish diversity
3. S(N) = Using cormorants as indicators of fish schools for fishermen.
4. B(GN) = As contributors to fish biomass through guano production.

Table 1: Identification and selection of goods, services and attributes provided by Neotropic Cormorants in Los Olivitos.

Potentially	**Selected for this analysis due to available information**
GOODS	
Meat for consumption: Meat (kg). in substitution of other kinds of meat. Eggs: Nests in trees at 20 mts. height, not collected. Guano (fertilizer): Not collected , washed by daily tides.	Cormorant as a food supply (meat)
SERVICES	
Indicator of fish schools : Artisan fishermen may follow birds in search of any kind of fish schools.	Valuation of the search time
Production via nutrients : Phosporus (P) and Nitrogen (N) from excrement to Phytoplankton- Invertebrates-Fish.	Valuation of fish biomass
Fish population regulation: Depredation on most abundant species, avoiding fish species dominance.	Valuation of fish diversity
Bird watching recreation	
They open up channels of investigation: parasites, otoliths, genetics, model simulation, etc.	
Indicators of water quality: Indicator of chemical pollutants.	
Protection against cutting of mangroves: 2 km. of roosting area limit the access to inner mangrove areas to be cut illegally.	
ATRIBUTES	
Conservation of Biodiversity	
Value of existence	

3. RESULTS AND DISCUSSION:

3.1 Ecological study results:

Abundance: Population is increasing exponentially. Population data 1982 to 2001, Fig. 3. Monthly population data 1998- 1999 (Gil de Weir, 2000). Highest number in June 2000 census was 24,000; and 40,000 in 2001. Population size 1982 – 1995 (Casler, and Weir pers. Comm.).

Distribution: During 1999 only 17% of the population fed in the Los Olivitos WRFR, and 83% in other none determined areas of Lake Maracaibo, Fig. 4 (Gil de Weir, 2000).

Diet composition results are available in Gil de Weir (2000), and are summarized here.

Stomach content and pellet analysis gave similar results except for shrimp consumption that was more abundant in stomach content analysis.

Consumption proportion = Fish 88,5 % and shrimp 11.4 % (max. shrimp consumption).

From 20 items consumed 14 fish species identified and 1 shrimp species. Four fish families, represent the main components in the diet, Fig. 5; and Table 2 shows the list of species and families identified via otoliths. Fish diversity in Los Olivitos is 74 species (Weir et al, 2003)

The diet composition and the average consumption vary monthly, Figs. 5 and 6.

The average daily consumption is 225g. In June, before migration occurs, consumption increased up to 800g/cormorant.

Neotropic Cormorant weight was 1.27 kg (n = 73); other Cormorant species in Africa = 1.5 kg (Hustler, 1991).

Nutritional requirement per day (RA) = 17.8 % of their body mass, other cormorant species = 15.6% (Hustler, 1991).

Average fish weight was obtained via otolith size for the main families consumed by Neotropic Cormorant,Table 3.

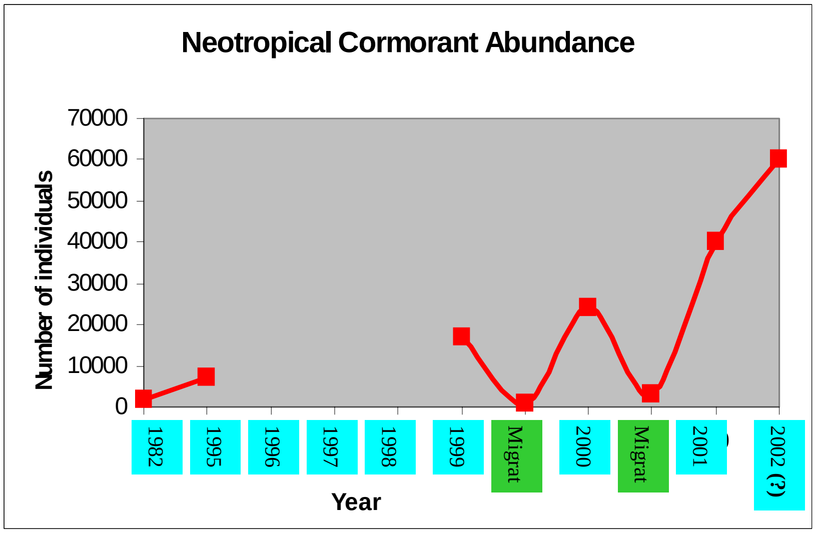

Figure 3. Neotropic Cormorant population in Los Olivitos Ecosystem, Zulia State, Venezuela 1982 – 2001**.**

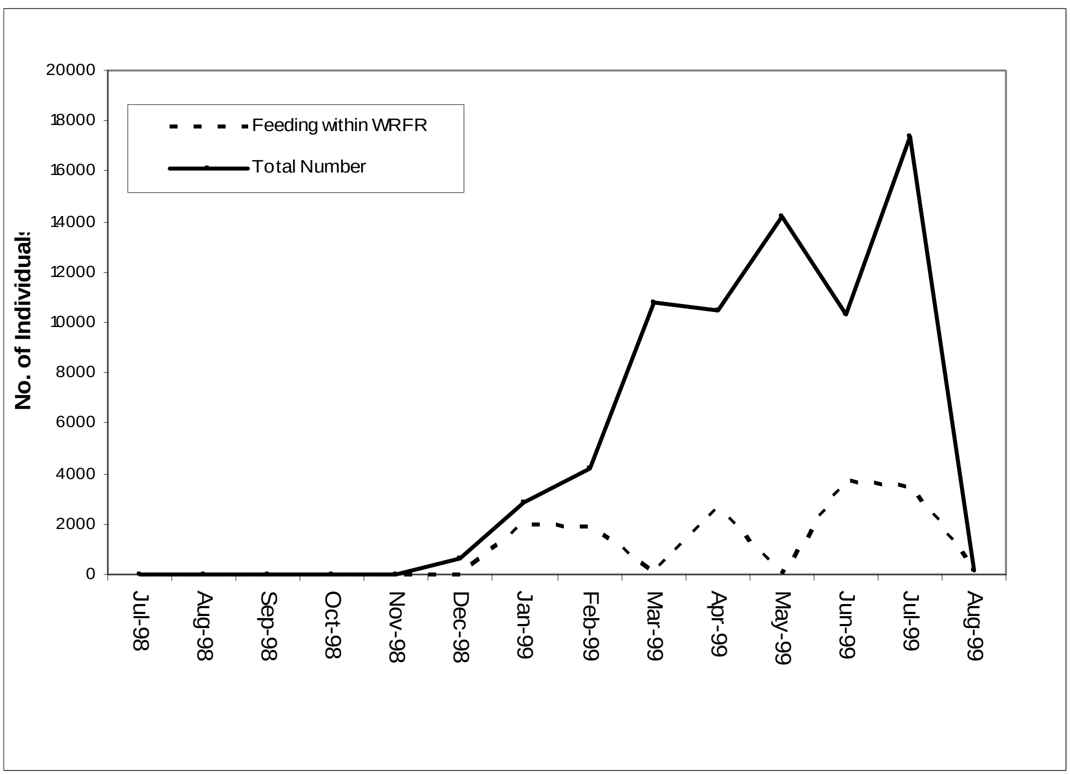

Figure 4. Neotropic Cormorant: Total Population Roosting and Feeding within WRFR

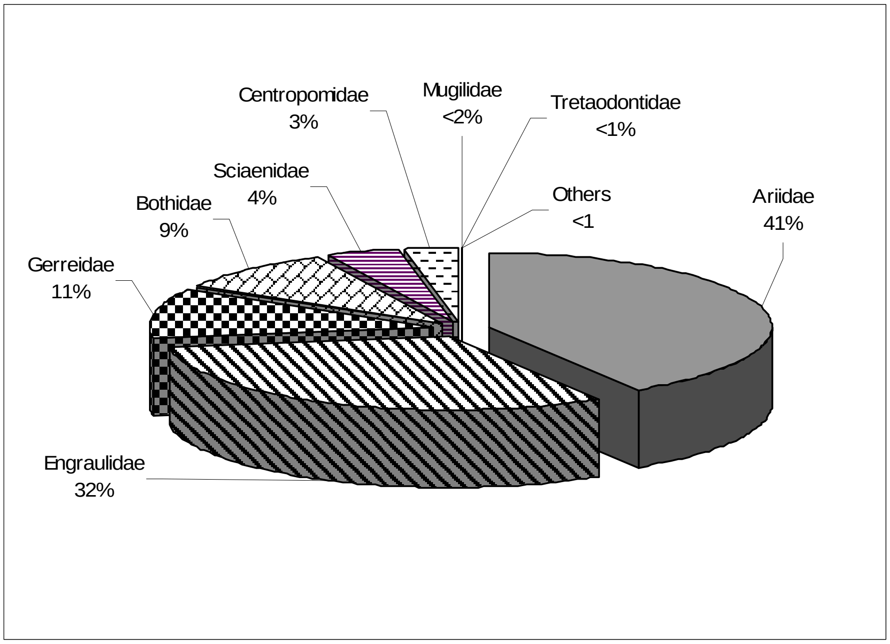

Figure 5. Diet composition of the Neotropic Cormorant in Los Olivitos WRFR.

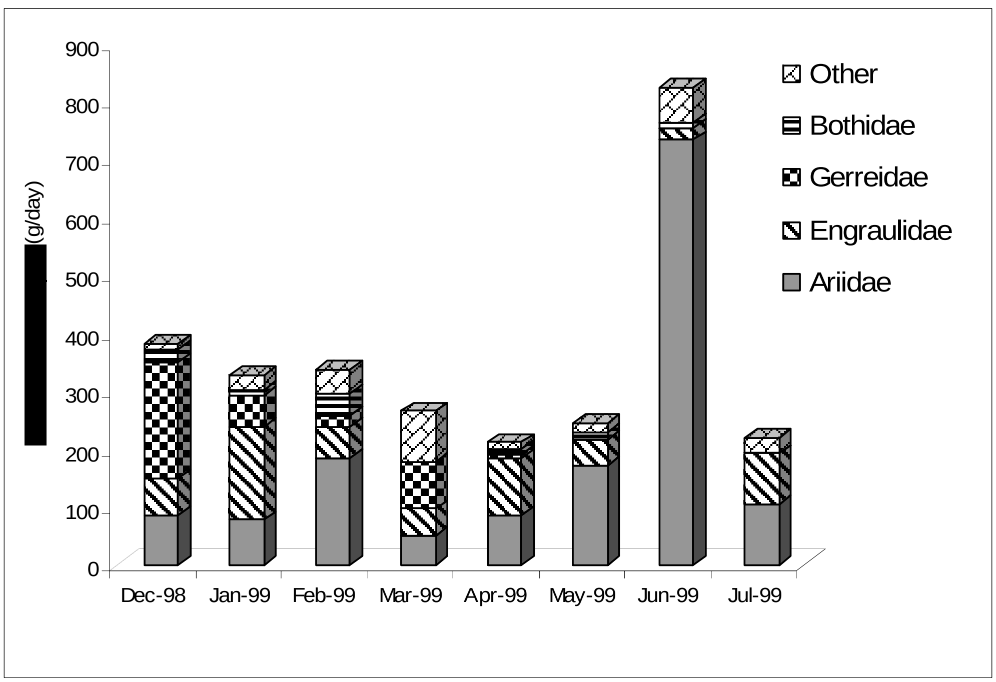

Figure 6. Neotropic Cormorant monthly biomass consumption in Lake Maracaibo.

Table 2. Neotropic Cormorant diet: Fish composition and relative abundance.

* Commercial interest.

Species & Family	Common name (spanish name)	Relative Abundance (%)
*Cathorops spixii** ARIIDAE	Catfish (Bagre dorado)	32.25
*Anchovia clupeoides** ENGRAULIDAE	Zabaleta anchovy (Arenque o Sardina)	29.81
*Diapterus rhombeus** *GERREIDAE*	Mojarra (Carpeta)	10.18
*Citharichtys spilopterus** *BOTHIDAE*	American Sole (Lenguado)	8.95
Arius herzbergii *ARIIDAE*	Sea Catfish (Bagre Guatero)	6.52
*Centropomus undecimalis** *CENTROPOMIDAE*	Swordspine Snook (Robalo)	2.96
*Micropogonias furnieri** *SCIANIDAE*	Whitemouth Croaker (Ronco Blanco)	2.15
Gobionellus oceanicus *GOBIIDAE*	Gobie (Gobidos)	2.06
*Mugil curema** *MUGILIDAE*	White Mullet (Lisa criolla)	1,74
Achirus lineatus *ACHIRIDAE*	American Sole (Lenguado)	0.93
Bairdiella ronchus *SCIANIDAE*	(Ronco e´pua)	0.90
Unknow I	?	0.40
*Ophioscion punctatissimus** *SCIANIDAE*	Roncador	0.32
Unknow II SCIANIDAE	?	0,29
Cynoscion spp.* SCIANIDAE	Acoupa Weakfish (Curvina de Lago)	0,26
Sphyraena? *SPHYRAENIDAE?*	Picua?	0.14
Batrachoides sp. BATRACHOIDIDAE	Sapito	0.03

Table 3.Fish weight and otolith size relationship for fish families consumed by Neotropic Cormorants at Los Olivitos WRFR.

Fish Families	Average fish weight (g)	Average otolith length (mm)
Engraulidae	28.42	3.8
Ariidae	56	8.9
Gerreidae	35	4.4
Bothidae	15	3.2
Centropomidae	45	5.5
Mugilidae	100	8.2
Tretaodontidae	65	5.3
Others	28	

4. ECONOMIC VALUATION BASED ON ECOLOGICAL FUNCTIONS

4.1. VALUATION OF HARVESTING CORMORANTS FOR FOOD

M(N)

4.1.1 Ecological and Economic Analysis:

Some aquatic birds generate economic benefits, taking into consideration if they are hunted (such as ducks), or if their eggs are consumed or feathers harvested or people value the species for its natural beauty via photography, etc. Cormorants can be considered relatively unproductive in comparison with other bird species of alternative economic use. Some references suggest that the first settlers of America hunted these birds for food. Cormorant populations were almost suppressed during the early 1900s due to egg collecting for human consumption and hunting by fishermen, who considered cormorants as competitors (Glahn *et al.* 2000).

In the valuation of goods provided by cormorants we discussed eggs and fertilizers. Eggs are profitable goods of cormorants, but at Los Olivitos, they are in nests 20m above the forest floor. Thus, these goods were not evaluated in this study.

Guano or fertilizer: Phosphorus (P) and Nitrogen (N) is well exploited in other countries like Peru and some African countries. It will not be evaluated as fertilizer here, because although the number of cormorants is high, guano deposition occurs on muddy surfaces washed by daily tides. Thus, guano does not accumulate.

Cormorant meat can be evaluated for human consumption, because it has been determined that some families consume this meat (personal com.).

Data are not available to calculate the sustainable maximum yield of cormorant meat, therefore the economic analysis applied will be the Method of Real Net Income

(Barton, 1995). The method of evaluation of goods for direct uses is the method of Net Income Flow.
Considering harvesting cormorants for food M(N) = P x Q – C x Q = Q (P – C) where Q is annual extraction of cormorant meat, P the market price of similar meat and C the costs of having cormorant meat available for consumption.

Q= Estimated from people or families that take advantage of cormorants (kg). Through surveys and communication with fishermen.
P= Estimation of the market price per kg of cormorant meat, in comparison to meat of similar quality (people prepare this meat as minced meat, adding coconut; it tastes like fish meat).
C= The cost of cormorant meat available for consumption, it will be considered the time invested for bird hunting plus time for preparing its meat for human consumption.
For this analysis it is convenient to establish the maximum amount of cormorants to be hunted or consumed.

In conclusion, although this value was not calculated due to lack of field data, we estimate that the result will be positive, which will represent a positive value in the final equation.

4.2 VALUE OF THE CONTRIBUTION TO FISH DIVERSITY MAINTENANCE **FD(N)**

4.2.1 Ecological Analysis:

The great species diversity in aquatic communities is one of the mysteries of ecology. The diversity of the community would be explained by the distribution of resources among the species that are not completely superimposed. This argument is based on two suppositions. 1. An interference (as cormorant predation) on organisms that are in competition due to limited resources, can maintain at a low level the densities of populations, so that both species are able to coexist. 2. When competition is ongoing, species will inevitably exclude, but in the real world, it is possible that the process of competitive exclusion never arrives to a single final stage, because any factor (such as predation by cormorants) that interrupts the process of competitive exclusion can avoid extinction and maintain diversity (Begon, *et al.* 1996).

We hypothesize that Neoropic Cormorants as generalist predators, can be feeding on the most abundant prey in the Lake Maracaibo areas, avoiding the dominance of such species over the others or increasing survival of other species, contributing in this way to maintain fish diversity. Table 2 and Fig. 5.

Another aspect as contributor of diversity is based in their daily mobility from different areas, transporting (attached to different parts of their body) other organisms as plants, seeds and larvae that can be introduced into habitat occupied by cormorants.

4.2.2 Economic Analysis:

The fishery and fishermen’s welfare in Los Olivitos depend on diversity of fish resources in the area and Neotropic Cormorants could be helping with this ecological “service” with some minimal level of biodiversity to maintain ecological functioning and resilience, condition necessary, according to Barbier, *et al.* (1994), for economic activity and human welfare.

FD(N) is defined as the contribution of cormorants to maintenance of fish diversity, and therefore is a function of N. This would be one of the services of greater value, with positive impact to the benefit of fishermen.

Although this value was not calculated due to lack of field data and feasibility of experimentation in Lake Maracaibo, we estimate that the result will be positive, which will represent a positive value in the final equation.

4.3 USING CORMORANTS AS INDICATORS OF FISH SCHOOLS FOR FISHERMEN **S(N)**

4.3.1 Ecological Analysis:

Cormorants are birds that concentrate in areas rich in nutritional resources, where phytoplankton and heterotrophic organisms take advantage of this abundance of food; large scale fisheries of the world are located in these high productivity regions (Begon *et al.* 1996).

The presence of large flocks of Neotropic Cormorants over water areas indicates that they may have detected a school of fish that could be of commercial interest for fishermen, therefore, their role as fish detectors is valuable for fishermen because they can save time and increase fisherman productivity.

The result of the distribution of the Los Olivitos cormorant population, showed that only 17% of the population feeds in areas within Los Olivitos WRFR, and the rest, or 83% of the population feed in other areas of the lake. We also observed several flocks with hundreds of individuals resting on the water, forming "black patches" or flying over a school of fish. Fish schools detected by cormorants could be bait fish, commercial fish or shrimps.

4.3.2 Economic Analysis:

Economic valuation of the time of work:

The economic valuation of the time of work was used, because it has an opportunity cost that is expressed in production terms. The salary – hour and the saved time considered as a factor to measure productivity, would give the economic value of the time.

To carry out the valuation of this service the following illustration Fig. 7 , shows how fishermen could go directly to the fish school with the help of cormorants in comparison to fishermen who are not helped by the birds.

A preliminary diagnoses of artisanal fisheries in Lake Maracaibo was developed in 1998 (INTECMAR, 1998) and general information was revised for this economic analysis.

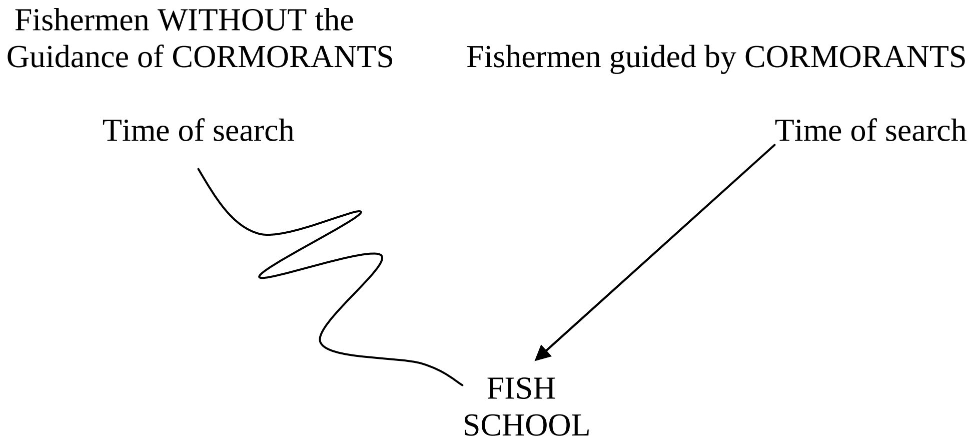

Figure 7. Representation of fishermen's movements with/without Neotropic Cormorant flock presence.

S(N) measures the value of cormorants as indicators of fish schools. Fishing time is reduced due to the service provided by cormorants identifying where fish schools are located.

Data:

1. Number of boats = 3,000 (Zulia State, SARPA, 1996), n. persons/boat = 5
2. Cost of maintenance/day = $24,000/day ($8/day/boat)
3. Cost of Fuel and oil/day = $30,000/day ($10/day/boat)
4.Cost of salary = $95,000 /day ($6.3/person/boat)
Costs of Production/day = $149,000/day (2+3+4)
Costs of Production/hour = $149,000/8 h = $18,625/hour
1h/Cost production/year= $6,798,125/year.
Calculation for two hours (2h) of saved time: $13,596,250
Calculation for three ours (3h) of saved time: $20,394,375

Fishing production in Zulia State, Year 1996 (According to SARPA, 1996) = $14,183,413/Year

This time saved S(N) = $6,798,125 /year, may reflect a greater well-being for fishermen. In addition to these savings, other items to consider are less food consumed in the boat during the task and fishermen's physical waste reduction.

4.4 VALUATION AS CONTRIBUITOR TO FISH BIOMASS THROUG GUANO PRODUCTION

FB(G,N)

4.4.1 Ecological Analysis

Pelicans and cormorants have played a very important contribution to nutrient cycling (Phosphorous and Nitrogen), those elements are either dissolved in the water to the floor or are washed and deposited on the bottom of marine waters (Odum 1971, Miller 1994).

Phosphorous (P) in form of certain phosphate ions (PO4 and HPO4) is an essential nutrient for vegetables and animals through ATP and ADP. The nitrogen (N) comes via uric acid into the system; incorporation to the nitrogen cycle is required by organisms in several chemical forms to synthesize proteins, nucleic acids (as DNA and RNA) and other organic compounds that contain nitrogen.

In order to estimate how guano production will generate and increase potential of fishing in Los Olivitos estuary, the following diagram is presented, Fig.8.

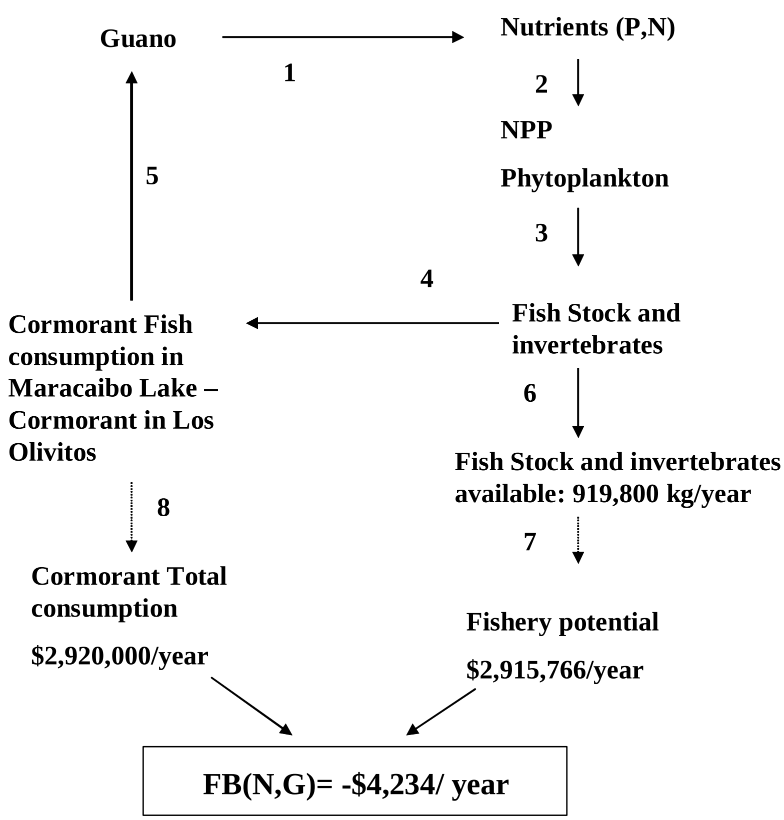

Figure 8. Neotropic Cormorant nutrient cycle and contribution to fish biomass via guano production.

To estimate biomass production via guano, we used the following information required to predict the pattern of energy flow (Begon *et al.* 1996).
Gross Primary productivity (GPP) is the total fixation of energy by photosynthesis, and Net primary productivity (NPP) represents the actual rate of production of new biomass that is available for consumption by heterotrophic organisms (see chart above).

Cormorant nutrient input, as a function of their guano production (G), is estimated using the energy flow method of Odum (1971).

1.Equation to determine the amount of guano (kg):

Guano = Excrements = EX = PE x C x N

Efficiency of cormorant consumption (EC) = 80% (Assimilation Efficiency)
Loss, via excretion (PE) = 20% (Begon *et al*, , 1996).
Fish Consumption(C) = 225g/day/ cormorant
Number of Neotropic Cormorants, Year 2001 (N) = 40,000 Fig 4.

Daily fish consumption (CP) = EC x C x N = 7,200 kg/day.
Daily loss via excretion (EX) = PE x C x N = 1,800 kg/day = Nutrients (N and P).

Assumptions: Biomass increases with the amount of nutrients, although the mechanisms are not clear (Begon, *et al.* 1996). The molecular weights of the minerals that compose humus are incorporated to the diatoms seaweed; it has been verified that these elements are part of them, and an increase in these products is translated in an increase of the biomass via biochemical and physiological processes (Cooksey, 1984).

2.The C:N proportion for protein production is 17:1 (Carbon: Nitrogen).The amount of Nitrogen turned to dry weight through gC, has not been studied but the relation between levels of g of C and the increase of dry weight, is 1gC = 2g. of dry weight. (Day *et al.* 1987.cit in Misch and Gosselink 1993).

Proportions: Phytoplankton (g) C: Nutrients (g) N = 17:1

3. Energy flow

GPP →	PPN→	HERBIVORE→	PRIMARY CARNIVORE→	SECOND CARNIVORE	
50%	10%	10%	20%		
61,200 kg/day ⇒	30,600 kg/day ⇒	3,060 kg/day ⇒	306kg/day ⇒	61.20 kg/day	
Phytoplankton	Invertebrates	Fish	Predators		

4. Fish Biomass (nutrients) = 3,060 kg x 365 days =1,116,900 kg/year
Fish Biomass input through guano production = 1,116 Tons/year
To estimate the Net fish biomass produced through the guano deposited in Los Olivitos, we have to consider the number of cormorants feeding in the Los Olivitos WRFR.

5**.**Average number of cormorants feeding in Los Olivitos WRFR = 2,400 indvs.
N in Los Olivitos x C x N. of days = 197,100 kg/year.

6.**Net biomass produced through guano production**:
1,116,900 – 197,100 = **919,800 kg/year**

To estimate contribution to fishermen's well-being,
Commercial fish price is estimated at $3.17/kg

7. Increment of potential fishery = $2,915,766/year

4.4.2 Economic Analysis based on depredation of commercial fish:

From the list of commercial fish and crustaceans observed in the diet of the Neotropic Cormorant in Los Olivitos and analysis of the diet composition, the following results were used to estimate commercial fish consumption.

Neotropic Cormorants consume 19 fish species, but only 9 are considered of commercial interest Table 3
Crustacean consumption = 1 shrimp species (*Litopenaeus schmitti*).
Consumption of commercial fish = 8 commercial species/18 = 0.44 Commercial fish proportion consumption = 88,5 x 0.44 = 39% Although they consume other species of commercial interest, only few were consumed in higher proportion, and average size of species was non-commercial Table 4. How much money represents g of commercial fish in the diet of Neotropic cormorants? Total g. consumed = 225g – 26g shrimp = 199g of total fish. Proportion of commercial fish = 39% Consumption of commercial fish = 39% of 199g = 77.6g = 0.077 kg Shrimp cost = $3/kg, Commercial fish average price = $1.6 kg

8.Commercial biomass consumed:

Max. shrimp consumption /cormorant/day = 0.026kg.x $3/kg = $0.08.
Commercial fish consumption / cormorant = 0.077 kg. X $1.6/kg = $0.12.
Cormorant consumption / day = $0.20/day
Cormorant Population = 40,000 individuals
Total consumption of commercial fish = 40,000 x $0.20/day = $8000/day
Total consumption of commercial fish = $8000/day

Total consumption per Year = $2,920,000/year

Fish artisan production in Zulia State = $14,183,172/year by 3,000 boats.
(With Cormorants' impact)

Fish Production without Cormorants could increase in $2,920,000 /year

Without cormorants: Fishing Gross Income in Zulia state = $14,183,172 + net benefit of the capture of fishes consumed by cormorants.

Estimation of net benefit: The estimation was based on an increase of the number of boats to capture the same amount of fish consumed by cormorants.
Total costs = Boats costs of maintenance + fuel cost + salary cost
Number of boats = 617
Cost Production = maintenance ($1.4) + fuel ($1.3) + salary ($16.7) = $4,368,977 /year
Net benefit /Year = Is the product of fish capture available if cormorants did not consume them.

Net Benefit =$2,920,000– $4,368,977= - $1,448,977/year, a negative balance.

This result shows that the fishery production would be the same without cormorants, or actually they are not in competition with fishermen.

The net impact of cormorant population on fish biomass =
Potential fishery (Guano) – Commercial fish consumption =
$2,915,766/year- $2,920,000/year = - $4,234/year.

B(N,G) = -$4,234/year

The value of this function is negative, based on guano production. In conclusion, Neotropic Cormorants are making a negative impact through this ecological function.

The total Value (TV) of cormorants (N) defined as

TV (N) = M(N) + S(N) + FD(N) + FB(N,G) was possible to estimate with the analyzed data, and the result was:

TV(N = S(N) + B(G,N) = 6,798,125 – 4,234 = $6,793,871/year

CONCLUSIONS:

The value of cormorants as a food supply M(N) probably will be positive in the equation, due to low costs of making cormorant meat available and because of the market price.

The value of the cormorants' contribution to maintenance of fish diversity, FD(N), could be positive because Neotropic Cormorants were feeding in high proportion on Ariidae, and Engraulidae which are very common species in Lake Maracaibo, and may increase survival of other species.

The value of cormorants as indicators of fish schools S(N), showed that fishing time is reduced, due to the service provided by cormorants identifying where fish schools are located, allowing fishermen to save between $6,798,125/year (1 hour of time saved) and $20,394,375/year (3 hours).

The impact of cormorants (40,000) on the fishery in Lake Maracaibo was estimated to be $2,920,000/year.

If fishermen attempt capture, the amount of fish available would require an additional investment of $4,368,977/year. This represents a negative balance (-$1,448,977/year). Neotropic Cormorants have a positive economic value for fishermen that exceeds the costs that they generate.

The value of contribution to fish biomass via nutrient input FB(N, G), estimated using the energy flow, was negative (-$4,234/year), that implies a decrease in the fishermen's benefit through this ecological function.

Estimation of the Economic Value of Neotropic Cormorants (40,000 individuals) in the natural area of Los Olivitos estuary was **$6,793,871/year,** based on two measured variables.

Neotropic Cormorant and artisanal fishermen in Lake Maracaibo are not in competition. Although this result seems different to others reported for similar cormorant species, our hypothesis is that the Neotropic Cormorant population is not yet at a critical level. Based on this conclusion, we are interested in continuing this study to analyze the same problem developing simulation dynamic models.

We emphasize the importance of these results for management policies of natural resources, that there is no conflict between Neotropic Cormorants and fishermen in Lake Maracaibo.

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LITERATURE CITED

Ainley, D., D, Anderson and P. Kelly, 1981. Feeding Ecology of Marine Cormorants in Southwestern North America. Condor 83: 120-131.

Barbier, E., J. Burgess and C. Folke, 1994. Paradise Lost?. The Ecological Economics of Biodiversity. The Beijer Institute. Earthscan, London, 267 pp.

Barton, D. 1995. Valoracion Económica Parcial de Alternativas de Manejo para los Humedales del Terraba-Sierpe, Costa Rica. Tesis para optar al Master Universidad Nacional.

Begon, M., J. Harper and C. Townsend, 1996. Ecology: Individuals, Populations and Communities. 3rd. de. Blackwell Science, 1068 pp.

Bojo, J, K-G . Maler and L. Unemo,1992. Environment and Development: An Economic Approach. Kluwer Academic Publishers, Netherlands. 211 pp.

Branco, ,J.O.,J.R.R. Braun, *et al*. (2002).Seasonal changes in the abundance of *Phalacrocorax brasilianus*(Gmelin) in the estuary of Scaco da Fazenda, Itajai, Santa Catarina, Brazil. Revista Brasileira de Zoologia 19 (4) : 1057 – 1062.

Brugger, K. 1995. Double-crested Cormorants and Fisheries in Florida. Colonial Waterbirds 18 :1) 110-117.

Cooksey, K. 1984. Role of diatoms in the mangrove habitat. *In*: The mangrove ecosystem: research methods. Sneadaker & Sneadaker, Unesco.

Duffy, D. 1995. Why is the Double-Crested cormorant a Problem? Insights from cormorant ecology and human sociology. Colonial Waterbirds 18:1) 25-32.

Gil de Weir, K. 2000. Abundancia y Dieta de la Cotua Olivacea (*Phalacrocrax olivaceus*) en el Refugio de Fauna Silvestre y Reserva de Pesca Cienaga de Los Olivitos. Tesis para optar a Magister Scientarium en Ecología Aplicada. F.E.C, Universidad del Zulia, Maracaibo, Edo. Zulia, Venezuela, 80pp.

Glahn, and K. Brugger. 1995. The impact of Double-crested Cormorants on the Mississippi Delta catfish Industry: A Bioenergetics model. Colonial Waterbirds 18:1) 168-175.

Glahn J, and Stickley, 1995. Wintering Double-crested Cormorants in the Delta region of the Mississippi: population levels and their impact on the catfish industry. Colonial Waterbirds 18:1) 137-142.

Glahn J, M. Tobin and B. Blackwell. 2000. A-Science-based initiative to manage Double-Crested Cormorant damage to Southern aquaculture. Issue. USDA. APHIS 11-55-010. United States.

Haynes R. and K. Goh. 1978. Ammonium and nitrate nutrition of plants. Biological Reviews 53: 465-510.

Hilty, S. 2003. Birds of Venezuela. 2nd. Ed. Princenton University Press, New Jersey, 878pp.

Hilty, S. and W.Brown, 1986. A guide to the Birds of Colombia. Princenton University Press, New Jersey 836 pp.

Hustler, C. 1991. The ecology of fish-eating birds on Lake Kariba, with special reference to the diving Pelecaniformes. Thesis submitted for the degree of Doctor of Philosophy. Department of Biological Science. University of Zimbabwe.

INTECMAR, 1998. Diagnostico preliminar de la Pesca Artesanal en el Lago de Maracaibo. Informe Final, Coordinado por Eduardo Klein. Universidad Simon Bolivar, Sartenejas, Venezuela.

Kameda, K. 1998. Material flow from aquatic to terrestrial ecosystems mediated by the Great Cormorant: A preliminary discussion. *In*: Proceedings of the VII International Congress of Ecology. INTECOL, Florence Italy 19-25 July. Ed. Farina, Kennedy and Bossu. 480pp.

Keith, J. 1995. Management policies for cormorants in Canada. Colonial Waterbirds 18(Special Issue 1) : 234-237.

Krebs, Ch. 1994. Ecology. The Experimental Analysis of Distribution and Abundance. 4th. Ed. The University of British Columbia. Harper Collins College Publisher. 801.pp.

Miller, G. 1994. Ecologia y Medio Ambiente. Grupo Editorial Iberoamerica, 867. pp.

Mitsch, W. J. and J.G. Gosselink. 1993. Wetlands 2nd. Ed. Van Nostrand Reinhold, New York, 722 pp.

Nettleship, D. and D. Duffy. 1995. The Double-Crested Cormorant: Biology, Conservation and Management. Colonial Waterbirds. Special Publication 1, Volumen 18.

Odum, E. 1971. Fundamentals of Eclogy. 3rd Ed. W.B. Saunders Company, Philadelphia. 574pp.

Phelps, W., R. Meyer de Schauensee. 1978, Una guia de las Aves de Venezuela. Graficas Armitano, c.a. 484 pp.

Price Y. And J. Nickum, 1995. Aquaculture and Birds: The Context for Controversy. Colonial Waterbirds, 18:1) 33-45.

Regidor H and A. Terroba, 2001. Feeding habits of Bigua *Phalacrocorax brasilianus* (Gmelin 1789) (Aves,Phalacrocoracidae) in northwestern Argentina. Boletin de la Sociedad de Biologia de Concepcion 72: 121-123.

Stotz, D.F., J. Fitzpatrick, T. Parker III and D. Moskovits. 1996. Neotropical birds. Ecology and Conservation. The University of Chicago Press. Chicago. Pp. 478.

Suter, W. 1994. Overwitering waterfowl on Swiss lakes: how are abundance and species richness influenced by trophic status and lake morphology?. Hydrobiologia 279/280**:** 1-14.

Suter, W. 1995 a. The effect of predation by wintering comorants *phalacrocorax carbo* on grayling *Thymallus thymallus* and trout (Salmonidae) populations: two cases studies from Swiss rivers. Journal of Applied Ecology 32:29 – 46.

Suter, W. 1995 b. Are cormorants *Phalocrocorax carbo* wintering in Switzerland approaching carrying capacity. An analysis of increase patterns and habitat choice. Area 83: 255-266.

Suter,W. 1998 Assesing the impact of piscivorous birds on freshwater fish populations and fisheries: Where do we stand? En: Proceedings of the VII Inernational Congress of Ecology. INTECOL, Florence Italy 19-25 July. Ed. Farina, Kennedy and Bossu.

SARPA, 1996. Informe. Produccion Pesquera de Lago de Maracaibo.

Telfair, R.C. II. and M. L. Morrison, 1995. Neotropic Cormorant (*Phalacrocórax brasilianus*). *In* the Birds of North America, No. 137 (A. Poole and F.Gill, eds.) The Academy of Natural Sciences. Philadelphia, and The American Ornithologists´Union, Washington ,D:C.

Wanink, J.H. and O.C. Chifamba, 1999. Interactions between freshwater fisheries and birds. Perspective in Ecology (A.Farina ed.) pp. 219 – 225. Backhuys Publishers, Leiden.

Weir, E., K. Gil, C. Casler, A. Urbina, G. Andrade, R. Buonocore,et al. 2004. Informe Final Proyecto Biodiversidad en la Cienaga de Los Olivitos, # 98003428 FONACIT.Venezuela.

Weller, M.W. 1999. Wetland Birds. Habitat Resources and Conservation Implications. Cambridge University Press.271 pp.

Weseloh, D., P. Ewins,J. Struger, P. Mineau, C. Bishop, S. Postupalsky and J. Ludwig. 1995. Double-crested Cormorants of the Great Lakes: Changes in Population Size, Breeding Distribution and reproductive Output between 1913 and 1991. Colonial Waterbirds, 18:1) 48-59.