Food intake, feeding behaviour and stock losses of cormorants, *Phalacrocorax carbo*, and grey herons, *Ardea cinerea*, at a fish farm in Arcachon Bay (Southwest France) during breeding and non-breeding season

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Abstract. The feeding ecology of cormorants and grey herons were investigated at a fish farm in Arcachon Bay (southwest France) during both breeding and non-breeding season. Cormorants were mainly recorded during winter and grey herons during both breeding and wintering seasons. Adult cormorants and herons were the most abundant age clas at the fish farm. Adult cormorants and herons were more successful at feeding than first-years and although younger birds spent more time feeding and their biomass intake rates remained lower than those of adults birds. Cormorants and herons took the same biomass intake per feeding session at the fish farm during the non-breeding season, about 200 g. The impact of the two ichthyophagous birds (cormorant and grey heron) was estimated as 53.0% (average predation of cormorant per year) and 10.8% (mean predation of heron per year) of the annual yield of the fish farm. This imposed a significant economic loss due to low productivity of the farm.

Key words: aquaculture, diet, foraging parameters, impact, piscivorous birds

Introduction

In French coastal and inland waters the cormorant (*Phalacrocorax carbo*) and the grey heron (*Ardea cinerea*) are commonly perceived as two great predator of fish stocks at fish farms (Hafner & Moser 1980, Im & Hafner 1984, Marion 1983, 1990, Marion & Marion 1983, 1987, Perennou 1987, Trolliet 1993a, 1993b).

In other countries of Europe most studies with these two fish-eating birds have focused on extensive aquacultures (Draulans et al. 1985, Carss & Marquiss 1991, Janda 1993, Carss 1994, Dirksen et al. 1995, Keller 1995, Suter 1995, Van Eerden & Gregersen 1995, Dekker 1997) rather than intensive systems (Carss 1990, Carss 1993a,1993b, Lekuona 1998) where fish stocks area reared at high densities.

Their feeding activities had been often considered to result in important economic losses (Meyer 1981, Marion 1983,1990, Utschick 1983, Draulans & Van Vessem 1985, Carss 1991, Osieck 1991, Dirksen et al. 1995, Keller 1995, Warke & Day 1995, Pérez-Hurtado et al. 1997, Lekuona 1998). Recently, Carss (1993a) found that these losses are small compared with other forms of fish mortality.

A wide variety of deterrent techniques (acoustic, visual and biological) has been tried in attempts to reduce cormorant and heron impact (Barlow & Bock 1984, Draulans

1987, Moerbeek et al. 1987, Feare 1988, Osieck 1991, Trolliet 1993a, 1993b, Kirby et al. 1996, Van Dam & Asbirk 1997, Lekuona 1998).

The present study gives some data on heron and cormorant predation at a fish farm in terms of piscivorous bird numbers during breeding and non-breeding seasons, food, feeding parameters and stock losses.

The study had several aims: 1) to know heron and cormorant abundance and age structure of their population in Arcachon bay and at a fish farm, 2) to determine the food and some feeding parameters of two species of piscivorous birds and 3) to quantify their impact on fish stocks.

Study Area, Material and Methods

The study was carried out in Arcachon Bay (Fig. 1), southwest France (44°40'N, 1°10'W), a coastal lagoon with variations in water level due to tides, triangular in shape, approximately 20 km wide and 161.3 km^2 in area (106.6 km^2 of mud and 54.7 km^2 of deep channels, Lekuona 1997). A colony of Ardeids breed there (Lekuona 1993, Lekuona & Campos 1995, Lekuona 1997).

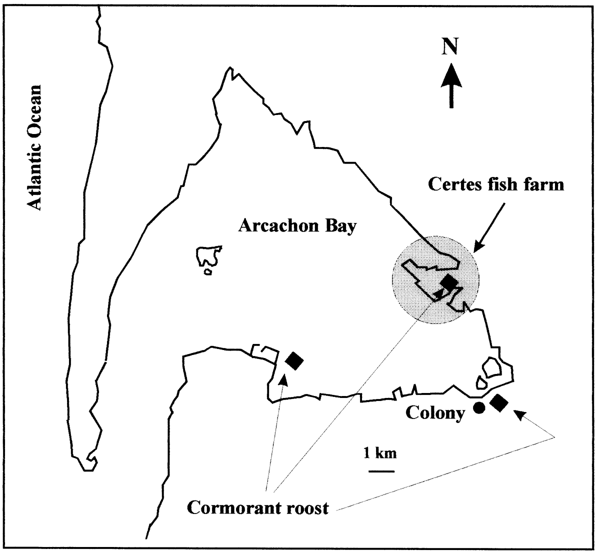


Fig. 1. Arcachon bay study area showing location of grey heron colony (•), winter roosts of cormorants (♦) and the study fish farm (Certes).

The farm was located in the oriental extreme of Arcachon bay. The fisf farm of Certes had an area of 142 ha, with two kind of fish ponds: deep ponds (1.5-2 m of depth and 3-4 m of width) and shallow ponds (0.2-0.5 m of depth and 1000-32000 m^2 of area, Lekuona 1993). Fish stocks (eel *Anguilla anguilla*, mullets *Quelon labrosus* and *Liza ramada*, gilthead *Sparus aurata* and bass *Dicentrarcus labrax*) were mainly reared at low densities in shallow ponds. The total yield per year of the fish farm was 9.1 Tm (35 $kg.ha^{-1}$ for eel, for mullets 100 $kg.ha^{-1}$, for gilthead 5 $kg.ha^{-1}$ and for bass 30 $kg.ha^{-1}$).

The observations on the both cormorant and grey heron's activities were carried out between February 1992 and December 1993, using a 20-60 x telescope. One day a week, between 07.30 h and 19.30 h the bay and the fish farm were visited to obtain an index of abundance of two piscivorous birds by transect counts on a standard route of land. The cormorant's and heron's indeces of abundance were each the maximum of four counts made each month throughout the study period. During non-breeding season cormorant and heron roosts were censused fortnightly at dusk. Two age-classes were taken into account both for cormorants and herons (adult and first-year birds). Birds were categorized on their plumage characteristics (Cramp & Simmons 1977). Most of birds could not be recognized individually (only few cormorants had coloured rings) and some of observations on different study days could have been of the same individuals. However, the data were recorded over several months (February 1992 to December 1993) and the foraging sessions were assumed to be independent. Cormorants and herons were always observed at a distance <100 m.

Each day the following data were noted for each bird in both natural feeding areas (Arcachon bay) and at fish farm (Certes): 1) Total time spent (Tt) in a feeding site, as the time elapsed from a bird's arrival to its departure (defined as a foraging session). 2) Foraging time (Ff), as the time used only for foraging within Tt by the two piscivorous bird species. 3) The number of feeding attempts during Ft and their results (successful and unsuccessful). 4) Dive time, only for cormorants, as the average of all dives made during each foraging bout in seconds. 5) Number, type and size of the captured prey. For herons four broad taxonomic groups of prey were used: amphibians, fish, insects, and crustaceans. The size of the prey was calculated only for fish (which were the most abundant prey, see below) in relation to the size of the both cormorant and grey heron's beak (8 cm and 12 cm, respectively, Cramp & Simmons 1977, Voisin 1991). In this way, for grey heron five size classes of fish were established: very small (<12 cm), small (12-18 cm), medium (19-25 cm), large (26-32 cm) and very large (>32 cm), and for cormorant five size classes were also established: very small (<8 cm), small (8-14 cm), medium (15-21 cm), large (22-28 cm) and very large (>28 cm).

The biomass (g wet weight) of fish was calculated according to the formulae of Richner (1986) for eel and flounder *Pleuronectes flesus*. For mullets, Thick-lipped grey mullet and thin-lipped grey mullet the equation $W = 6.86\ 10^{-6}L^{3.0796}$ (W = wet weight in g, L = total length in mm) was calculated according to the data of Arne (1938). The biomasses (g wet weight) of gilthead and bass taken were calculated according to the average weight of similar-sized specimens captured in the study area.

Cormorant and heron predation (the estimated biomass of fish removed, in kg) was calculated on monthly and per species bases as:

$$\Sigma Y_{ij} = N_j \times C \times P_{ij}$$ (Suter 1995)

where N_j is the number of cormorant days during the month *j*, C is the daily food consumption (g/day) and P_{ij} is the proportion of the species *i* in the diet (% in biomass) recorded in the month *j*.

Two averages were compared using the Student's t-test (parametric data) and Mann-Whitney Z-test (non-parametric data) and frequencies were compared using the χ^2 test, with Yates correction as necessary (Sokal & Rohlf 1979, Fowler & Cohen 1992). The Bonferroni sequential correction test was made in multiple comparisons to avoid making the Type I error (reject the null hypothesis when, in fact, it is true) and for keeping the overall error of the test set below 5%. Chandler (1995) showed that sometimes this kind of correction was extremely conservative. Thus, our statistical results have been explained basically without correction, when their biological meaning was very evident.

Results

Heron and cormorant counts and age ratio

Grey heron numbers increased in spring (Fig. 2) due to start of the breeding season in the near ardeid colony located in a riparian wood near the fish farm (<10 km) and rose during the summer (post-fledgling period of juvenile grey herons). During the breeding season adult herons were the most important age class in the study area. During summer juvenile numbers were more abundant in Arcachon bay, falling during autumn when adults showed a high level.

Cormorant roost numbers increased in autumn, remained relatively high during the winter, before falling during the spring to a low level in summer (Fig. 3). Adult birds were more abundant during autumn and winter than during spring and summer, when first-year birds had a high level.

Seasonal changes were found in the abundance index of two species of fish-eating birds at the fish farm during the present study (Fig. 4): for herons due to management desiccation of extensive ponds (second week of March 1922 and first week of may 1993) and for cormorants due to a change in the feeding behaviour at the farm: very often cormorants foraged solitarily but in November 1993 social fishing (>300 birds) was observed in several shallow ponds, increasing the predation on fish stock (see below).

Diet, feeding behaviour and fish stock losses

The eel was the main fish species captured by both herons and cormorants in Arcachon bay and at the fish farm (Table 1). Flounders were also taken by two species of piscivorous birds but only in natural habitat. Gilthead and bass were taken by cormorants at low numbers at the fish farm. Other prey species taken by herons were not important (crustaceans, amphibians and insects). The main amphibian and invertebrate taxa identified as a heron food were: frogs *Rana perezi*, insects (mainly beetles, Coleoptera) and shrimp, *Crangon* spp. and shore crab, *Carcinus maenas*.

During the breeding season, grey heron spent less total time at the fish farm ($t=13.6$, $p<0.001$), more foraging time ($t=18.4$, $p<0.001$) and had a higher biomass intake ($t=3.2$, $0<0.01$) than in Arcachon bay (Table 2). During winter some feeding parameters showed the same pattern as the breeding period: grey heron spent less total time at fish farm ($t=4.44$, $p<0.001$) and took more biomass ($t=1.94$, $p<0.05$) with less feeding time ($t=2.79$, $p<0.01$). The Bonferroni sequential test gave the same statistical results.

The agression rate observed at the fish farm was higher than in the bay during the breeding season ($Z=9.2$, $p<0,01$). In the area under study agressions were not found during winter season.

During winter cormorant (Table 3) spent more time fishing in the bay than at the fish farm ($t=7.2$, $p<0.001$) and the dive time was also greater in bay than at fish farm ($t=16.2$, $p<0.001$). No differences were found between feeding habitats in the biomass intake of

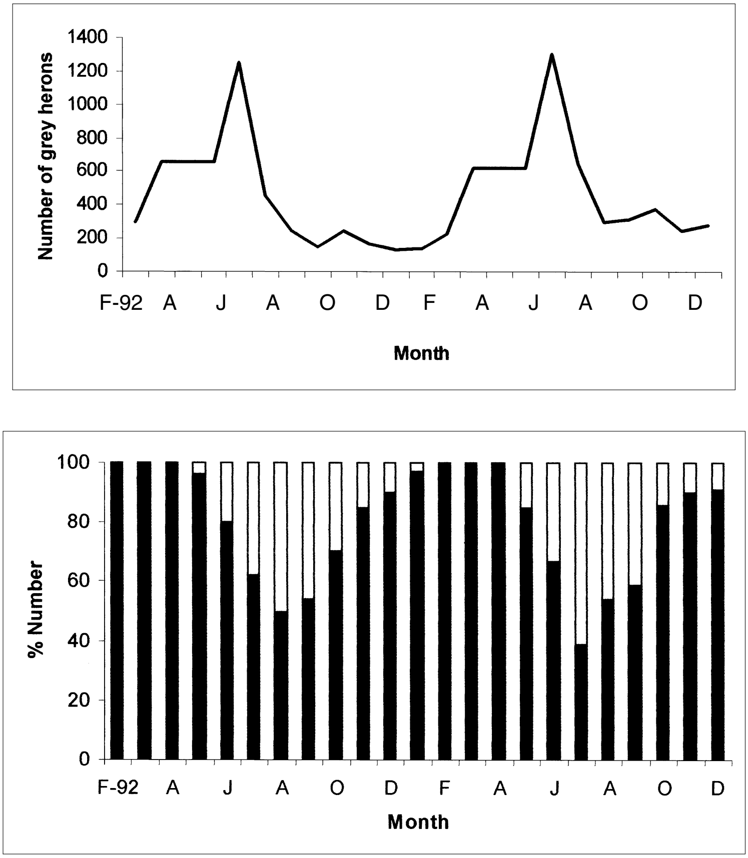
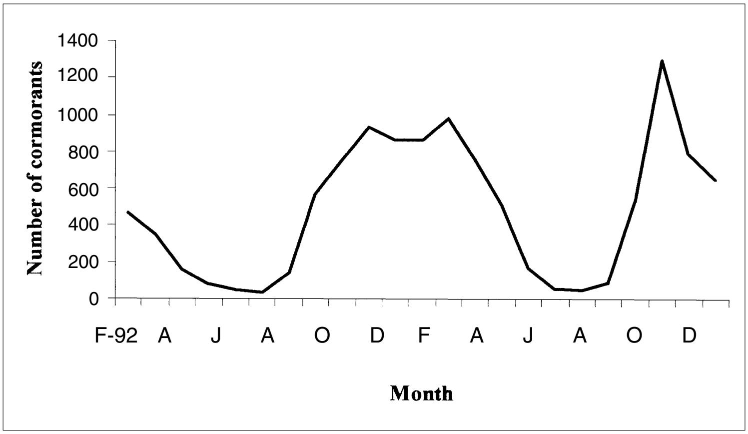


Fig. 2. Number of grey herons (upper) and age-structure population (lower) during the study period in Arcachon Bay (southwest France). Data are percentage numbers, black: adult birds, white: of first-year birds.

Table 1. Food of cormorants and grey herons in natural feeding habitats and at the Certes fish farm in Arcachon Bay (southwest France) during the breeding (B) and non-breeding season (NB).

Piscivorous bird	Grey heron				Cormorant	
Feeding habitat	Bay		Fish farm		Bay	Fish farm
Prey	B	NB	B	NB	NB	NB
Eel	2251	341	615	284	1833	885
Mullet	66	50	108	46	1256	250
Flounder	34	24	0	0	166	0
Gilthead	0	0	0	0	67	20
Bass	0	0	0	0	0	16
Unidentified fish	128	92	34	47	1034	57
Other prey species	537	162	67	34	0	0
Total	3016	669	824	411	4356	1228



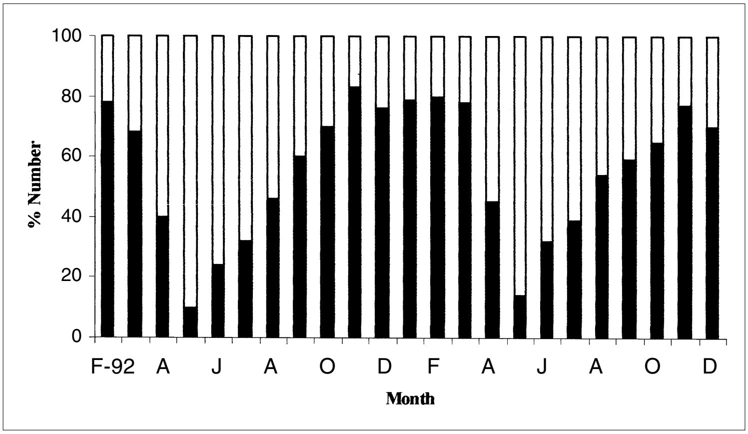


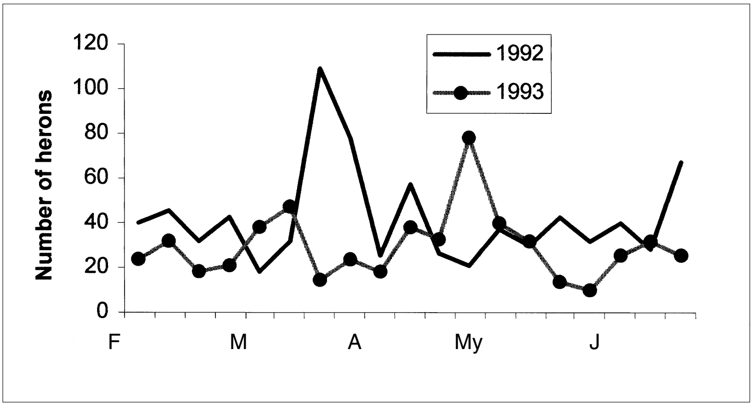
Fig. 3. Number of cormorants (upper) and age-structure population (lower) during the study period in Arcachon Bay (southwest France). Data are percentage numbers, black: adult birds, white: first-year birds.

wintering cormorants (t=0.35, NS). Cormorants and herons had the same biomass intake per feeding session at the fish farm during non-breeding period (t=0.47, NS).

Both adult grey heron and cormorants (Table 4) were more successful at feeding than first-year birds and younger birds (χ^2=41.7, 1df, p<0.001 and χ^2=26.4, 1df, p<0.001, respectively), spent less time feeding (t=16.3, p<0.001 and t=11.7, p<0.001, respectively) and their biomass intake remained higher (t=9.6, p<0.001 and t=10.8, p<0.001, respectively) than those of juveniles at fish farm.

Great differences were found in the length of fishes captured by both cormorants and herons in the bay and at the fish farm (χ^2=32.1, 4df, p<0.001 and χ^2=27.9, 4df, p<0.001, respectively, Fig. 5). At the fish farm cormorants caught very large fishes whereas grey heron captured large and very large fishes. In Arcachon bay grey heron took significantly more small and medium size fishes than at the fish farm.

During breeding season fish losses by grey herons were 12.7% in 1992 and 8.9% in 1993 of the total fish farm yield (the average impact per year was 10.8%). During the study



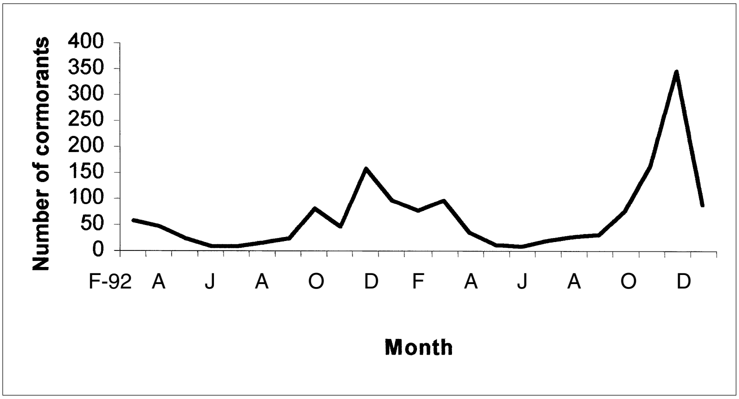


Fig. 4. Census of grey herons at the fish farm during the breeding season in 1992 and 1993 (upper) and number of cormorants during the study period (lower).

Table 2. Foraging studied parameters in feeding bouts made by grey herons in Arcachon bay and at Certes fish farm during breeding and non-breeding season. N: number of foraging bouts, Tt: total time spent in the habitat (min), %: percentage of success, Ft: foraging time (min), B: biomass intake (g wet weight) and A (aggression rate, Ag min^{-1}). Tt, Ft, B and A as average±standard deviation.

Habitat	Bay	Fish farm	Bay	Fish farm
Season	Breeding		Non-breeding	
N	192	68	96	47
Tt	136.4±21.5	83.2±23.0	193.8±23.3	175.8±23.0
%	72.9	73.1	56.0	61.7
Ft	27.7±7.9	51.4±15.4	42.8±10.3	36.8±10.3
B	197.7±44.9	214.3±41.9	172.7±61.7	197.7±61.7
A	0.086±0.05	0.43±0.32	0.00±0.00	0.00±0.00

period cormorant losses were 38.4% in 1992 and 67.6% in 1993 (the average predation per year was 53.0%). The habit of mass fishing by cormorants observed in winter 1993 significantly increased the annual impact.

Table 3. Foraging studied parameters in feeding bouts made by cormorants in Arcachon bay and at fish farm during non-breeding season. N: number of foraging bouts, %: percentage of success, Ft: foraging time (min), D: dive time (s) and B: biomass intake (g wet weight). Ft, D and B as average±standard deviation.

Feeding habitat	Bay	Fish farm
N	100	78
%	14.7	34.1
Ft	27.9±5.7	8.9±2.6
D	24.3±4.4	10.7±3.3
B	195.8±51.4	208.8±58.9

Table 4. Foraging parameters of cormorants and grey herons at a fish farm in southwest France taking into account the age classes. N: number of foraging bouts, %: percentage of success, Tt: total time spent in the feeding habitat, Ft: feeding time (min), D: dive time (s), B: biomass taken (g wet weight). Tt, Ft, D and B are given as average±standard deviation.

Species	N	%	Tt	Ft	D	B
Grey Heron						
Adult	129	72.3	66.5±12.1	31.7±6.7	-	200.4±46.2
First-year	53	39.6	143.2±38.4	50.6±19.4	-	159.2±34.7
Cormorant						
Adult	22	44.0	10.5±2.3	7.3±1.5	8.3±2.3	228.9±41.4
First-year	16	15.1	17.5±1.9	13.5±2.9	13.2±1.6	141.6±19.9

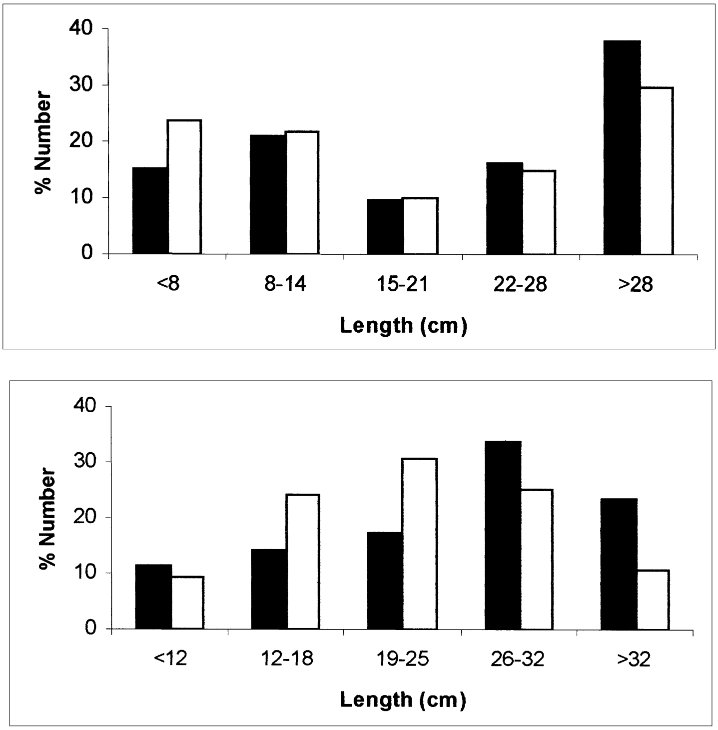


Fig. 5. Length of prey (cm) captured by cormorants (upper) and grey herons (lower) at Certes fish farm (black) and in Arcachon bay (white). Data are percentages.

Discussion

As a consequence of the rapid increase of both cormorant (Van Eerden & Gregersen 1995) and heron populations (Voisin 1991) in Europe, interference with fisheries has risen (Marion & Marion 1983, 1987, Moerbeek et al. 1987, Marion 1990, Carss 1994, Van Dam & Asbirk 1997, Callaghan et al. 1998, Leopold et al. 1998).

Arcachon bay area was located within a region with high heron and cormorant density (Campos & Lekuona 1994, Lekuona 1999), where adult birds were the most abundant age class in coastal and inland waters (Lekuona 1997). In the present study cormorant numbers increased at the fish farm during winter and the heron number increased during breeding season due to some management techniques. Both adults and juveniles birds visited the fish farm during all the study period, but they showed significant age-related differences in feeding performance (Carss 1993b). Young birds were able to compensate their lower success by attempting more feeding strikes or dives (Desgranges 1981, Lekuona 1997). In this study both age classes took fish of a similar size as did those studied by Draulans (1987) and Carss (1993b), but juvenile birds fed for more time at the fish farm than did adults. Draulans (1987) also found that first-year herons were less successful at foraging thatn adults at low prey densities; similar data were found in the present study.

Cormorants and herons could not be recognized individually and some observations could have been made on the same bird, and this fact may affect the comparisons between two age classes. However, the data were recorded over 24 months with great differences always between age classes so that the foraging sessions were assumed to be independent and representative of the impact made by cormorants and herons at the fish farm.

An adult (heron and cormorant) needs a biomass intake per day of 300-500 g of fish (Cramp & Simmons 1977, Marion 1990, Carss 1993b, Suter 1995, Lekuona & Campos 1997, Van Dam & Asbirk 1997). The biomass intake rates at the farm in relation to the feeding time of the two species were considerably higher than other published rates (Cook 1978, Richner 1986), but similar data were found for grey heron at cage fish farms in Argyll (Carss 1993b). Thus, the daily requirements of food could be met at the fish farm making a second foraging session and many of the cormorants and herons probably caught all their prey there. At the fish farm, food requirements of the two ichthyophagous species were satisfied within a shorter foraging time than in Arcachon bay.

Foraging activity of breeding grey herons and wintering cormorants in Arcachon bay was strongly influenced by variations in sea water level due to tides (Lekuona 1997, 1999), but no significant differences were found in their feeding activity at the fish farm during tides (Lekuona 1997) because the water level was constant during most of the study period.

At the study fish farm the cormorant predation on fish stocks was higher than heron impact, but these rates represented a considerable economic loss. Similar date were found in other regions of Europe (Im & Hafner 1984, Perennou 1987, Marion 1990, Osieck 1991, Lekuona 1998).

Most studies on fish-eating birds have been focused in estimate direct loss of fish stocks (Marion 1990, Osieck 1991), but some other factors must be taken into account (parasites, physiological poor condition, blindness, wounded fish...) (Carss 1990, 1993b). Also in some regions of Europe available data at fish farms are anecdotal or based on second-hand information (C a r s s 1993b), also this author found that not all of the fishes taken by grey heron were healthy. Parasited trouts moved slowly just below the surface and they formed a high proportion of the prey caught by herons. Thus, such predation did not represent a direct loss. It is obvious that very often it is extremely complicated to quantify the interaction between piscivorous birds and fisheries.

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