Study of Great Cormorant *Phalacrocorax carbo* populations breeding and wintering in Greece

Liordos Vasilios & Vassilis Goutner

Department of Zoology, School of Biology, Aristotelian University of Thessaloniki, GR-54006, Thessaloniki, Greece

acinonyx@otenet.gr - goutner@bio.auth.gr

Abstract. In Europe, the Great Cormorant population has increased rapidly in recent years and its status has changed from threatened and protected to a thriving one. The increase in numbers of this fish-eating species and its potential impact on the fisheries has drawn the attention of the public and scientific community alike. The purpose of this study is to provide needed information on the population size, growth, diet, and genetic identity of the Greek Great Cormorant populations. Research will be concentrated on the main breeding areas: the Axios and Evros Deltas, and the Lakes Kerkini and Prespa, with the addition of the Messolonghi lagoon during the wintering season. Data on population, egg, and clutch size is also presented and analysed.

Introduction

The European Great Cormorant population status has changed from threatened and protected to thriving, due to rapid increase in recent years. An increasing trend has also been detected in Greek populations. Since there is inadequate information on the bird's ecology and biology in Greece, its study is the subject of a Ph.D. thesis. The design of the thesis as well as some data on breeding populations, clutch and egg size, are discussed here.

Aim of the study

The increase in numbers of this fish-eating bird has caused considerable conflicts with the fisheries industry and angling interests in many countries (Im and Hafner 1984, Russell *et al*. 1996). Therefore, much research has been conducted and management and control plans formulated (Krohn *et al*. 1995, Kirby *et al*. 1996, Bildsøe *et al*. 1998). In Greece, due to population increase and fishermen's complaints, Great Cormorant population size, growth, feeding ecology, and genetic identity need to be thoroughly examined.

According to the above discussed, information on the following matters is sought:

1. Estimation of breeding and wintering populations of the Great Cormorant.
2. Study of its feeding ecology (diet composition, daily consumption, fish size, fishing areas, and foraging strategies).
3. Measurement of biological parameters (such as volume of the clutch and nestling growth rate) for evaluating population fitness.
4. Genetic analysis for determination of population structure, differentiation and provenance.

Study Areas

During the breeding season, research will be concentrated on the Great Cormorant's nesting sites: the Axios and Evros Deltas, and the Lakes Kerkini and Mikri Prespa. The Axios and Evros Deltas, and the Messolonghi Lagoon will be the study areas for the wintering season (Fig. 1).

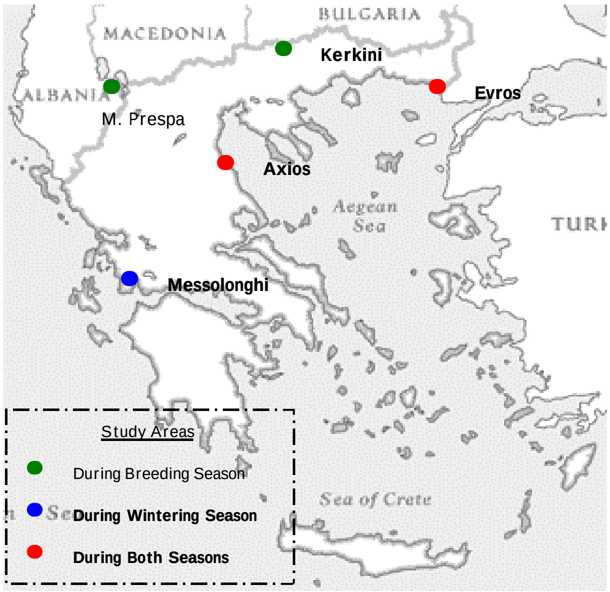

Figure 1. Map of Greece showing the areas where the Great Cormorant study is conducted.

Fieldwork

This will be conducted within two periods: the breeding (April-midJune) and wintering (October-February). Fieldwork began in April 1999, its completion is expected in February 2002, and includes the following:

A) Breeding season

1. Population estimation (direct count of active nests).
2. Clutch size recording and measurement of egg length and breadth for estimating egg volume.
3. Measurement of nestling parameters (weight, bill length, bill and head length, tarsometatarsus length) for calculating their growth rate after a method proposed by Ricklefs and White (1975).
4. Collection of nestling regurgitations and pellets for determining the composition of their diet.
5. Collection of blood samples (from 30 nestling for each area) for genetic analysis. From each nestling, 1ml blood is taken and stored in 10ml TNES-Urea buffer.

B) Wintering season

1. Population estimation at roosts.
2. Collection of pellets at roosts.
3. Collection of birds under licence (106810/4126/6-10-99, Ministry of Agriculture). Thirty birds from each wintering site are being sampled for diet and genetic analysis.

Laboratory analyses

1. Analysis of regurgitations, pellets, and stomach contents (Carss 1997). Food items (mainly fish) will be identified to the lower possible taxon. Measurements of fish and otolith length will also be taken for constructing regression equations in order to determine Great Cormorant diet quantitatively.
2. Birds collected in the field are immediately dissected and appropriate samples obtained and stored. In addition, some useful information and measurements are taken:

Information recorded

Age
Sex
Weight (g)
Straightened right wing length (mm)
Bill length (mm)
Bill+head length (mm)
Right tarsometatarsus length (mm)

Samples taken

Body feathers
Blood spots (on filter paper)
Breast muscle (deep-frozen and in alcohol)
Liver (deep-frozen)
Stomach (deep-frozen)
Kidneys (deep-frozen)

3. Blood and liver samples will be used for genetic analysis (Goostrey *et al*. 1998).

Breeding population size

Great Cormorants first recorded to breed in the Axios Delta, in 1944, when a 6-pair colony was found (Handrinos and Akriotis 1997). Nowadays, they nest on trees in four colonies. In Lake Kerkini, they nest on Willow *Salix alba* õ *fragilis* hybrids, over water. In Lake Mikri Prespa, they nest on Juniper *Juniperus foetidissima*, on Vidronissi island. In the Evros Delta they nest on Tamarisk *Tamarix smyrnensis*, over water, and, finally, in the Axios Delta on Tamarisk *Tamarix hampaena* and some Common Alder *Alnus glutinosa*, on an island.

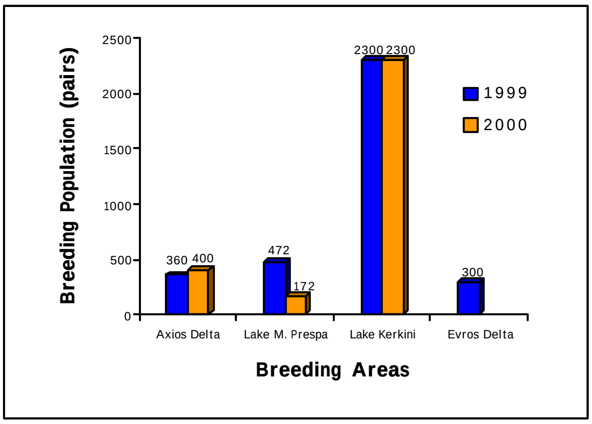

Figure 2. Breeding populations of the Great Cormorant in the four breeding colonies. Note the great reduction in numbers in Lake Mikri Prespa. It is not certain what has caused it, but severe deterioration of nesting trees quality, due to the birds' faeces, is the most possible explanation.

Nesting pairs were counted during the 1999 and 2000 breeding seasons (Fig. 2), with the exception of the Evros Delta in 2000. The breeding colony was inaccessible due to a dam destruction. The Kerkini and Axios populations were practically stable, whereas the Mikri Prespa colony showed a stark decrease from 472 to 172 pairs. A plausible explanation could not be given, except of that of nesting trees deterioration. Nesting elsewhere in this region was not observed.

The overall breeding Great Cormorant population evolved from 540-570 pairs in 1971 and c. 600 pairs in the early 1990s (Handrinos and Akriotis, 1997), to c. 3200 in 1999 (Fig. 3), showing a great increase of over 600% during the last three, especially the last one, decades.

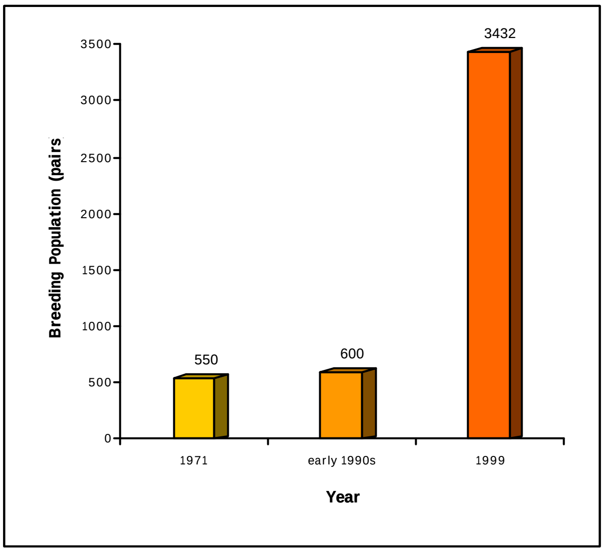

Figure 3. The Great Cormorant breeding pairs have risen sharply over the past 30 years. This may have happened due to protection of breeding sites, increase of food availability, and increasing number of fisheries.

Clutch and egg size

The maximum length and breadth of the eggs of twenty complete clutches in each area were measured. One-way Analysis of Variance (ANOVA) and the Tukey test were used for statistical analyses.

Clutch size was found between 3 and 5 eggs in all the areas and complied with the range of 3 to 4 (6) given by Cramp and Simmons (1977).

Table 1. Clutch size, egg and clutch volume of the Great Cormorant (means are given with standard errors, n is the number of clutches).

	Clutch Size		Egg Volume (cm^3)		Clutch Volume (cm^3)		
	Mean	Range	Mean	Range	Mean	Range	n
Evros Delta	3.8±0.14	3-5	48.58±0.53	39.98-58.82	183.52±8.67	131.88-275.79	20
Lake Kerkini	3.8±0.16	3-5	50.63±0.57	37.29-62.12	191.27±9.16	137.69-288.79	20
Lake M. Prespa	3.95±0.14	3-5	48.74±0.48	36.42-57.22	191.39±8.01	130.57-268.43	20
Axios Delta	3.8±0.16	3-5	47.69±0.83	38.93-78.40	180.16±9.54	121.70-286.28	20

In Lake Mikri Prespa the mean clutch size was 3.95 eggs being slightly, but not significantly, higher than in the other breeding colonies (3.8) ($F_{3,76}$= 0.26, P= 0.85, Table 1, Fig. 4).

The measurements of maximum length (L) and breadth (B) were used for the calculation of egg volume and shape index.

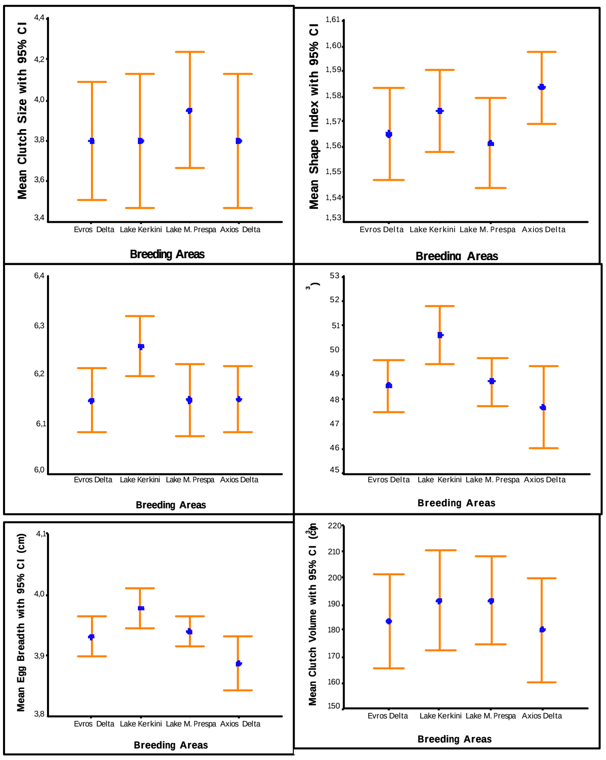

Figure 4. Means of measurements and calculations of Great Cormorant egg parameters (with 95% Confidence Intervals) at their breeding colonies in Greece.

Table 2. Length, breadth, and shape index of the Great Cormorant eggs (means are given with standard errors, n is the number of eggs).

	Egg Length (cm)		Egg Breadth (cm)		Shape Index		
	Mean	Range	Mean	Range	Mean	Range	n
Evros Delta	6.15±0.03	5.58-6.75	3.93±0.02	3.67-4.19	1.56±0.01	1.44-1.73	76
Lake Kerkini	6.26±0.03	5.61-6.93	3.98±0.02	3.61-4.34	1.57±0.01	1.42-1.71	76
Lake M. Prespa	6.15±0.04	5.42-6.84	3.93±0.01	3.63-4.15	1.56±0.01	1.37-1.77	79
Axios Delta	6.15±0.03	5.52-7.14	3.89±0.02	3,57-4,64	1.58±0.01	1.46-1.72	76

The formula of Hoyt (1979), $V= 0.51LB^2$, and the ratio L/B were used for estimating egg volume and shape index respectively. The comparison of data showed no significant difference in mean egg length ($F_{3,303}$= 2.6, P= 0.52) and shape index ($F_{3,303}$= 1.4, P= 0.24) between the four areas whereas significant differences were detected in mean egg breadth ($F_{3,303}$= 4.5, P= 0.004) and mean egg volume ($F_{3,303}$= 4, P= 0.0082, Tables 1&2, Fig. 4). Further statistical analysis (Tukey test) showed that the eggs were significantly broader ($q_{303,4}$= 5.17) and larger ($q_{303,4}$= 4.75) in Lake Kerkini (mean egg breadth, 3.98 cm; mean egg volume, 50.63 cm^3) than the Axios Delta (mean egg breadth, 3.89 cm; mean egg volume, 47.69 cm^3). Overall, differences among clutch volume means were not found ($F_{3,76}$= 0.4, P= 0.74, Table 1, Fig. 4).

It was expected for the four breeding populations to display similar clutch sizes since they are determined mostly by heredity (Welty 1975). Nevertheless, variation in clutch size within a species may occur due to several reasons, such as: age, food availability, season, and genetic differences between individuals (Gill 1994). Clutch size did vary among studied populations, but not significantly so.

Shape index deviates strongly from 1 (sphere) in all the areas (Table 2), indicating that the shape of the eggs is elongate. Egg size is considered highly heritable and can serve as an index of body size (Olsen and Marples 1993). Variation in egg volume is indicative of variation in body size and may be evidence of subspecies of differing body size. Such subspecific separation does occur in the Great Cormorant (*P. c. carbo* larger than *P c. sinensis*) and the significantly larger eggs in Lake Kerkini could suggest subspeciation. Nevertheless, safe conclusions cannot be drawn since population age structure (adult birds lay larger eggs) and other factors that may contribute to egg volume variability (as for clutch size in the previous paragraph) have not been examined. Subsequent genetic analysis will help to assess the levels of differentiation between the four breeding populations. Difference in the mean clutch volume was not detected although mean egg volume was found significantly larger in Lake Kerkini than the Axios Delta. This happened because clutch volume also depends on clutch size and within-clutch egg size variation.

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