ADVANCES IN THE ECOLOGY OF LAKE KARIBA

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Cover Top: Typical ringnets as utilized in Kapenta fisheries on Lake Kariba
Bottom: Lake Kariba: The littoral area and draw-down zone
Back cover: Lake Kariba: The ecology of the littoral area is strongly influenced by wildlife.

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THE ECOLOGY OF FISH-EATING BIRDS AND THEIR IMPACT ON THE INSHORE FISHERIES OF LAKE KARIBA

Kit Hustler

INTRODUCTION

Lake Kariba was created when a dam at Kariba Gorge was closed in December 1958 and the lake began to form. It is now one of the largest man-made lakes in the world and the first of that size to have been built in Africa.

Little is known about the number, diversity and feeding biology of fish-eating birds on the Zambezi River before Kariba dam was built. Information on the status of birds in the Middle Zambezi Valley which is now under water has been inferred from the present distribution of birds downstream the dam wall (Irvin 1981, Donnelly and Donnelly 1983).

Most fish-eating species which were present in the middle Zambezi valley before inundation still occur on the lake (Donnelly and Donnelly 1983) and only those which occupied specialized habitats now lost through flooding have disappeared or become scarce and restricted (e.g. Rufous-bellied Heron, African Skimmer, Little Bittern). White-breasted Cormorants disappeared from the lake after 1963 but have now returned (Hustler *et al.* 1986, Hustler 1986a).

Species that have colonized the lake include the Black Egret, Lesser Black-backed Gull, Grey-headed Gull and White-winged Black Tern. The last three species have probably responded to the large areas of open water formed by the lake and the increase in fishing activity (Begg 1973, Hustler 1986b). There is no permanent population of Pelicans on Lake Kariba (Irwin 1981) but small numbers have been recorded periodically in recent years (Hustler 1987). These birds are abundant in shallow lakes such as Lake St. Lucia, South Africa (Whitfield and Cyrus 1978) and Lake Nakuru, Kenya (Vareschi and Jacobs 1984), and are absent from Lake Kariba because there are few suitable shallow areas.

Fish-eating birds on the lake can be divided into residents, migrants and vagrants. It is likely that most resident species have increased in number because of the longer shoreline and greater availability of fish. Intra-African or palearctic migrants may be present for up to six months every year but their numbers vary considerably.

Half of the species of birds that eat fish on Lake Kariba also take other food (see Table 9.1). They can be divided into groups according to their method of fish capture, i.e. surface plungers, waders and divers. Surface plungers (Kingfishers, Terns, Fish Eagle, Osprey) dive into the water from a perch or after

Table 9.1 The status (S), diet (D) and method of fish capture (M) of the main fish-eating birds on Lake Kariba. Nomenclature follows Irwin (1981); status from Irwin (1981) and Donnelly and Donnelly (1983); diet and method of fish capture from MacLean (1985)

	S	*D*	*M*
Podicipedidae			
abchick (*Tachybaptus ruficollis*)	M	F/I	D
Phalacrocoracidae			
hite-breasted Cormorant (*Phalacrocorax carbo*)	BR/M	F/O	D
Reed Cormorant (*P. africanus*)	BR/M	F/I	D
Anhingidae			
Darter (*Anhinga melanogaster*)	BR/M	F/O	D
Ardeidae			
Grey Heron (*Ardea cinerea*)	R/M	F/I	W
Goliath Heron (*A. goliath*)	BR/M	F/O	W
Purple Heron (*A. purpurea*)	R/M	F/O	W
Great White Egret (*A. alba*)	R/M	F/O	W
Little Egret (*Egretta garzetta*)	M	F/O	W
Yellow-billed Egret (*E. intermedia*)	R/M	F/O	W
Black Egret (*E. ardesiaca*)	M	F/I	W
Squacco Heron (*Ardeola ralliodes*)	M	F/I	W
Madagascar Squacco Heron (*A. idae*)	M	F/I	W
Green-backed Heron (*Butorides striatus*)	R/M	F/O	W
Scopidae			
Hamerkop (*Scopus umbretta*)	BR/M	O/F	W
Ciconiidae			
Saddlebill (*Ephippiorhynchus senegalensis*)	M	F/O	W
Yellow-billed Stork (*Mycteria ibis*)	M	F/I	W
Accipitridae			
African Fish Eagle (*Haliaeetus vocifer*)	BR	F/O	P
Pandionidae			
Osprey (*Pandion haliaetus*)	M	F	P
Lariidae			
Lesser Black-backed Gull (*Larus fuscus*)	M	C	P
Grey-headed Gull (*L. cirrocephalus*)	BM	C	P
Whiskered Tern (*Chlidonias hybrida*)	V	I/O	P
White-winged Black Tern (*C. leucogaster*)	M	I/F	P
Rhyncopidae			
African Skimmer (*Rhynchops flavirostris*)	V	F	P
Alcedinidae			
Pied Kingfisher (*Ceryle rudis*)	BR	F/I	P
Giant Kingfisher (*Megaceryle maxima*)	R/M	F/I	P
Malachite Kingfisher (*Corythornis cristata*)	BR	F/I	P

Notes: Status: B = Breeds on the lake, R = Resident, M = Migrant, V = Vagrant
Diet: F = Fish, I = Invertebrates, C = Carrion, O = Other vertebrates. The order given is the preferred food type.
Method: D = Diver, W = Wader, P = Plunge diver

hovering and can only exploit no more than the first metre of water. Waders (herons, egrets and storks) are restricted by the length of their legs and beaks and can only fish in water no more than 1 metre deep along the shorelines. Divers (Cormorants and Darter) pursue fish underwater and are limited by the maximum depth to which they can dive and by water transparency.

Birkhead (1978) showed that Reed Cormorants (*Phalacrocorax africanus*) and Darters (*Anhinga melanogaster*) remove large quantities of fish from the lake, thus potentially competing with the commercial fishery. However, fish-eating birds are only likely to have a significant effect on the yields of commercial fisheries when they remove large amounts of fish of the same species and age groups as those caught by the fishery (Furness and Monaghan 1987).

This paper intends to quantitatively assess the impact of fish-eating birds on the fisheries yield of Lake Kariba for the period 1986–1987. For that purpose, estimates of the amount and type of fish removed are needed.

MATERIAL AND METHODS

Habitats investigated

Four habitats were distinguished on Lake Kariba and birds were counted in each of them (Table 9.2). They are:

Gently sloping shores

These shores are characterized by shallow water with a mean slope less than 1 degree and extensive beds of submerged macrophytes. The shoreline is dendritic, exposed in some places but with many sheltered bays.

Steep sloping shores

These shores are generally rocky with a mean slope of 11 degrees, a few dead trees and little or no submerged vegetation. Most of these shorelines are exposed to wave action.

Flooded trees

These are the remains of the former woodlands flooded by the lake and the tops of the dead trees emerge above the surface in shallow water. The area of these three habitats was determined by tracing them from the Lake Kariba charts; it amounted to about 310 km^2 during this study.

Open water

This habitat comprises the rest of the lake, with a mean depth of 30 m and an area of 4,700 km^2 at the time of this study.

Birds counts (Figure 9.1)

Six transect trips were operated in each habitat type in the Sanyati basin. The transects began and ended at known places such as Baobab trees, termite mounds, fishing villages and fish eagle nests. It was difficult to measure the shoreline length from the map as the lake level was some 7 m below normal, so the time taken to complete each transect was recorded. The length of each transect was calculated as follows:

$$S = V.T,$$

where S = the length of the transect (m), V = speed of the boat (m/s) and T = mean time (s). The width of all transects was approximately 100 m and the outline of the shore was followed as closely as possible. In the flooded trees the width was reduced to 50 m as visibility there was restricted. The starting points of the open water transects were determined by travelling towards known places for the same time and at the same speed. The mean length of the transects (kilometers ± standard deviation) were 5.1 ± 2.5, 3.8 ± 1.8, 2.5 ± 0.9, 2.9 ± 0.3 for gently and steeply sloping shores, flooded trees and open water respectively.

Table 9.2 Comparison between gently and steeply sloping shorelines on Lake Kariba

	Gentle	*Steep*
Total length (km)	247	1917
Mean slope (degrees)	0.9	11.1
Mean distance from the shore (m) along the bottom to a depth of 10 m (S_b)	636.6	51.9
Area on the bottom (m^2) in the 0–10 m depth interval along 1 km of shoreline	636,646	51,942
Total related area (km^2)	158	99
The effect of the slope of the shore on		
(a) the number of fish	744.8	103.8
(b) the biomass of fish (kg)	1426.0	370.6

Notes: a: Number of fish caught x S_b b: Biomass of fish x S_b

Birds were counted from a small boat travelling at a speed of 200 metres per minute along each transect. Counts started at 0815 and were usually completed by 1200. The time taken to complete each count was recorded. All the birds seen between the boat and the shoreline or on the shore were recorded. The areas in which counts were done on separate days were far apart of separated by land masses in order to minimize the probability of counting the same birds twice.

Inside the Sanyati basin, counts were carried out over 4 days in each months during 1986 and 1987. Additional similar counts were made west of the Sanyati Basin (Figure. 9.1) in January, May and August 1987.

Computation of the abundance of birds

The number of birds of all species on each shoreline type in each month was calculated as follows:

$$N = N_s/S,$$

where N = number of birds per kilometer, N_s is the sum of the number of birds of species s seen and S is the sum of the lengths of all six transects along a given habitat. The mean abundance of the birds was calculated using N for each month in 1986 and 1987.

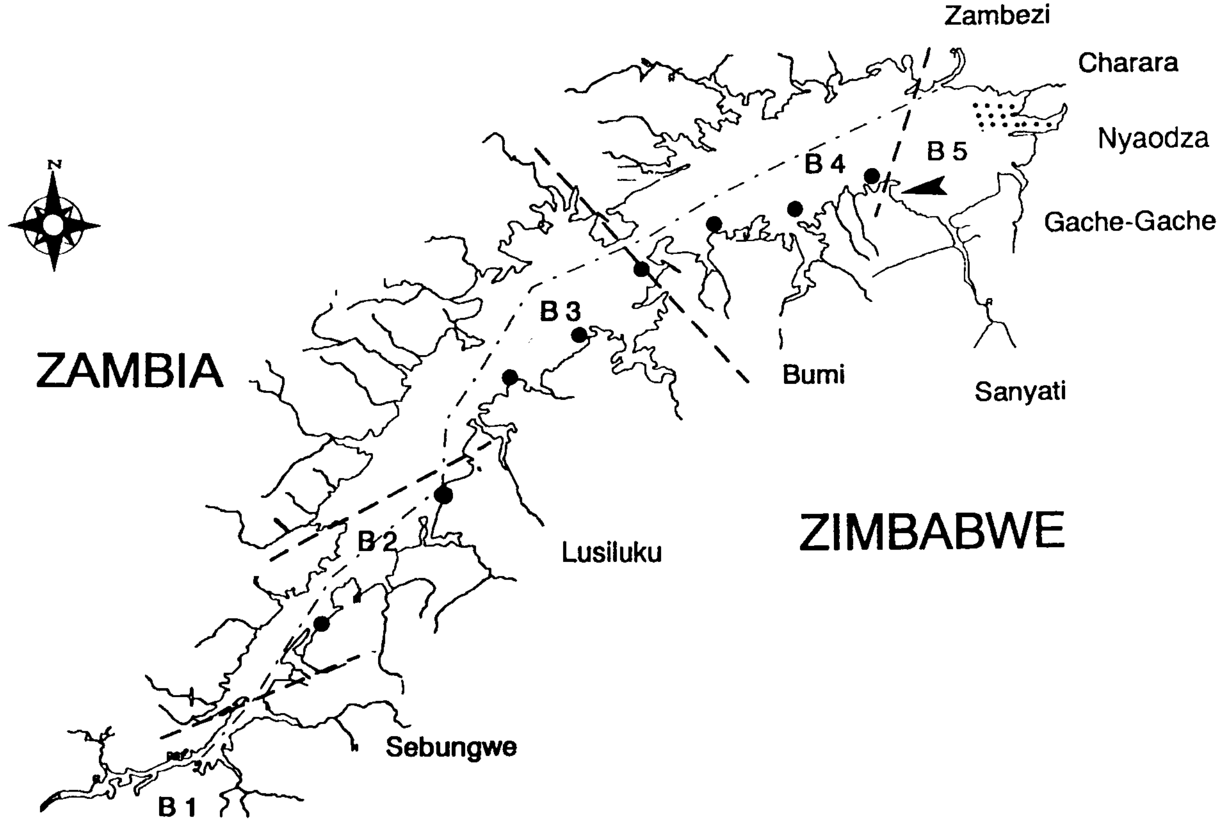


Figure 9.1 Lake Kariba, showing the places mentioned in the text. Transects in the Sanyati Basin were located on the shoreline between the town and the Gache-Gache river. The other transects (•) were located on the shoreline between Fothergill Island (arrowed in basin 5) and the Sebungwe river estuary. Cormorants were shot in the shaded areas in basin 5

The total number of birds on gently and steeply sloping shorelines was the product of their density (no. km^{-1}) and the total length of each shoreline type. The total number of birds in the flooded trees and open water was the product of their density (no. km^{-2}), i.e. length of the transect x 100 m) and the total area of each habitat type.

Seasonal variations in the abundance of birds

The analyses of seasonal variations in the numbers of fish-eating birds was confined to the most numerous species recorded on the gently sloping shorelines only because wading birds were not recorded regularly on the other shoreline types. Only data collected in the Sanyati Basin were used as they were more complete than the data obtained from west of this basin.

The level of the lake does not affect the areas where the divers and plunge divers feed but determines the length and nature of the shoreline which is available to wading birds for feeding. Their numbers were compared with the lake level which was recorded daily at the hydro-electric power station. The level of the lake at the time the birds were counted was calculated as follows:

$$L = (L_{d1}+L_{d2})/2,$$

where L = lake level during the counts, L_{d1} = lake level on the day counts were started and L_{d2} = lake level on the day counts were completed.

Food consumption of the bird community

In order to determine the quantity of food eaten by the birds on the lake it was necessary to estimate

- the total population of each species (see above)
- the individual daily food consumption

Food consumption by captive birds

Three Reed Cormorants, two White-breasted Cormorants and five Darter nestlings were removed from their nests and hand reared. Darters were difficult to keep in captivity and only one survived to the experimental stages. Once they could fly the birds were isolated and housed in a large aviary and provided with fish in a 6 cubic meters circular galvanised iron tank.

The total weight of fish introduced into and the weight of dead fish later removed from the tank were recorded. The birds caught the fish by themselves and were not hand fed. The experiments lasted 7 days after which the water was drained from the tanks and the remaining fish collected.

The weight of fish eaten over the experimental period (seven day period) was calculated as:

$$W_e = W_i - (W_d+W_a),$$

where W_e = the weight eaten, W_i = the total weight of fish introduced, W_d = the total weight of the dead fish removed and W_a = the total weight of the uneaten fish which were also removed when the experiment ended. All values are in grams. W_e was divided by seven to give the daily weight of fish eaten. Fish of different sizes were fed to the birds in order to assess the effect of size on the number of fish they ate.

The predicted fish consumption

These birds were studied in order to compare their known food consumption with the predicted food consumption as computed by the equation of Nagy (1987):

$$FMR = 8.01w^{0.704},$$

where FMR = the field metabolic rate (kJ day^{-1}) and w = the mean weight (g) of each species. The FMR was then divided by 5.77 to covert it to weight in grams (Jackson 1986) and then multiplied by 1.23 to take into account the 81% assimilation efficiency rate for fish-eating birds (Ricklefs 1974).

This value was then multiplied by the average number of birds of each species present every day on the lake in order to obtain the daily food consumption of the whole bird community. It was then extrapolated for the whole year.

Diet

Ten Reed Cormorants were shot every month in 1986 in order to examine their stomach contents. Most birds were shot on the south side of Antelope Island and also occasionally in the tree line north of Charara point (Figure 9.1). The birds were measured, weighted to the nearest gram and dissected within an hour after being collected. The weight of the stomach contents was recorded and, when possible, individual fishes from the stomachs were weighed and identified using Balon (1974), Jubb (1961) and Kenmuir (1983). Darters were not shot because it was initially thought they were too few to sustain a collecting programme. Instead, information on their diet was obtained from Birkhead (1978) and Donnelly and Hustler (1986).

The fish removed by fishermen

The weight of commercially important fish species removed by the inshore fishery on the Zimbabwean side of the lake was available from Sanyaanga *et al.* (1990). Catch data from the Zambian side of Kariba were obtained from Scholz and Meetwa (1990) and Crul and Roest (1995). The amount of commercially important fish removed by spearfishermen, poachers and recreational anglers is unknown but it is assumed to be of marginal importance.

RESULTS

The number of fish-eating birds

Fourteen species made up 96.8% of all the fish-eating birds seen; the most abundant of which was the Reed Cormorant (51.5%). The White-winged Black Tern and Darter contributed to a further 37.5% of the total (Table 9.3). These three species constituted 89% of all the fish-eating birds that were recorded. They are therefore the most likely birds to have an impact on the inshore fishery of Lake Kariba.

The gently sloping shorelines had the greatest proportion of divers, waders and surface plungers, whilst the open water had the least (Figure 9.2). There were similar numbers of birds in the Sanyati Basin and the western parts of the lake although there were fewer Grey Herons in the Sanyati Basin (Table 9.4).

Table 9.3 The mean abundance (no km^{-1}) of birds seen on gentle (G), steeply sloping shores (S), flooded trees (F) and in the open water (O) on Lake Kariba during 1986 and 1987 (95% confidence interval in brackets)

Species	*G*	*S*	*F*	*O*	*Total*
Reed Cormorant	5.3 (1.3)	1.6 (0.3)	15.1 (3.8)	*	10512
White-breasted Cormorant	–	–	0.1 (0.2)	–	49
Darter	1.0 (0.2)	0.5 (0.1)	3.0 (0.7)	–	2203
Dabchick	0.9 (0.6)	*	–	–	650
Goliath Heron	0.1 (0.03)	*	*	–	96
Great White Egret	0.5 (0.1)	*	*	–	311
Grey Heron	0.2 (0.1)	–	–	–	102
Purple Heron	*	–	–	–	20
Little Egret	0.2 (0.1)	–	–	–	119
Black Egret	0.2 (0.1)	–	*	–	106
Squacco Heron	0.3 (0.3)	–	–	–	150
Yellow-billed Egret	*	–	–	–	15
Madagascar Squacco Heron	*	–	–	–	11
Green-backed Heron	*	*	*	–	12
Yellow-billed Stork	*	–	–	–	11
Saddlebill	*	–	–	–	6
Hamerkop	*	*	–	–	3
Fish Eagle	0.1 (0.1)	0.2 (0.1)	0.1 (0.03)	–	196
Osprey	*	–	–	–	1
Pied Kingfisher	0.4 (0.1)	0.2 (0.1)	0.1 (0.03)	*	340
Malachite Kingfisher	*	*	–	–	11
Giant Kingfisher	*	–	–	–	1
White-winged Black Tern	3.8 (2.3)	0.5 (0.3)	6.2 (3.8)	0.6 (0.2)	5462
Whiskered Tern	*	–	–	–	4
Grey-headed Gull	0.1 (0.1)	*	0.5 (0.4)	0.01 (0.1)	179
Lesser Black-backed Gull	–	–	*	*	4
No. of species	24	12	12	5	

Note: * = less than 0.01 birds per kilometer

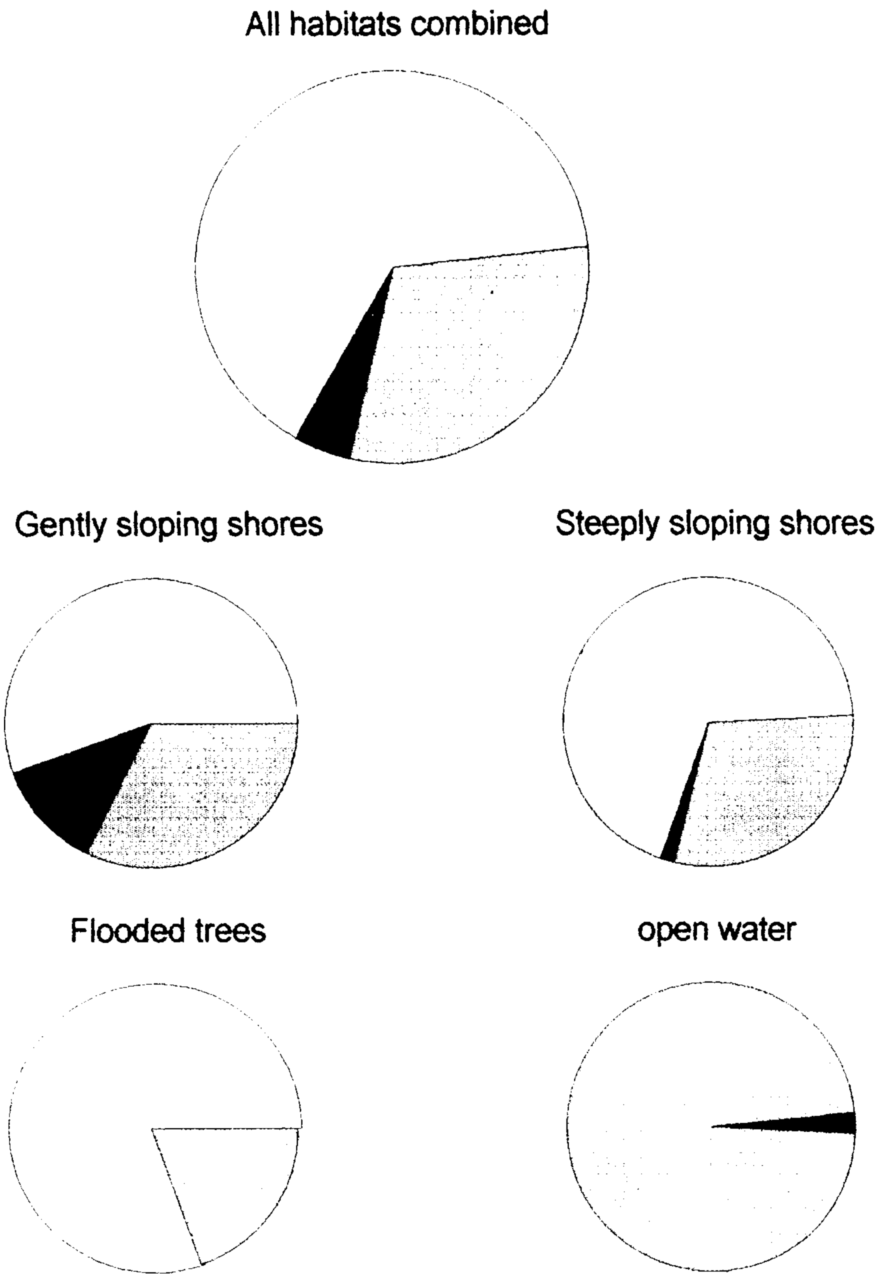


Figure 9.2 The proportion of diving (□), wading (■) and surface plunging species (□) in the four habitat types on Lake Kariba

Table 9.4 The abundance (no km^{-1}) of the most numerous species in all habitats on the lake west of (L) and in the Sanyati Basin (B) in 1987 (t = Student variable)

Species	*Gentle*			*Steep*			*Flooded Tree*			*Open Water*		
	B	*L*	*t*	*B*	*L*	*t*	*B*	*L*	*t*	*B*	*L*	*t*
Divers												
Reed Cormorant		8.7	6.70	0.54	1.70	0.80	#2.63	27.7	15.30	1.98		
Darter	1.2	1.4	0.84	0.50	0.30	1.19	6.30	3.1	1.89			
Waders												
Goliath Heron	0.1	0.2	1.82	0.02	0.05	0.82						
Grey Heron	0.3	1.0	*5.18									
Great White Egret	0.6	1.3	2.17									
Little Egret	0.3	0.6	0.90									
Black Egret	0.2	0.5	1.00									
Squacco Heron	0.3	0.4	0.23									
Plunge divers												
Fish Eagle	0.2	0.2	0.00	0.10	0.10	0.00	0.10	0.5	2.14			
Pied Kingfisher	0.3	0.3	0.00	0.20	0.20	0.00						
Grey-headed Gull	0.5	0.2	0.71									
White-winged Black Tern	7.4	1.0	1.09#	0.50	0.20	0.79	12.20	1.7	#0.77	0.40	0.70	0.75

Notes: All data from the same month in 1987. The bad weather in November restricted the counts that could be done so for gently and steeply sloping shorelines d.f. = 6 and for flooded trees and open water d.f. = 4. * $p<0.01$

Variances significantly different (F test, $p<0.01$) so d.f. = 3 for gentle and steep shores and d.f. = 2 for flooded trees after Snedecor and Cochran (1967).

The seasonal variation in the abundance of birds

The diving birds

The number of Reed Cormorants and Darters decreased from February to a minimum in May and June and then increased to a maximum in December and January (Figure 9.3). There was a significant relationship between the number of Reed Cormorants seen and the number of fish caught in 1987. More Reed Cormorants were seen in 1987 than in 1986 and the numbers of fish caught in 1987 were significantly less than those caught in 1986. This did not hold true for the Darters.

The wading birds

The numbers of Herons and Egrets were negatively correlated with the level of the lake and only the numbers of Little Egrets and fish were correlated; there were no other significant correlations between the number of Herons and Egrets and the number of fish (Table 9.5).

The plunge divers

There were no significant relationships between the number of Pied Kingfishers and Grey-headed Gulls and the abundance of fish while the numbers of Fish Eagles and White-winged Black Terns were significantly correlated with the number of fish caught (Table 9.5).

Table 9.5 Regression equations of the relationships between the abundance of fish-eating birds and the level of the lake in 1986 and 1987 and the abundance of prey-fish in 1987

	Lake level	*Abundance of fish*	
Divers[1]			
Reed Cormorant	–	N = 3.30NF + 3.07 (0.76)	
Darter	–	N = 0.19NF - 0.89 (0.44)	
Waders			
Goliath Heron	N = –0.05L + 26.0 (–0.61)	N = 0.02NF + 0.10	(0.30)
Grey Heron	N = –0.07L + 35.5 (–0.33)	N = –0.002NF + 0.28 (–0.01)	
Great White Egret	N = –0.23L + 109.6 (–0.47)	N = 0.06NF – 0.37	(0.21)
Little Egret	N = –0.20L + 95.0 (–0.52)	N = 0.17NF + 0.05	(0.61)
Black Heron	N = –0.20L + 93.8 (–0.70)	N = 0.13NF + 0.04	(0.49)
Squacco Heron	N = –0.34L + 165.4 (–0.54)	N = 0.32NF – 0.002 (0.47)	
Plunge divers[1]			
Fish Eagle	–	N = 0.08NF + 0.02 (0.63)	
White-winged Black Tern	–	N = 5.59NF – 1.82 (0.79)	
Pied Kingfisher	–	N = 0.01NF = 0.38 (0.05)	
Grey-headed Gull	–	N = –0.16NF + 0.35 (–0.33)	

1 The level of the lake does not affect the areas used for fishing by these birds.
2 N = The number of fish-eating birds (km^{-1}); L = Level of the lake (m. a. s. l.) in 1986 and 1987; NF = The abundance of prey fish ($trap^{-1}$ h^{-1}) in 1987.
3 Values in brackets are the correlation coefficients. * = $p<0.05$ ** = $p<0.01$

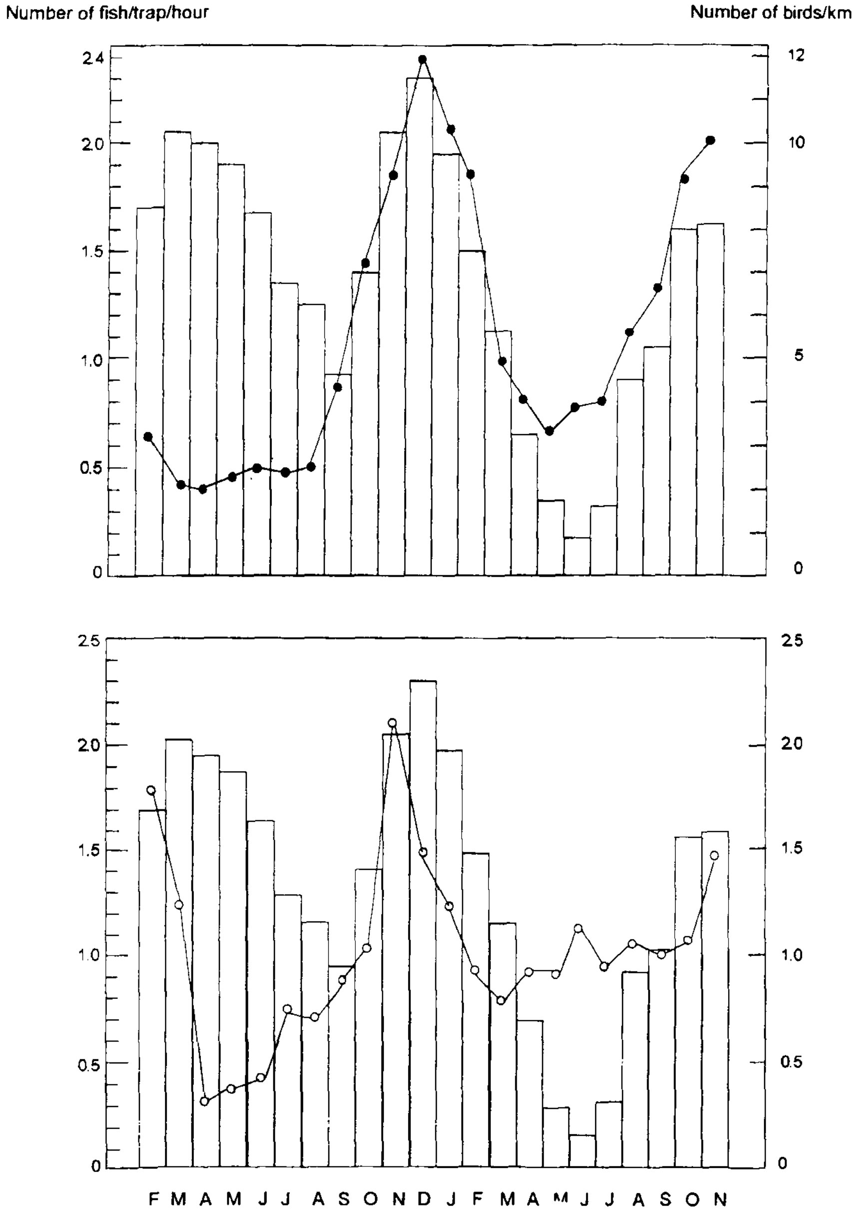
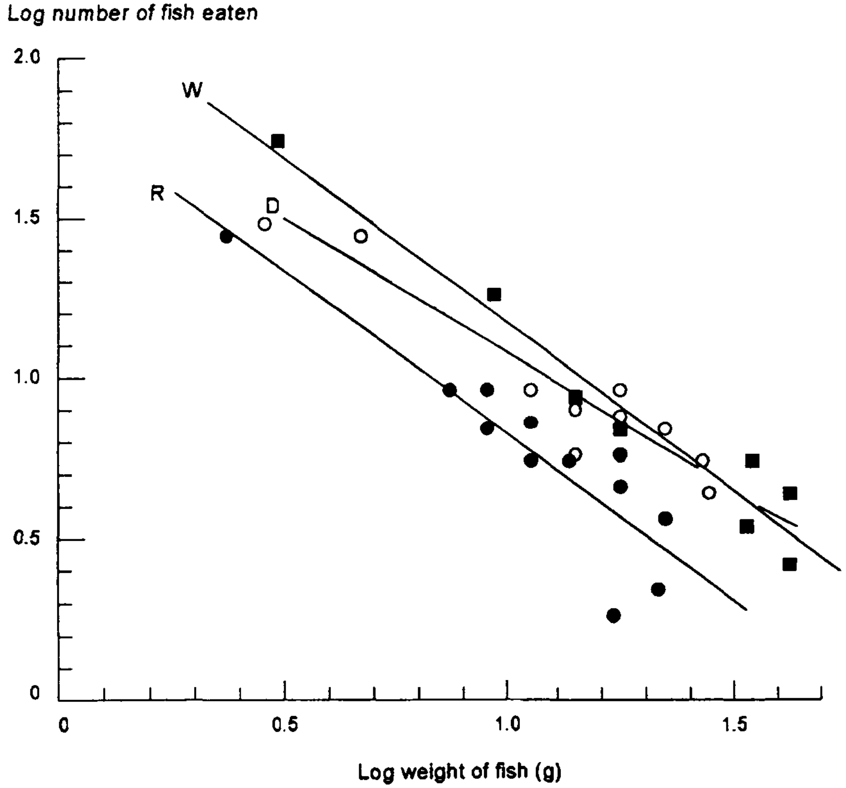


Figure 9.3 The relationship between the numbers of Reed Cormorants (top, •) and Darters (bottom, o) and the numbers of fish caught in water 2 m deep on gently sloping shores (histogram). There were more Reed Cormorants in 1987 than in 1986 ($t = 3.44$, $p<0.02$, d.f. = 11) and less fish in 1987 than in 1986 ($t = 2.44$, $p<0.05$, d.f. = 11). There was no significant difference in the numbers of Darters between 1986 and 1987. All data are three months running means

Fish consumption by Reed Cormorants, White-breasted Cormorants and Darters

There was a significant relationship between the number of fish eaten by all three species of diving birds and the size of the fish given to them. The birds ate more of the small fish than the larger ones in order to fulfill their daily food requirements (Figure 9.4).



• and R = Reed cormorants ○ and D = Darters ■ and W = White-breasted cormorants

Figure 9.4 The relationship between the weight of fish and the number eaten daily by Reed Cormorants ($y = -1.0x + 1.93$, $r = -0.91$, $p<0.01$), White-breasted Cormorant ($y = -0.99x + 2.26$, $r = -0.98$, $p<0.01$) and Darters ($y = -0.83x+1.99$, $r = -0.91$, $p<0.01$)

The value of fish consumption by all three bird species calculated with the equation of Nagy (1987) were all higher than the experimental values (Table 9.6). However, it was decided to use the computed value of the daily fish consumption for every species considered in this study because the low values obtained in the experiments on Cormorants and Darters might come from the fact that captive birds usually need less energy than wild ones do and therefore require less food.

Table 9.6 A comparison of the empirically and experimentally derived amounts of daily fish consumed by the three species of diving birds on Lake Kariba

	Reed Cormorant (499, 12.4, n = 10)		*White-breasted Cormorant (1644,27.5, n = 6)*		*Darter (1410, 68.0, n = 9)*	
	D	*%*	*D*	*%*	*D*	*%*
Emp.	135.5	27.1	313.6	19.1	281.5	20.0
Expt	109.2	21.9	190.2	11.6	164.7	11.7

Notes: Figure in brackets is the mean weight (g) of the bird during the experiments, the 95% confidence limit of the mean and the number of experiments (n).

D = the fish consumption in g per day.

Emp. = the fish consumption derived from the equation in Nagy (1987).

Expt = the fish consumption obtained from the captive birds.

% = the percentage of body in fish consumed daily.

Diet

Published data on the diet of the Darters (Birkhead 1978, Donnelly and Hustler 1986) show that they eat a lot of fish which are of no commercial importance (Table 9.7). Most of the fish species eaten by the Reed Cormorants shot on Lake Kariba were also of little commercial value (Table 9.8) i.e. *Ph. darlingi* and *Ps. philander* and has remained similar for 15 years (Table 9.8). This supports the use of the previous data on the diet of the Darter (Birkhead 1978, Donnelly and Hustler 1986) in this study. Data on the relative importance of various fish species by weight in the diet of these birds are also available (Birkhead 1978) which show that commercially important species make 58.1% by weight of the fish eaten by Reed Cormorants and 51.4% by Darters (Birkhead 1978). This high figures come from the fact that commercially important cichlids eaten by Cormorants, for instance, were larger than the non-commercial ones (Table 9.9).

Total fish consumption by fish eating birds on Lake Kariba

The quantitative data used in order to estimate the total fish consumption of the bird community of Lake Kariba are summarized in Table 9.10. The number of birds of each species in Table 9.10 is different from the total quoted on Table 9.3. This comes from the fact that Table 9.10 gives the average number of birds which are feeding on the lake every day. These figures were obtained by using an index of activity of the birds (see Hustler 1991).

In the period 1986–1987, piscivorous birds removed an average of 1584 kg of fish per day, which amount to 579 tonnes per annum. This represents 16% of the catch of the inshore fisheries (3,600 tonnes see Table 9.11) and 1.3% of the ecological production of the inshore fish community (Table 9.12).

Table 9.7 Diet of the Darter at Lake Kariba

Species	*1971/2* [1] *n*	*%*	*1976* [2] *n*	*%*	*Total* *n*	*%*
Brycinus lateralis	56	20.0	2	1.8	58	14.8
Barbus unitaeniatus	1	0.4			1	0.3
Pharyngochromis darlingi	40	14.3	78	69.0	178	45.3
Pseudocrenilabrus philander	60	21.4				
Synodontis zambezensis	1	0.4			1	0.3
Hippopotamyrus discorhynchus	6	2.1	6	5.3	12	3.1
Schilbe mystus/Eutropius epressirostris			1	0.9	1	0.3
Micralestes acutidens	1	0.4			1	0.3
Tilapia rendalli *	44	15.7	9	8.0	53	13.5
Oreochromis mortimeri *	41	14.6	17	15.0	58	14.8
Serranochromis codringtoni *	3	1.1			3	0.8
Hydrocynus vittatus *	22	7.9			22	5.6
Clarias gariepinus *	2	0.7			2	0.5
Total	280	99.0	113	100.0	393	99.6
Unidentified cichlid	31				31	
Unidentified fish			1		1	
Number of birds	28		21		49	

* indicates species of commercial importance n = number of recorded fish
(1) Donnelly and Hustler (1986) (2) Birkhead (1978)

Table 9.8 Diet of the Reed Cormorant at Lake Kariba (legends: see Table 9.7)

Species	*1971/2* [1] *n*	*%*	*1976* [2] *n*	*%*	*1986* *n*	*%*	*Total* *n*	*%*
Brycinus lateralis	88	13.8	6	1.8	27	11.7	121	10.0
Brycinus imberi					1	0.4	1	0.1
Barbus lineomaculatus			3	0.9	1	0.4	4	0.3
Barbus unitaeniatus			3	0.9			3	0.2
Barbus sp.	6	0.9					6	0.5
Pharyngochromis darlingi	301	47.0	264	78.3	128	55.4	751	62.1
Pseudocrenilabrus philander	47	7.3			11	4.8		
Synodontis zambezensis	64	10.0	6	1.8	12	5.2	82	6.8
Synodontis nebulosus	1	0.2			4	1.7	5	0.4
Hippopotamyrus discorhynchus					1	0.4	1	0.1
Marcusenius macrolepidotus			3	0.9			3	0.2
Schilbe mystus/Eutropius dep.			3	0.9			3	0.2
Labeo altivelis	1	0.2					1	0.1
Tilapia rendalli *	74	11.6	3	0.9	28	12.2	105	8.7
Oreochromis mortimeri *	34	5.3	36	10.7	6	2.7	78	6.4
Serranochromis codringtoni *	2						2	0.1
Mormyrops deliciosus *			10	3.0	4	1.7	14	1.2
Mormyrops longirostris *					4	1.7	4	0.3
Hydrocynus vittatus *	15	2.3			4	1.7	19	1.6
Limnothrissa miodon *	1	0.2					1	0.1
Clarias gariepinus *	6	0.9					6	0.5
Total	640	100.0	337	100.0	231	100.0	1210	100.0
Unidentified cichlid	112		61		19		193	
Unidentified fish					47		47	
Number of birds	128		50		120		298	

Table 9.9 The mean individual weight (g) of commercially important and other cichlid fish eaten by Reed Cormorants shot in 1986 (see Tables 9.7 and 9.8 for details).

Important cichlids	16.48 g	(5.22)	34 (a)
Unimportant cichlids	2.09 g	(0.32)	100 (a)

Notes: Figure in brackets = 95% confidence limits; (a) = number of fish

Table 9.10 The quantity of fish eaten (t) by the most abundant fish-eating birds on Lake Kariba in 1986–1987. N = The mean number of birds on the lake each day (the upper confidence limit is given in brackets). DFC = The total amount of food eaten per day (The estimated consumption based on the upper confidence limit is given in brackets). YFC = The amount of food eaten per year (tonnes)

Species	*Body Weight g (1)*	*Fish eaten*	*N g day (2)*	
Reed Cormorant	562	147	4978	(6727)
Darter	1500	294	1327	(2907)
Dabchick	154	59	225	(370)
Goliath Heron	4300	617	63	(96)
Grey Heron	1500	294	50	(50)
Great White Heron	1100	236	125	(135)
Litte Egret	447	125	50	(65)
Black Heron	313	98	50	(60)
Squacco Heron	300	95	75	(145)
Fish Eagle	3000	479	502	(617)
Grey-headed Gull	278	90	43	(100)
Pied Kingfisher	80	37	487	(514)
White-winged Black Tern	57	29	2945	(5474)
Total			10920	(17260)

Species	*DFC (Kg)*		*YFC (tonnes)*	
Reed Cormorant	732	(989)	267	(360)
Darter	390	(854)	142	(312)
Dabchick	13	(22)	5	(8)
Goliath Heron	39	(59)	14	(21)
Grey Heron	15	(15)	6	(6)
Great White Heron	30	(32)	11	(12)
Litte Egret	6	(8)	2	(3)
Black Heron	5	(6)	2	(2)
Squacco Heron	7	(14)	3	(5)
Fish Eagle	241	(296)	88	(108)
Grey-headed Gull	4	(9)	1	(3)
Pied Kingfisher	18	(19)	7	(7)
White-winged Black Tern	85	(159)	31	(58)
Total	1585	(2482)	579	(905)

Notes: (1) Body weight of Reed Cormorants shot at Kariba, others from MacLean (1985). (2) Daily food consumption calculated using the equation in Nagy (1987) and an assimilation efficiency of 1.23 (Ricklefs 1974).

Table 9.11 A comparison between the estimated quantity (tonnes) of commercially important fish harvested by fishermen and eaten by fish-eating birds (based on mean quantity of fish eaten) in Lake Kariba

	Actual catch[1]	*Fish consumed*	*% of total catch*
Inshore fishery	3 600	579	16
Pelagic fishery	30 000		
Total	33 600	579	2

Notes: [1]Data from Zimbabwe (Sanyanga *et al.* 1990) and Zambia (Scholz and Mweetwa 1990) combined for 1989.

DISCUSSION

Influence of shoreline types on the number of bird species

Reed Cormorants, Darters and White-winged Black Terns make up the majority of birds recorded. Similar results have been reported from marine environments where a few species of birds account for most of the numbers (Furness 1982).

Twice as many bird species were recorded on the gently sloping shorelines than on the steeply sloping shores at Kariba (Table 9.3) because wading birds were seen there. Wading birds are limited to shallow water by the length of their legs (Whitfield and Blaber 1979a) and were scarce or absent from steeply sloping shores. Only the Goliath Herons have legs which are long enough to enable them to exploit these shorelines. The abundance of fish on gently sloping shorelines is four times greater than on steeply sloping ones (Marshall and Langerman 1988). When combined with the steep slope, this can also explain the lack of wading piscivorous birds on steeply sloping shores.

In a similar way, fish-eating birds forage almost entirely in shallow water on gentle slopes at Lake St Lucia (Whitfield and Blaber 1978, 1979 a and b, Berruti 1983).

The small number of bird species recorded in open water was expected. Few of them can feed successfully in deep water and the open water is occupied almost entirely by plunge divers, i.e. mostly Terns and Gulls.

The number of the most abundant birds in the Sanyati Basin was similar to that recorded in the western parts of the lake (Table 9.4). The extent of the various habitats in the western parts of the lake may account for the significant difference of the variance of the mean number of birds in the two areas. Most of the shoreline west of the Sanyati Basin consists of steeply sloping shores resulting in a concentration of birds on gently sloping shorelines. Birds move between the different basins although the scale of these movements is unknown. Reed Cormorants nesting north of Fothergill Island regularly fed close to the research station and a nestling which was colour ringed close to Kariba town, was resighted in Chete Gorge.

Table 9.12 Assessment of the impact of fish eating birds on the inshore fish populations of Lake Kariba

Fish species	*Biomass*	*P/B*	*Ecol. production (tonnes yr⁻¹)*	*% (weight) of food*		*Fish consump. (tonnes yr⁻¹)*		*All birds (tonnes)*		*Actual catch (tonnes yr⁻¹)*
				cormorants	*darters*	*cormorants*	*darters*			
Small Characids (1)	756	3.8	2873	0.8	2.9	2.2	4.2	8.8		680
Cyrprinids (2)	98	0.6	59	0.5	0	1.1	–	1.7		30
Mochokids (3)	450	0.9	201	5.5	0	14.7	–	20.6		50
H. discorhynchus	1190	1.9	2261		227	0.0	32.2	45.6	)	
M. macrolepidotus	476	1.3	619	8.1	0	21.6	–	30.4	)	
M. deliciosus	910	0.5	455	5.5	0	14.7	–	20.6	)	950
M. longirostris	560	0.5	280		2.4	–	3.4	4.7	)	
E. depressirostris	28	1.0	28	3.6	6.3	9.6	8.9	26.9	)	
Unidentified Cichlids	–	–	–	5.5	1.7	14.7	2.4	24.2		
T. rendalli	504	1.2	605	3.4	4.5	9.1	6.4	22.0		230
O. mortimeri	1274	0.9	1083	49.2	44.5	131.4	63.2	276.1		450
P. darlingi	6398	5.5	35189						)	
P. philander	14	7.7	118	17.9	15.0	47.8	21.3	98.0	)	500
S. codringtoni	126	1.0	126						)	
Total	12810		43800	100	100	267.0	142.0	579.0		(4) 2890

(1) Mainly *B. lateralis* (2) Mainly *L. altivelis* (3) Mainly *S. zambezensis* (4) 700 tonnes of *H. vittatus* not incorporated

Notes: The biomass of various species was estimated from their proportion (% weight) of the total inshore biomass. These proportions are the means of Balon's (1974), Mitchell's (1976) and Karenge and Kolding's (1995) values; inshore biomasses are the mean of Balon's (1976) and Marshall and Langerman's (1988) values.
P/B ratios for *P. darlingi* and *P. philander* from Hustler and Marshall 1990).

Seasonal pattern of abundance and movements of birds on Lake Kariba

Diving birds

Data from Kariba and elsewhere in Africa (White 1945, Tree 1962, Bowmaker 1963, Laycock 1965, Junor 1969, Aspinwall 1971, 1984, Madge 1972, Tucker 1980, Junor and Marshall 1987) suggest that there is a regular movement of Reed Cormorants which is linked to the onset and intensity of the rains but may also be related to the numbers of fish. Reed Cormorants avoid rivers in full flood in the Zaire basin (Chapin 1932) and Elgood *et al.* (1973) record dispersal to pools away from flooding rivers in east Africa. They are more common at other permanent inland waterbodies during the dry season (Milstein 1975, Beesley and Irving 1976, Skead and Dean 1977, Boschoff *et al.* 1991) and it is possible that long distance movements involving a large number of birds are taking place.

In Kenya, the movements of Darters are related to localized rainfall (Lewis and Pomeroy 1989) while, elsewhere in Africa, they make considerable local movements (Irwin 1981, Brown *et al.* 1982). At Barberspan and Lake Mutirikwe, Darters are recorded in all months with an increase in number in the winter months (Junor 1969, Skead and Dean 1977, Junor and Marshall 1987) while at Kariba their numbers are lower during the winter months (Figure 9.5). This suggests that Darters may also undertake long distance movements which are linked to some environmental factor like rainfall and its related effects on the populations of prey-fish.

Wading birds

The decline in the numbers of Herons and Egrets between May and September is closely tied to the level of the lake (Table 9.5). When the lake rises the shoreline vegetation is flooded which gives cover to fish and makes difficult for wading birds to catch them. When the lake drops, the shoreline is relatively bare as there is little vegetation in the zone which had been previously inundated and fish are easier to see and catch because of the reduced cover.

The numbers of wading birds, except for the Little Egret (Table 9.5), showed no relationship with the number of fish caught. There may be two reasons for this. Firstly, most of these birds do not feed exclusively on fish (Table 9.1) and secondly the fish sampled in this study were trapped at a depth which cannot be used by wading birds.

Differences between experimental and empirical daily food consumption rates of the diving birds

The food eaten by the captive birds was variable. Those birds which had fed well the day before ignored or showed little interest in the fish provided whereas they pursued them immediately if they were hungry. Darters reduce their daily energy requirements by absorbing insulation when they spread their wings (Hennemann 1982 and 1983) which might account for some of the difference between the experimental and empirical estimates of their food consumption (Table 9.6). Cormorants do not use the spread-wing posture to absorb insulation and simultaneously reduce their metabolic costs (Hennemann 1983).

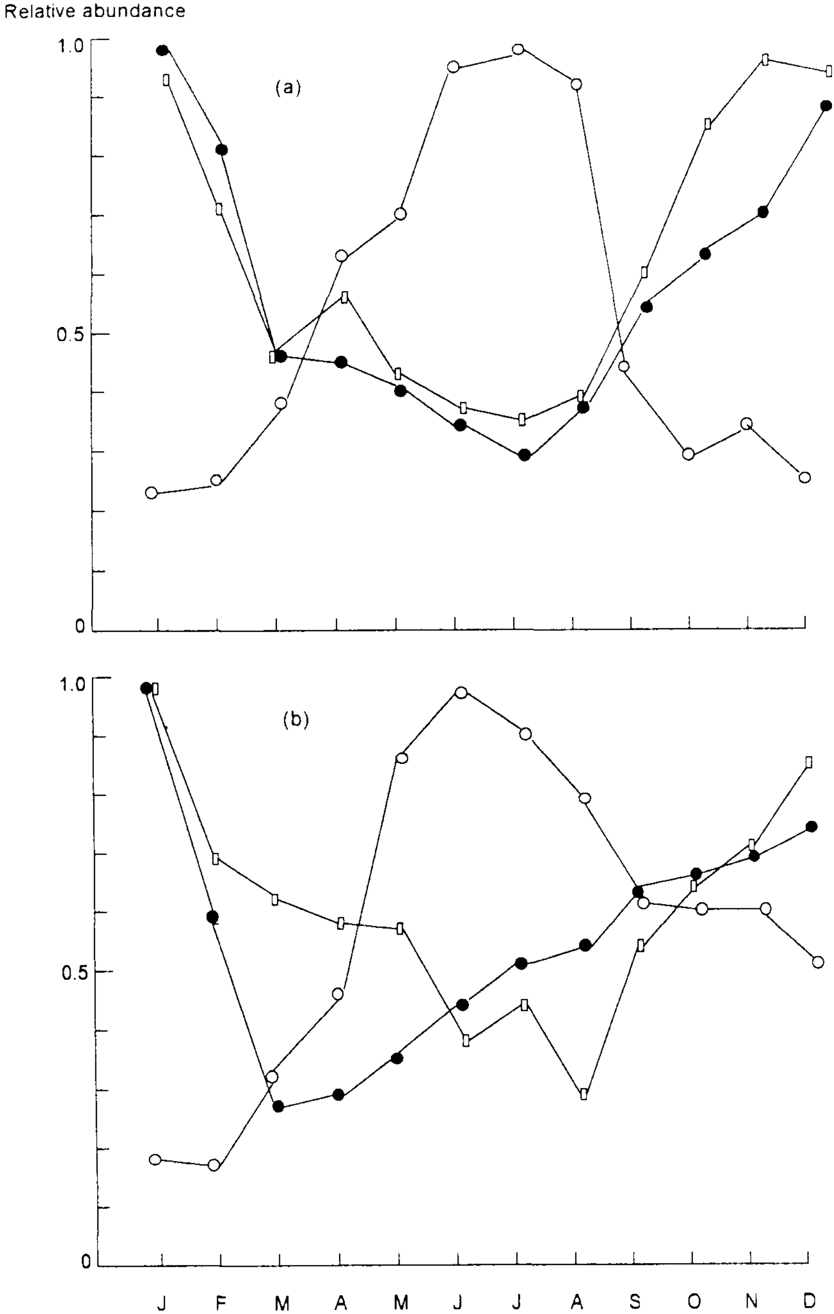


Figure 9.5 The annual variation in the relative abundance of Reed Cormorants (top) and Darters (bottom) on Lake Mutirikwe (• data from Junor and Marshall, 1987), Barberspan (○ data from Skead and Dean, 1977) and Kariba (□)

The quantity of fish removed by birds from Lake Kariba

The energy requirements of adult birds account for between 50 and 70% of the energy required by a number of fish-eating bird populations (Furness 1982, Furness and Cooper 1982). The energy needed for existence and foraging by adult Cape Cormorants (*P. capensis* Sparmann) accounted for 92.1% of the total energy budget (Furness and Cooper 1982). This means that food consumption values will be sensitive to errors in the estimates of bird populations.

In addition, most models which determine the amount of fish eaten by birds are based on data from birds which breed only once a year (Wiens and Scott 1975, Furness 1982, Furness and Cooper 1982). However, Reed Cormorants and Darters breed all year round in Zimbabwe (Irwin 1981) and the energy needed from breeding may be much higher than quoted above. Nothing is known about the breeding success or the numbers of times Cormorants or Darters breed on Lake Kariba because their colonies were widely scattered throughout the exposed trees.

CONCLUSION

The impact on the inshore fish community and the commercial fishery

In order to assess the impact of predation on a population, to have detailed information on its mortality and fecundity, densities in different habitats and migration patterns of the prey and the predator is needed. These data are lacking or incomplete for most of the fish and birds which live at Kariba. Similar problems were experienced by Campbell (1982) on Lake Malawi.

The numbers of fish eaten by all three diving species during the food consumption experiments depend on their size (Figure 9.4). All sizes of fish are available in the lake and this has influence on the amount of fish the birds will eat. The impact of birds on the fish will depend on the size of the fish which are available, which in turn, is related to the time of year. For example, the sizes of fish available immediately just before and after breeding are different and this would influence the number of fish eaten by the birds at these times. Most of the cichlid species show a disparity in size at the same age (Fryer and Iles 1972, Lowe-McConnell 1975, Hustler and Marshall 1990) and this could influence the number of fish species which are eaten by the birds at different times of the year. If the fish breed for different periods at various times of the year, this will also influence the sizes of different species available to the birds at different times of the year.

Birds compete directly with commercial fisheries if they are eating fish species of the same size as those which are harvested (Furness and Monaghan 1987). In some marine coastal fisheries, where commercial fisheries and birds compete for the same species and sizes of fish, sea birds remove the equivalent of 22–29% of the commercial catch (Wiens and Scott 1975, Furness 1978, Furness and Cooper 1982).

In Lake Kariba, cichlids which are susceptible to commercial fishing gears weigh 200 g or more (Marshall *et al.* 1982) while at Kariba, the most abundant birds eat fish which are too small to be harvested commercially (Table 9.9). However, birds are eating juvenile fish of commercial species which are not yet harvested because of their small size and have some impact on the population of fry and juveniles. The population dynamics of the juvenile cohorts of the commercial fish species are unknown, so it is impossible to determine the relative effect of the predation of the birds on these size classes.

The growth rates of some cichlids have been shown to be density dependant (Fryer and Iles 1972, Lowe-McConnell 1975) and if the birds were removed to allow more individuals to survive, it is likely that the catch will not increase significantly because of this density dependant growth. In this instance, it is likely that the birds are benefitting the fishing industry by reducing the number of juveniles in those cohorts and thus allowing faster growth of the survivors.

Fish-eating birds are pests only when the fish they catch deprive fishermen of their fish. The most common fish-eating birds on Lake Kariba remove, at most, 25% of the amount harvested commercially (Table 9.11) and a negligible quantity (2%) when compared to the total ecological production of fish in the inshore area of the lake (Table 9.12). This result is similar to those elsewhere where fish-eating birds were found to have a limited effect on the commercially important fishes caught by man (McNally 1957, Bowmaker 1963 and 1964, Linn and Campbell 1986). Local fishermen at Kariba do not see birds as competitors for fish, but use them as a source of food which is regularly harvested (pers. obs.)

Recently, the food consumption of fish-eating birds was evaluated in several other shallow aquatic ecosystems as summarized on Table 9.13 (Moreau *et al.* 1993, Mavuti *et al.* 1995, Moreau unpublished). It appears that the impact of birds as compared to the one of fishery on the fish stocks can be of first importance (see, for instance, Lake Naivasha and Lake Ihema). However, it is highly variable without any apparent predictible trend.

Table 9.13 A comparison between the estimated quantities of fish (tonnes) consumed by fish-eating birds (Y.F.C.) and harvested by fishermen in several shallow tropical aquatic ecosystems

Ecosystems	*Fish ecol. prod.*	*Y. F. C.*	*Actual catch*	*YFC/Y %*
Lake Kariba (littoral area)[a]	44000	579	3600	16
Lake George[b]	10809	319	3575	8.9
Lake Naivasha[c]	1954	532	315	168
Lake Ihema[c]	3105	153	279	54
Lake Parakrama[d] Samudra	1164	226	838	32

Sources: [a] This study, [b]Moreau *et al.* 1993, [c]Mavuti *et al.* *1995*, [d]Moreau unpublished

Assuming that the birds populations are equally shared between Zambia and Zimbabwe, it can be estimated that birds consume 290 tonnes of fish per annuum. It is more than twice what is consumed by crocodiles: 140 tonnes (Games and Moreau this volume). Birds eat about 210 tonnes of cichlids and 4 tonnes of characids, whereas crocodiles consume 30 tonnes of cichlids and 39 tonnes of characids (see Figure 8.5 in Games and Moreau this volume).

These results confirm the findings that crocodiles and birds have a very limited impact on the littoral fish stocks of Lake Kariba. In addition, the compared impact of birds and crocodiles can be highly variable from a fish family to another.

SUMMARY

The impact of fish-eating birds on the commercial fishery of Lake Kariba was investigated. The extent of suitable habitats determines the amount of fish they remove from the lake and this led to an investigation of the constraints of feeding underwater by Cormorants and Darters. The most numerous fish-eating birds were the Reed Cormorants (*Phalocrocorax africanus*) and the Darter (*Anhinga melanogaster*). They were most abundant on gently sloping shorelines, and, like other fish-eating birds species, showed a marked seasonal variation in numbers, increasing from July to January and then declining through to June. The numbers of Reed Cormorants were correlated with fish abundance. Reed Cormorants consumed 20%, White-breasted Cormorants 10% and Darters 11% of their body weight in fish every day. Most fish species eaten by Reed Cormorants and Darters were not exploited commercially and they removed an equivalent of about 16% of the commercial inshore fisheries catch and only 1.3% of the overall ecological fish production of the inshore fish community. It is therefore accepted that fish-eating birds have only a little impact on the fish community and inshore fisheries in Lake Kariba.