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# Population fluctuations and their causes in the African Fish Eagle, (*Haliaeetus vocifer* (Daudin)) at Lake Naivasha, Kenya

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## Abstract

The population of (*Haliaeetus vocifer* (Daudin)) at Lake Naivasha, Kenya, was censused over a 13-year period (1987–99). During this time it declined by over half, to a low of 70 birds, by 1996. Breeding effectively ceased, with no courtship or nesting observed for most of the 1990s. The reason seemed to be a food shortage, which provided enough to stay alive but not enough to breed. Declines in the main prey items – fish species and red knobbed coot (*Fulica cristata*), occurred during the early 1990s and feeding conditions were worsened by a combination of increased turbidity in the lake, floating mats of exotic vegetation and the loss of shallow lagoons behind fringing *Cyperus papyrus.* This explanation was confirmed when heavy rains, following the strong ENSO event in 1997–98, caused a rapid lake level rise of 3 m vertically, flooding new lagoons behind formerly stranded *C. papyrus*. Breeding re-commenced, leading to 17–24 fledged juveniles in a population exceeding 100, by 1999. This population of *H. vocifer* is a valuable index of both the health of the lake and of its littoral ecotone.

## Introduction

The African fish eagle (*Haliaeetus vocifer* (Daudin)) is a species of aquatic ecotones: its food items are aquatic fish and birds and its preferred perching and nesting habitats are horizontal branches of trees close to or overhanging the water (Brown, 1980). It is a top predator of the aquatic food web, as its fish prey may be herbivorous or carnivorous while its bird prey may be herbivorous or piscivorous (Brown & Hopcraft, 1973). Rarely do individuals feed on terrestrial prey and when they do, it is likely they are immature and scavenging (Krueger, 1996). It occurs at alkaline lakes, such as lake Bogoria, Kenya where it feeds upon lesser flamingos (*Phoeniconaias minor*), but it is much more common in freshwater lakes or rivers (Brown, loc cit.).

The population at Lake Naivasha was reported as the densest population in Africa, based on studies in the late 1960s and early 1970s (Brown, loc cit.). The lake was very full at this time (Becht & Harper, 2002) and the density represented approximately one bird $km^{-2}$ of lake or, more realistically, a maximum density of just under 3.5 birds $km^{-1}$ shoreline (maximum count 224 birds (Brown, loc cit.), shoreline estimated as 65 km from lake level in Becht & Harper (loc cit.)).

Birds of prey have been used as indicators of environmental health for several decades (Watson, 1991; Ormerod & Tyler, 1993). Initially, this was because the amplification of contaminants such as pesticides or heavy metals in food chains had led to heavy mortalities of predators in the temperate zone in the 1960s (Peakall, 1993), which still continues in the tropics under certain pest-control operations (e.g., Bruggers et al., 1989). Heavy metals have caused certain concern; for example lead in the north temperate zone (from lead shot) and mercury in aquatic ecosystems (because of use in industry discharging wastes to water (Peakall, 2002). A study of the contamination of 42 eggs of *H. vocifer*, and tissues from two adults, at lake Kariba in Zimbabwe 1989–90, found that DDT residues affected hatching success but suggested that the population size was more likely limited by nest site availability (Douthwaite, 1992). The two samples from adults also contained high levels of mercury, which were considered to pose a future problem as the risk from pesticides was expected to decrease with cessation of DDT use for tsetse fly control (Douthwaite, loc. cit.).

More recently, birds of prey have been used as ‘umbrella species’ in the promotion of conservation because of the effects of land use change upon them (Fanshawe & Bennun, 1991; Sorley & Andersen, 1994). The *H. vocifer* population of lake Kariba is believed to be limited more by the availability of trees for nesting than contamination (Douthwaite, loc. cit.) and so indicates aspects of land use changes there.

At Lake Naivasha, the lake and the land-water ecotone have been degraded in the last two decades by human intervention. Arrival of the exotic floating species: *Salvinia molesta* in 1970 and *Eichhornia crassipes* in 1988 have created floating rafts in the shallows (Adams et al., 2002) which have probably impeded *H. vocifer* fishing. Intensive horticultural development has directly accelerated *C. papyrus* and tree (mainly *Acacia xanthophloea*) clearance along the littoral edge (Boar et al., 1999) and application of fertilizers and pesticides at or just behind it (Ntayia & Ngatia, 1995; Donohue & Thenya, 1998), could drain directly into the lake where the buffering effect of *C. papyrus* has been lost by clearance. The lake is now moderately eutrophic as a consequence of the loss of buffering which has resulted in the former ‘North swamp’ at the entry of the two rivers, being reduced to a riparian fringe (Kitaka et al., 2002). Any one of these changes could impact the population of *H. vocifer* through food, nesting or breeding success.

The population of *H. vocifer* has been studied from 1987 to the present, with the aim of using the species and its health as an indicator of lake health as well as better understanding the population dynamics and ecology of the species. This paper analyses the population changes between 1987–99 and their implications.

## Methods

Fish eagles are very territorial birds, holding linear territories along the shoreline: at lake Naivasha they make very few forays on land because of intra-specific hostility largely from augur buzzards (*Buteo augur*) (personal observations). Their brown and white colouring makes them very conspicuous and they spend most of the day perching overlooking water. For these reasons it is feasible for the total population of an aquatic ecosystem to be counted. In this study, counting was carried out by boat and 25 HP outboard motor, with observation using binoculars and location using hand-held GPS (Garmin, USA) and compass (bird location was compass bearing and estimated distance from the GPS location of the boat). The whole lake counts usually commenced at 07:30 h. Usually one-third of the lake was counted per day, in three successive days. In the later years of the study, the census repeated three times within a 2-week period.

Juveniles and immature birds can be distinguished from adults by the pattern of white, and males from females by difference in white plus the tone of their calls (Brown, loc. cit.). In this paper we just separate adults from juveniles plus immatures, and paired from single adults.

The whole population was counted, rather than a smaller sample of the whole and there was minimal human error in counting birds, because they are seen singly rather than in a flock. Any error is caused by the birds being absent from view. Territory-holding birds were not usually absent; when they were, it was either because they were not perched near to the lake (unlikely) or because one individual was soaring out of sight. Non-territory holding immature and adult birds represent a more vagrant component of the population. Time of day was varied on one part of the lake to test whether that affected number of birds counted. On three occasions, repeated counts were made on 16 territories known to be occupied, in order to calculate the frequency of absent birds. In 1994 and twice in 1997, counts were repeated for six successive days. The probability of not making a full census from a single count was thus estimated as the counting error. In 1995, counts were repeated monthly for 6 months, and the corrections from the repeat daily counts used to estimate the contribution of vagrant birds to the population pool at the lake.

The land-water edge habitat of the shoreline in each territory was recorded in 1994, 1996 and 1997 on a five-point scale, which described the physical and vegetation combinations. The extent of shoreline tree cover, tree composition, distance of treeline from water, shoreline papyrus cover and any other relevant features were estimated for the location of each eagle seen. In 1997 a video camera was used to film 100 m either side of each fish eagle seen so a visual record of the habitat vegetation could be used to confirm the accuracy of the estimates made from the boat. The categories, were:

1. Rocky shore with continuous canopy (*A. xanthophloea, Ficus spp*) and *C. papyrus* lake frontage.
2. Flat shore with ± continuous canopy cover close to lake edge of scattered mature *A. xanthophloea* trees with intermittent *C. papyrus* clumps;.
3. Open grassland with scattered trees and intermittent *C. papyrus*;
4. Continuous papyrus frontage with flat reclaimed lake bed behind where receding water levels had exposed large areas of land, (see Hickley et al., 2002 for contour map of the lake), trees at distance, along the edge of the former (1960s–70s) higher lake edge
5. Degraded *C. papyrus* frontage (burnt or cleared), flat reclaimed lake bed behind, trees cleared or continuous only at considerable distance.

In each whole-lake eagle count, details of the perch type were recorded. The perch categories were: *Acacia*, *Ficus* or *Eucalyptus* mature trees, dead trees, tree stumps, fringing papyrus *Eichhornia* clumps, other floating vegetation, or man-made objects.

The food of the birds was determined by analysis of remains from beneath perching trees (area cleared after each visit). These were dissected and examined under a microscope.

Forty-one birds were trapped, between 1997 and 1999, weighed, measured and ringed (banded). A small blood sample was taken for future use. Trapping was by nooses attached to a floating fish, which attached to the bird's legs when it swooped to capture the fish. 34 birds were trapped between April 1996 and July 1997 and five dead birds measured similarly. Five birds were trapped in 1998–9. Weighing was by spring balances to the nearest 1 g.

## Results

No significant difference was found between counting early in the morning, mid-day or early afternoon. The lake was usually calmest in the early morning, and so this was the time of day used for the majority of counts.

The remains examined from visits to perch sites of four pairs in the south-east of the lake ($n = 20$) indicated that *H. vocifer* feeds continuously on birds (100% remains contained feathers black, probably coot, 75% contained bird bones) and regularly on fish (50% of remains contained fish and crayfish).

The repeat counts visited the same 16 territories on 17 different days (occasionally not all 16 were visited; Table 1). Thirteen were the same territories between the 3-year gap. There was a total of 268 territory-counts; on 30 territory-counts only a single bird was seen. On 13 territory-counts, neither bird was seen. This means that, on average, a single bird was absent or missed for every 8.9 pairs counted and on average, a pair was absent or missed for every 20.6 pairs counted. Examining successive counts, it took on average four counts (four successive days) to be 100% certain of seeing both birds in every one of the 16 territories. In a whole lake count, many of which were only carried out once (albeit several times a year in some years), the recorded count is likely to have underestimated the total count by approximately one pair every 10, or 10%. This is an acceptable error for a total population census when a single count is undertaken and can be borne in mind when considering the data below. When successive counts were undertaken shortly after each other, the mean and confidence limits represent the lower error of a total population count. These confidence limits, in the years where successive monthly counts were taken (see below), were close to 10%. Single counts are likely to underestimate the total population by 10%, and so in successive monthly counts where a deviation by more than 10% occurs, it is likely to be a result of vagrant birds. The longest period of consecutive monthly counts was 23 months in 1995 and 1996, made by RBC and MZA whilst doing PhD studies on other bird species. The average, 97.4 ± 4, reflects a consistent count for most of the period (Fig. 1) although a slight decline from beginning to end could be seen. The implication is that a population of close to 110 fish eagles existed at lake Naivasha in this period. There are only two months when there was evidence of vagrants: in February 1995, when although the population count was not outside limits, 11 birds were counted in Oloidien lake when its normal complement was four (two pairs). The second was April 1995, when 117 and 120 birds were counted (at beginning and end of the month) compared with 83 before. Counts for the next 2 months were over 100,

*Table 1.* Raw data from 17 days successive counts in three periods 1994 and 1997. Dash indicates not visited

| Territory number | Territory name | Count 1 3/23/94 | Count 2 3/26/94 | Count 3 3/27/94 | Count 4 3/29/94 | Count 5 3/30/94 | Count 1 12/4/97 | Count 2 13/4/97 | Count 3 18/4/97 | Count 4 19/4/97 | Count 5 20/4/97 | Count 6 24/4/97 | Count 1 19/7/97 | Count 2 20/7/97 | Count 3 21/7/97 | Count 4 23/7/97 | Count 5 24/7/97 | Count 6 25/7/07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hippo point | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | Round bay | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 2 | 1 | 1 | 1 |
| 3 | *Ficus bay* | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 | 1 | 2 | 1 | 1 | 0 |
| 4 | Bay Point | 1 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 |
| 5 | Barton’s | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 2 |
| 6 | Cunningham | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 0 | 1 | 2 | 1 | 1 | 0 | 2 | 0 | 2 | 0 |
| 7 | Os Jetty | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 0 | 1 | 2 | 2 | 2 | 2 | 2 |
| 8 | Djinn Pal | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 0 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 |
| 9 | Elsa | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 10 | P&L | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 2 |
| 11 | Wallington’s | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 0 | 1 | 2 | 2 | 1 | 1 |
| 12 | Fish Eag Inn | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 1 | 2 |
| 13 | Fish Camp | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 14 | Sher | 2 | 2 | 2 | 2 | 2 | – | – | 2 | 2 | 1 | 2 | – | – | 2 | 2 | 1 | 2 |
| 15 | Bunny’s | 2 | 1 | 1 | 2 | 1 | – | – | 2 | 2 | 2 | 2 | – | – | 1 | 1 | 2 | 2 |
| 16 | Root’s | 2 | 2 | 2 | 1 | 2 | – | – | 2 | 1 | 2 | 2 | – | – | 2 | 1 | 2 | 2 |
| 17 | Safariland | – | – | – | – | – | – | – | 2 | 2 | 2 | 2 | – | – | 2 | 2 | 0 | 2 |
| Total birds | | 30 | 30 | 28 | 29 | 29 | 25 | 22 | 24 | 26 | 28 | 25 | 20 | 19 | 25 | 22 | 24 | 26 |
| Percentage of total counted | | 94 | 94 | 88 | 91 | 91 | 78 | 69 | 75 | 81 | 88 | 78 | 63 | 59 | 78 | 69 | 75 | 81 |

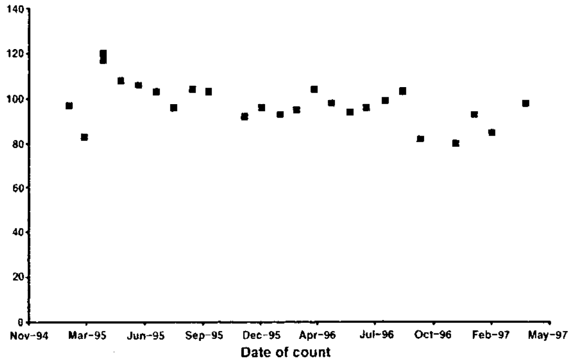


*Figure 1.* The whole-lake counts recorded at monthly intervals between January 1995 and November 1996.

before falling back to average. In both examples, a maximum of 10% of the population, 10 individuals, was probably made from vagrant birds.

Forty-nine whole lake counts were made between 1987 and the end of 1999. For 12 years from the commencement of the study, there was a consistent decline in numbers, the population halving from its late-1980s level of around 165 birds (150 counted + 10%). The lowest population was reached in April 1998, when 62 birds were counted, indicating a population total of about 70 (Fig. 2). During this time the percentage of juvenile and immature birds in the population fell to zero, remaining there in the early 1990s, rising slightly in the mid 1990s (Table 2).

A marked change in the fortunes of the population came about in 1998, through to 1999. Total counts increased from the April 1998 low to about 100 birds throughout 1999 (Fig. 3). Moreover the population recommenced breeding in early 1998, with an average percentage of fledged juveniles in the 1999 counts of 20.7 ± 9.8% ($n = 5$). This was the highest recorded in any year since the study began. Throughout the 1990s, only isolated individual juveniles had been seen, until an upsurge of courtship and nest building behaviour was observed in late 1997, which led to

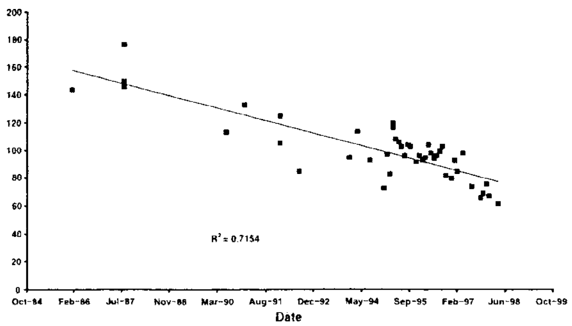


*Figure 2.* The whole-lake counts of *H. vocifer* between 1987 and 1996 (one count from 1986, Johnson et al., 1986) is included).

*Table 2.* The annual mean percentage of non-adult birds recorded in the whole-lake counts, 1987–1997

| Year | Percentage non-adult |
|---|---|
| 1987 | 6.73 |
| 1991 | 0 |
| 1992 | 0 |
| 1993 | 0 |
| 1994 | 0 |
| 1995 | 1.9 |
| 1996 | 0.9 |
| 1997 | 1.9 |

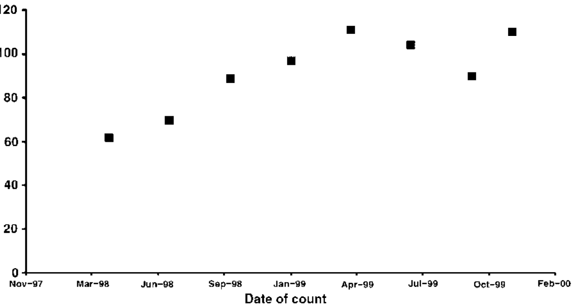


*Figure 3.* The whole-lake counts of *H. vocifer* between 1997 and 1999.

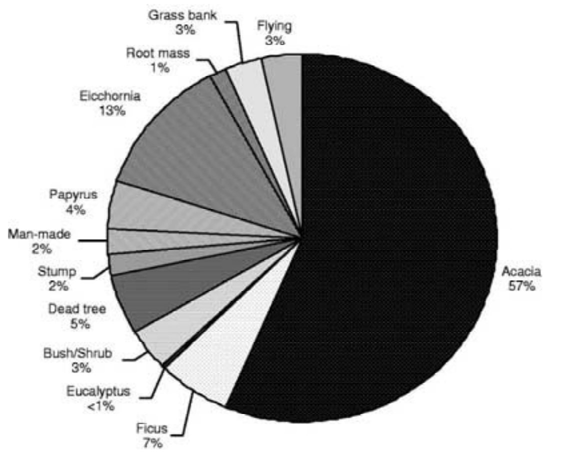


*Figure 4.* The percentage distribution of habitats at which *H. vocifer* individuals were seen, 1995 and 1996.

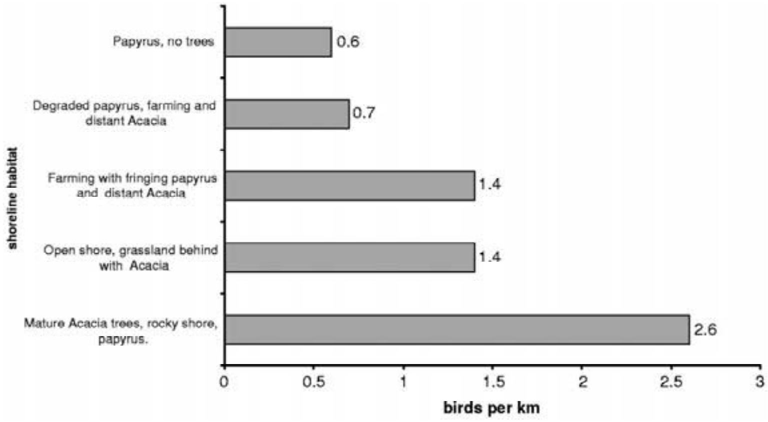


*Figure 5.* The mean density of birds recorded in five different riparian habitat type, 1995 and 1996.


*Figure 6.* The distribution of the five habitat types along the lakeshore.

an estimated half the population (15 pairs) engaged in breeding activity in early 1998, then 38 new nests built by early 1999 (not all active), and finally one-fifth of the population juvenile (17–24 birds) in 1999.

The weight of adult birds captured in 1997 was 3.01 $\pm$ 0.3 kg (females, $n = 19$) and 2.35 $\pm$ 0.02 (males, $n = 16$). In 1999, out of the five birds caught, one male and one female were each heavier than any of the same sex measured in 1997, although too few were caught to ascribe any statistical meaning to this.

Birds were seen predominantly perched on tree branches (64%) above the lake but also on lower objects overlooking the lake (12%) and floating vegetation in the lake (21%). Only for 3% of the time were they seen flying (Fig. 4).

Continuous woodland fringed the lake in 1996–7 for 27 km of shoreline, when the whole lake population counted was close to 100 birds. This shoreline accounted for the highest density of birds, rocky shores 2.6 km$^{-1}$ and flat shores 1.4 km$^{-1}$ (Fig. 5), approximately 57 birds. A further 20 km of shoreline, with intact *C. papyrus* edge and trees behind, held 1.4 km$^{-1}$ and accounted for a further 28 birds. Six km of shoreline had trees absent or the lake shore degraded by agricultural clearance, holding 0.6 km$^{-1}$ and accounting for four birds. The difference was significantly higher in 'natural' habitats (1996 $\chi^2$=19.5, 1997 $\chi^2$= 21.2, df=4, $p$<0.001). The distribution around the lake was thus uneven, with most birds around the western and southern shores and fewest in the north or south-east (Fig. 6).

## Discussion

When it became apparent that the population was declining in the early 1990s, three reasons were sought, grouped as habitat loss, food loss and pesticide (or other poisoning).

Suitable riparian habitat could be lost in two ways. Naturally, it can be lost by lake level decline, which on the one hand shortens the total length of shoreline and on the other hand results in papyrus clumps becoming stranded on dry land as the shore progressively moves further away from fringing mature *A. xanthlophloea* trees. The lake level during the time the *H. vocifer* population was first studied by Brown, 1968–71, was increasing after a very rapid rise in 1966; in the 5 years to 1971 it rose 5 vertical m. The population counted by Brown increased by half in this time (Fig. 7). The ri-

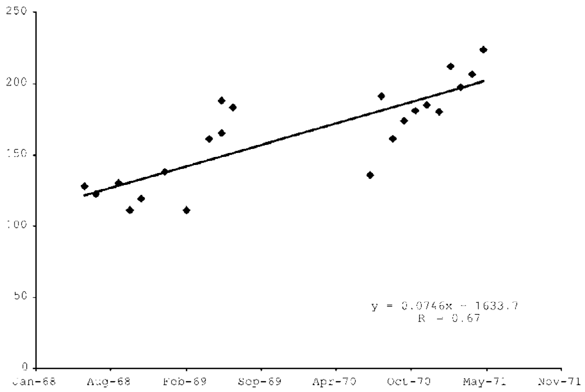


*Figure 7.* The whole lake population census of *H. vocifer* in 1968–1971 by Leslie Brown and colleagues (Brown, 1980).

parian land use at this time was low-intensive ranching and small-scale vegetable growing, so it is likely that the population responded to an increase of lake area making new shoreline territories available.

The lake level decreased about 2 m from June 1990 to 1996 (Becht & Harper, 2002) with some small short-term rises of 50–80 cm in 1992 and 1994. The lake had declined 4 m vertical between its maximum level in the late-1960s and its level in 1996, losing 20% of shoreline length in the flattest topography. This loss could only explain a loss of 15 birds from the maximum recorded at high lake levels.

The lake in the late 1970s was probably surrounded almost totally by *A. xanthophloea*/*Ficus* spp. woodland. At 1996 densities for riparian woodland, the loss in habitat accounts for another 15 birds. A combined loss of 30 birds as a result of anthropogenic and natural habitat change does not fully explain the population fall.

Even in two areas of 'prime' habitat studied by Brown (1980) – rocky wooded shore at Crescent Island and Hippo Point – there have been absolute declines, from 16 to 14 and 11 to 7 pairs respectively between 1970 and 1996/7 (Fig. 8). This implies that the additional causes of population decline lie away from the riparian habitat. There may have been at least three reasons for this:

(a) contamination of lake by pesticides leading to breeding failure;
(b) decline in absolute availability of prey – coot or fish;
(c) loss of feeding opportunity – as the lake has become infested with floating alien weeds (*Salvinia* and *Eichhornia*) and there is a decrease in transparency of lake water due to eutrophication.

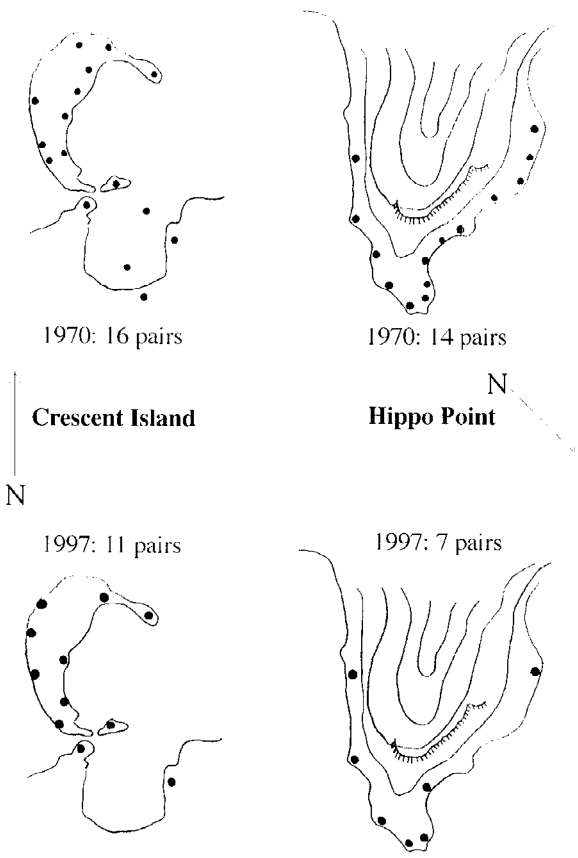


*Figure 8.* The territory location of *H. vocifer* pairs on two locations of 'prime habitat' in 1968 (Brown 1980) and 1997. See Figure 6 for the location on the main lake.

The first reason is unlikely, as Gitahi et al. (2002) found no evidence for pesticide amplification in lake food chains. Contamination by organophosphate pesticides, not detected as tissue residues, or other poisons, would logically be expected to lead to more mortalities, which has not been detected by resident naturalists (J. Root, pers comm.). Lincer et al. (1981) earlier measured DDT in a number of organisms from Naivasha and the other Rift Valley lakes Baringo, and Nakuru. They too found that there was limited contamination in Naivasha. In Zimbabwe, several workers culminating in Douthwaite (1992) had found levels of DDT (and mercury from unknown sources) in birds around Lake Kariba Zimbabwe sufficently high to pose a risk to the population, although censuses in 1987 and 1990 showed that hatching success was greater than 72%. The area investigated had been widely treated for tsetse fly control using organochlorine pesticides, the use of which was declining, and so it is unlikely that in Naivasha, where there is no known

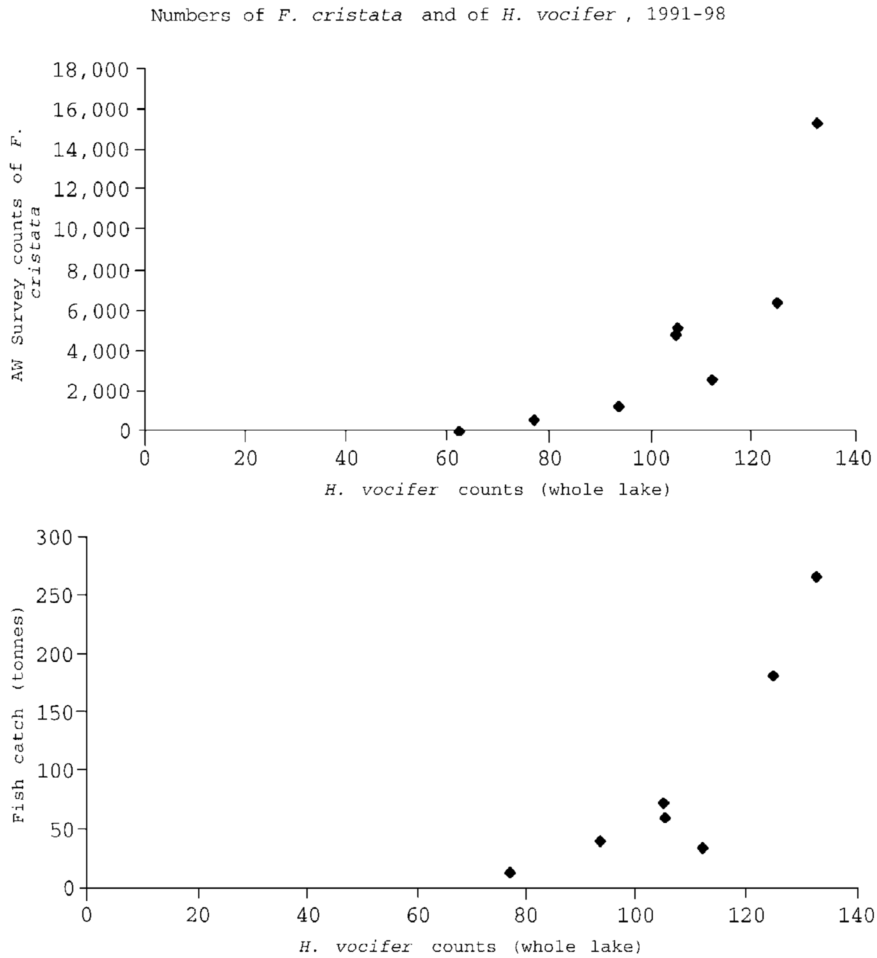


*Figure 9.* The correlation of numbers of coot (*F. cristata*) and commercial fish catches at lake Naivasha with the numbers of *H. vocifer* counted. (*F. cristata* numbers from the African Waterfowl Census data, every January).

extensive use of organochlorine pesticides on the scale of tsetse fly control, there has been contamination sufficient to cause breeding failure.

The second reason is a distinct possibility. Fish catches have declined (if measures of commercial catches is an accurate indication of populations and availability to *H. vocifer*) as a consequence of overfishing (Hickley et al. 2002). At the same time, coot have declined as a consequence of the loss of their main food, submerged plants, which have themselves disappeared as a result of consumption by the exotic crayfish *Procambarus clarkii* (Harper et al., 2002). The declines of both fish and coot show good correlations with the decline in *H. vocifer* numbers through the 1990s (Fig. 9).

The feeding habitat of *H. vocifer* has changed markedly. The lake shallows are now dominated by floating exotic vegetation which curtail the area of open water and the absence of a submerged plant littoral brings the turbidity of the open, eutrophic, lake, to the shore (Harper, 1992). Leslie Brown described the best feeding habitat at the end of the 1960s as the wide lagoons with water lilies, clear water full of fish, and other water birds. Food was optimal. The fish eagles fed on fish, young water birds and pirated prey from pelicans and herons. This sheltered habitat no longer exists. Today the lake level is low, there are no water lilies, and the water is turbid. The eagles are forced to fish in open water, a habitat that Leslie Brown described as poor (even in 1968). Now, fish eagles with no lakeside trees utilise the *Eichhornia crassipes* for perching. This must be a poor substitute for a 25-m high perch in an *Acacia* or *Ficus* tree with branches overhanging the water where an eagle can

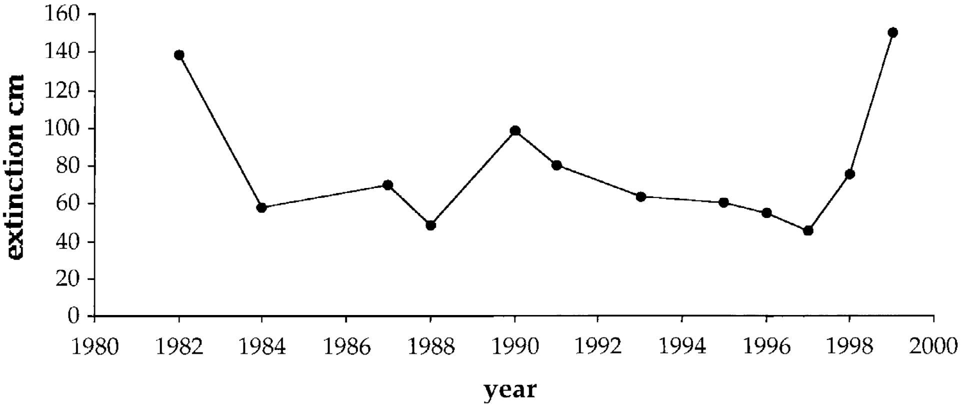


*Figure 10.* Transparency in the water of Lake Naivasha, 1982–1999.

swoop with great speed and dexterity to snatch a fish by surprise. Fish eagles in the past have also taken coot and flamingo, but it would be difficult to achieve surprise from a low perch, and an eagle catching a bird from this position was never observed.

The birds trapped and weighed were lower in weight than the range given by Brown (1980), the female average was at the lower end of the range (3–3.63 kg) and the male average closer to the middle (1.99–2.5 kg). This lends support to the hypothesis that food limitation prevented breeding, since the female needs to put more energy into egg production. Final support is provided by the continuous breeding throughout the 1990s of one pair of *H. vocifer*, fed daily on a turkey head per individual, by the owner of the land on which they held their territory (S. Higgins, pers. comm.).

Studies elsewhere lend support to the conclusion that the population was limited by food, both absolute quantity and availability. A study of ospreys in Oregon in 1992 (Henny, pers. comm. to M. Virani) found that when the ospreys arrived 2–3 weeks late at their nesting sites, in poor body condition, most did not lay eggs. Following a treatment of a lake with rotenone to kill the fish, osprey breeding was reduced and prey delivery rates were about half the rate observed at a nearby lake not treated with rotenone. Eltringham (1975) reported a density of 3.5 *H. vocifer* $km^{-1}$ and Sumba & Hebrard (1988) 2.4 $km^{-1}$ along the Kazinga Channel in Uganda. Examination of present-day densities in more detail (Kreuger, 1995) showed similar densities to these earlier studies. Along the Kazinga channel in optimal biotopes he found that density varied from 1.75 to 3.25 individuals $km^{-1}$. This compares with 1.4–2.6 $km^{-1}$ in the best habitats at Naivasha. In the Kyambura Gorge and the bush grassland, both less suitable biotopes, densities fell to between 0.45 and 0.58 $km^{-1}$. At Naivasha in degraded vegetation these were similar. The density found at either end of the channel, around Lake Edward was 1.9–2.6 $km^{-1}$ of shore and at Lake George 1.0–1.1 *H. vocifer* $km^{-1}$ of shore. These are similar waters, and Lake George in particular is highly turbid with algal growth and continually wind-mixed (Burgis & Morris, 1988). Brown (1980) found densities at Lake Baringo that were variable but low, with long stretches of the shoreline apparently suitable but not occupied by eagles. Baringo is a highly turbid lake whose catchment has suffered badly from soil erosion since the 1950s. There is thus some evidence from elsewhere that turbid lake waters support lower populations of *H. vocifer*, but where the water is in a physically suitable environment (e.g., Lake George water flowing down the Kasinga channel, which is wide, shallow and with littoral lagoons and *C. papyrus*) combined with suitable tree densities, increases *H. vocifer* density. Eltringham (1975) also found distribution related to availability of trees for perching.

The final 2 years of this study gave unexpected support to these conclusions. The courtship, breeding and increase in numbers followed a sudden rise in lake level (Becht & Harper, 2002). That rise flooded several tens of $km^2$ land, behind papyrus which had become rooted in the former shallow sediments. In these new flooded lagoons, tilapias bred rapidly, submerged macrophytes germinated and attracted coot, and the lagoons remained clear. They did not connect directly to the lake, being behind *C. papyrus* where that existed, but even where they did, the lake itself had become much clearer by the dilution with river water whose sediment settled (Fig. 10). For a short time, in 1998, littoral conditions returned partly to those described as 'optimum' by Brown (1980) and the population of *H. vocifer* returned towards the level of breeding recorded by him.

In conclusion the study showed the population of *H. vocifer* was limited in the 1990s by lack of available food, which enabled the adult population to maintain territories but not to breed. Probably birds were not replaced on territories that had been vacated because of severe unsuitability for feeding or one bird's death. The species does give a summary of the overall health of the lake and thus provides both a good indicator (a census only takes 3 days) and a 'flagship' for raising environmental awareness.

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