AFRICAN PARKS (ETHIOPIA) NECHSAR NATIONAL PARK PROJECT

Sustainable Use of the Lake Chamo Nile Crocodile Population

Project Document

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for

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INTRODUCTION AND BACKGROUND

I visited Lake Chamo in June, 2006 during the making of a documentary film on crocodiles. The numbers and sizes of the Nile crocodiles (*Crocodylus niloticus*) seen at the lake during that brief visit were impressive and it was apparent that here was an opportunity for the development of a conservation and management scheme for crocodiles which could benefit both the species as well as the local people. I wrote up my observations in a note to African Parks and the Ethiopian Wildlife Conservation Office which generated considerable interest, resulting in the present consultancy. During this current visit I was able to talk to a number of the main stakeholders at the Government, African Parks and local levels. In this short time it was of course not possible to get a complete grasp of all the politics, problems and intricacies of the ecological and societal complex that make up Lake Chamo, the Nechsar National Park (NNP) and the people who live in and around the area. Any mistakes made in drawing conclusions and making recommendations are purely my own.

The timing of the consultancy coincided with the peak of the crocodile nesting season in order to try to determine the productivity of the lake's crocodile resource. This is also ostensibly the driest time of year when the lake level should be at it's lowest, affording the optimum opportunity to count crocodiles. As luck would have it, unseasonal rains both locally and in the surrounding mountains raised the lake to a seasonally unusual level, drowning many of the traditional crocodile basking and nesting areas including the famous tourist attraction 'Crocodile Market'. However, with the able help of my son, Nik Whitaker, a capable crocodile biologist, the hospitality and professional assistance of the African Parks staff and collaborating agencies, we were able to fulfill most of the objectives of the mission.

OBJECTIVES

1. To conduct a field assessment of Lake Chamo, in order to bring together basic information on the crocodile population size/dynamics/ecology, spatial distribution, seasonal movements, reproductive biology and ethology.

2. Based on these findings, to formulate a management plan for the conservation and sustainable utilization of the Lake Chamo crocodile resource via egg collection for ranching, plus tourism and hunting. The management plan will include participation from local communities, benefits to these people and for the Nechsar National Park.

METHODOLOGY

Background

Crocodile surveys have been carried out on Lake Chamo by several different people/agencies using a variety of methods since 1977, the results of which are recorded in Tables 3, 4 and 5. None of the surveys carried out by day or night on Lake Chamo have been corrected for so-called 'observer bias' (depending on factors such as experience, quality of binoculars, fatigue) or 'visibility bias' (depending on dynamics such as lake level, percentage of crocs submerged or in vegetation, moonlight). While numbers of crocodiles counted in such surveys are subject to immense variation because of these factors, some trends become obvious. Absolute numbers of crocodiles counted in day time surveys went up from 360 in 1984 to 1183 in 2004. However, our 2007 day survey revealed less than a third and our night survey less than half of the 2004 count. Refer to map, Figure 2 in the Appendices for a comparison of day survey results.

Surveys of habitat, crocodile numbers, basking and nesting sites and interviews with fishermen were mainly carried out by boat as described below.

January, 2007 surveys

Though this is the 'low water' dry season and ostensibly the best time to see numbers of crocs on exposed banks, local rains before our arrival (and during our stay) and rains in the surrounding mountains caused a significant rise in the lake level, flooding most basking banks and many nesting areas including the famous tourist spot, 'Crocodile Market'. This is certainly a factor contributing to the comparatively low total numbers of crocodiles counted during both our day surveys (346) and night surveys (541), and may or may not reflect a reduction in total numbers of crocodiles in the three years since 1183 crocodiles were counted in February 2004 (Wakjira et al, 2004). Another day and night census at next lowest water is essential.

Day crocodile census surveys: 22-24/1/07

We used the African Parks metal boat of about 6.5 meters with an Evinrude 40 hp OBM. The boat driver was African Parks Scout, Meaza Messele, croc observer was R. Whitaker, data recorder was Habtamu Assaye and GPS recorder was N. Whitaker. Equipment used was a Canon 10X30 image-stabilizing binocular and Garmin, Etrex Vista GPS. The average starting time was 0900 till about 1700. There is definite tapering off of crocodile basking during the peak heat of the day (1200-1500) which can also drastically affect numbers observed. Traveling at an average speed of 9.5km/hr, at an average distance of 50 meters from shore, we were able to cover the approximately108km lakeshore in 3 days.

In order that our counts could be comparable to those done in the past (except for the aerial count done by Graham and Gebre, 1997 which arbitrarily divided the lake shore into 5km sections), the same system of zonation as set up by Bolton in 1984 was used. However, it was found that there are several inconsistencies in past counts with reference to the exact location of the beginning and end of each zone (including with previous GPS coordinates). During our surveys we made basic observations on the physical and

vegetative character of the shoreline and suggest that the ecological zonation as originally established by Bolton be standardized by using both GPS as well as physical features (including place names) so that future surveys will follow the same zonation even without using GPS. The suggested zonation with brief descriptions is given in the Appendices and includes minor changes so as to incorporate habitats such as nesting beaches into the more important zones with higher croc densities. These could be useful in future formation of Community Conservation and/or Community Wildlife Management Areas or even addition to the NNP. The results of our day census surveys are given in Table 3, below.

Night census surveys: 26-28/1/07

Crocodiles are primarily nocturnal animals which feed and are most active after dark. This, plus the fact that the reflective tapetum in their eyes causes a very visible eyeshine during night time spotlight counts, makes night survey the most effective way of seeing the largest number of crocs in most habitats (though crocs in swamps and thick vegetation will naturally be hard to spot). While we used the same zonation as for the day surveys, we did not do systematic size differentiation except in the swampy edge in the southern Zone 6, where we attempted to locate smaller size classes with limited success.

Gebre and Wakjira (1996) carried out a night survey of Zone 2 (approximate 10% of the lake shore) in order to derive a Correction Factor (CF) for their day counts. They determined a CF of 1.8 for Zone 2, interestingly, the same Correction Factor we arrived at for the whole lake, by comparing our night and day surveys. Our night survey appears to be the only crocodile night count done for the whole of Lake Chamo to date and should be instituted as an annual event.

We used the African Parks metal boat about 6.5 meters long powered by an Evinrude 40 hp OBM. The boat driver was African Parks Scout, Mengistu Meku, observer was R. Whitaker, data recorder was Habtamu Assaye and GPS recorder was N. Whitaker. Equipment used was a 6V Maglite spotlight and Garmin, Etrex Vista GPS. At an average distance of 50 to 75 meters off shore and a speed of 8.5km/hr we were able to cover the lake shore in three nights.

For maximum effectiveness of the light in reflecting croc eyes and in order that the crocodiles aren't easily able to see the boat and observers, moonless nights make the best survey times. Due to constraints of timing and to keep a level of consistency with the day surveys, our night surveys were carried out when the moon was in half phase. However, a complete heavy overcast helped to make the nights dark.

Concentrations of hippo at several places made for interesting boat maneuvering. Hippos are not used to seeing/hearing motorboats on the lake at night and tend to charge toward deep water, often straight at the boat. In order to avoid possible injuries to hippos from the propeller blades they must be given a wide berth when their eyeshine (easily differentiated from croc eyeshine) is detected in the spotlight. Other complications included submerged trees in several sections of the lake and the mud flats at the Sagoein (Mazoria), Sille and Kulfo river mouths.

The major cost of the three days and three nights census surveys (covering the entire shoreline twice) was for fuel (315 litres), a little over Etb 2500. Other costs were for oil, food, batteries and boat operator's salary for a total of about Etb 3600 or USD 450, all in all a cost effective exercise.

RESULTS

Day Surveys

Covering about one third of the lake shore each day for three days, we counted a total of 346 crocodiles of all size classes. A breakdown by size classes and zones is given below in Table 1.

We counted about 20 active fishing camps on the shore outside of the NNP with from 2 to 20 boats in each. Both monofilament as well as the thick-corded 'gancho' gill nets, averaging 20 to 30 metres in length, are set by day and night along with longlines (baited hooks) up to 60 metres long. Fisherman were fairly candid about the fact that crocs occasionally get tangled in nets but it is impossible to assess what percentage drown in nets. Large crocs routinely rip through finer gill nets, but these are deadly for smaller crocs. Even the biggest crocodiles are vulnerable to tangling and drowning in the touch gancho nets. Our finding of two dead adults and releasing one tangled adult from a gill net, all on the NNP shoreline, was graphic evidence of the severity of the problem.

We also counted 117 hippos around the lake during the day surveys. Some were in pods of 10 or more and baby hippos were very evident in all the larger groups. There are reports of hippo poaching for meat from the southern part of the lake, pointing to the need for intensive patrolling by Game Scouts and the establishment of Community Conservation areas. Hippos are not just good for tourism, they are essential components of aquatic ecosystems, converting graze into valuable fertilizer nutrients and thus enhancing the fish population. Reports of their decline elsewhere in Ethiopia as far back as 1997 and the fact that "NNP is the only protected area where there is a chance of maintaining a viable wild population of this species means there is therefore a heavy responsibility on NNP to introduce measures to protect hippos in park waters (including L. Abaya)" (Graham and Gebre, 1997).

Table 1. DAY SURVEY CROCODILE CENSUS, LAKE CHAMO, BY ZONES AND SIZE CLASSES (22-24/1/07)

Zone	< 1m	1.5 – 2	2-3	3-4	4-5	>5	Totals	Hippos
1		6	32	33	14	1	86	45
2	1		15	32	8	2	57	32
3		1	9	13	3	2	28	1
4			2		3	1	6	4
5							NIL	13
6							NIL	3
7	1		4	23	8	2	38	12
8		9	50	51	20	1	131	7
Totals	2	15	112	152	56	9	346	117

Night Surveys
On the first night we covered 42 kms (roughly a third of the lakeshore) in Zones 2, 3, 4 from 19:35 to 01:40 with a half hour break and time spent checking for small crocs at the nesting beaches. Concentrations of adults were noted at Gandjulle I. (38), Gandulo beach (19), Sagen beach (5) and the general tendency was for the crocs to avoid open, windy areas. Most of the crocs seen were adults, two were about 1meter long and one was truly massive, an estimated 5.5 meters or more in length. About 10% were very wary and went under at approaches of 100m. Crocs on communal nesting beaches were also particularly wary, the departure of one into the water at boat approach of 100m would trigger the others to rush in. The small islands northeast of Gandjulle I. near the lake shore seem to be favoured by several very large male crocs which were seen both by day and by night. For Zones 2, 3, 4 we noted a density of 3.59 crocs/km of shoreline.

A careful search of bushes and shoreline near the nesting beaches of Gandulo and Sagen for young crocodiles (where egg harvests were not carried out since 2004, and which could have yielded 2000+ hatchlings) revealed none. There is little nearby swamp habitat which would be suitable for hatchlings/yearlings and we can only conclude that mortality for hatchlings here is in the order of 90 to 100%.

On the second night we covered a distance of about 44km Zones 5, 6 and 7. What was most interesting about Zones 5 and 6 is that we saw no crocs here by day in this heavily disturbed (by fishermen and pastoralists) area which has virtually no basking or nesting banks, but by night we saw 75, including the largest number of smaller crocs seen during the entire survey period: a group of seven 1m size crocs. The observed density of crocodiles for these two ecologically similar zones was 2.27crocs/km.

Zone 7, consisting mainly of Little and Big Bolle Bays, had predictably higher concentrations of crocodiles, being the most important nesting area in the southern part of the lake and containing some of the lake's largest males. The density observed for this small zone of 10.9km was 7.16crocs/km of shoreline.

Table 2. **NIGHT SURVEY CROCODILE CENSUS, LAKE CHAMO, BY ZONES (26-28/1/07)**

Zone	Totals
1	85
2	98
3	30
4	23
5	42
6	33
7	78
8	152
Totals	541

Survey Results on the Nechsar National Park shoreline of Lake Abaya

The most recent crocodile survey of Lake Abaya was an aerial survey carried out in February, 1997 (Graham and Gebre, 1997) which counted a total of 91 crocodiles and 8 hippos on the 323 shoreline for an overall density of 0.28 crocs/km. Ten crocodiles (for a density of 0.18 crocs/km) and zero hippos were counted on the 55 km of shoreline within the Nechsar National Park and the highest number of crocs they saw (49) was on 90 kms of the eastern shoreline.

On the 8th of February, 2007 we did a survey by boat of the 55km of the Lake Abaya shoreline that is within the NNP. Observers: R. Whitaker, Kafato Tirsse, Recorder: Claire Mylchreest, GPS Recorder: N. Whitaker, Boat Operator: Meaza Messele. Starting at 0900 and using the Arba Minch University metal boat with the A.P. 40hp Evinrude OBM, we covered the shoreline (at an average of 50 to 100m offshore in about 6 hours (including two stops to check crocodile nesting beaches and for lunch). We saw a total of 4 crocodiles (3 of them near the boat landing) and 11 hippos. The most disappointing aspect of the survey was the total lack of evidence of any recent nesting at the black sand beach called Abaya, where 29 nests were found by AMCR staff in 1989. We passed several more good potential nesting sites but the lack of visible crocodiles or even tracks/droppings/old eggs shells indicates that there is very little if any nesting within the NNP shoreline of Lake Abaya.

There is an abundant presence of fishermen and their camps along the shoreline (concentrated on the eastern shore) with gill nets, including the deadly (for crocodiles) 'gancho' nets and long lines, set close to the shore near the potential nest sites as well as around the several islands in the very scenic Hitu Bay, within the easternmost limit of the NNP boundary. Though the fishermen interviewed spoke of 'many' crocodiles in the area, a sample night census (stopped because of rain and an impending storm) revealed only 4 crocodiles in a 10km stretch of ideal shoreline. Extrapolating this finding for the 55km coastline gives a density of 0.4 crocs/km, a sad state of affairs in what appears to be excellent crocodile habitat. The crocodiles appear to have been either killed off by accidental drowning in nets or moved to more hospitable parts of the lake (if such exist).

Lake Abaya is subject to sudden high winds and waves and not as simple to survey as is Lake Chamo. However, it would be very worthwhile to conduct complete day/night lake surveys by boat with a nest survey during the breeding season, perhaps backed up by an aerial survey, to come to a realistic estimate of the present crocodile and hippo populations. Fishermen told us of two crocodile nest sites in other parts of the lake, Fura and Autous Camp which should be checked out. Jason Roussos, (pers.comm.) mentions seeing small concentrations of crocs and hippos from the air near the Belaite River mouth at the North end of the lake where there was a military camp till recently. Though Lake Abaya is considered to have a much lower primary productivity than Lake Chamo, its potential in terms of the crocodile resource could be high if the right protection and management actions were implemented. There is also considerable tourist potential here.

We observed several large herds of zebra at obviously regular drinking spots on the lake shore and the scenery is dramatic.

Other sites not surveyed (which are known to or likely to contain crocodiles) for lack of time and which need to be done were: the length of the Kulfo River, the Haro Ropi lake and the Sille and Sagoein rivers.

SURVEY RESULTS AT CROCODILE NEST SITES – LAKE CHAMO

Introduction

Most of this information is based on the records kept by the Arba Minch Crocodile Ranch, collated by Assegid Gebre, Ranch Manager, and ground-truthed on three additional days of surveys by us with Kafato Tirsse, AMCR Scout and Meaza Messele, African Parks boat operator. This should not be considered a complete listing of all nest sites. One difficulty is that there are often several names for each place (often a nearby hill rather than a feature along lake shore) and the location and details of each of these (and others as they are identified) should be an ongoing process of refining the facts and locations. See 'Nest Locations at Lake Chamo' and Tables 7 and 8 in the Appendices for details and coordinates of nest sites.

It can be seen that there are numerous dynamics which affect the nest sites, including increasing vegetative cover, unseasonal rains leading to submergence of nest sites and disturbance by fishermen, pastoralists and farmers (the latter negative anthropogenic influences which obviously need to be contained in some important nesting areas). **Crocodiles have apparently been forced from several prime nesting areas with adjacent optimum hatchling/juvenile crocodile habitat by disturbance and this could be one of the factors strongly influencing juvenile survival and recruitment to the adult population. Thus 'location stability' is an important factor to monitor and understand** (refer to Table 10 in the Appendices on differentiation of shoreline habitat).

An interesting feature of Lake Chamo's nesters (compared to some other Nile crocodile populations such as in the Okavango in Botswana where 90% of the nests are solitary) is that communal nesting is the rule. A general impression was gathered that suitable nesting grounds for crocodiles are limited here and that to optimize sites for what seems to be a growing population, disturbance needs to be minimized at critical sites and habitat manipulation (clearing of vegetation for example) will be necessary in some areas (Jason Roussos, pers.comm.). We were also able to observe that there are some female crocs which nest individually and which probably contribute a significant (10%?), but unknown number of nests to the overall total.

With the limited time available we are only able to report where the known nesting areas are and what the trends have been. The lake shore be surveyed in detail with the able assistance of experienced Scouts like Kafato Tirsse and carefully mapped in relation to habitat types, with special emphasis on suitable nesting areas.

Nest census/monitoring
In future, crocodile population monitoring needs to definitely include as complete as possible inventory of the entire annual nesting effort by the adult female croc population. In the past, the AMCR staff have only counted the number of nests collected, leaving us to speculate on what the actual productivity of this population is. The highest number of nests reported from the lake shore was in 2004 when 262 nests were collected (11,840 eggs for an average clutch size of 45). During the course of our surveys and in discussion with AMCR staff it was apparent that nest predation at laying time (mainly by Nile monitors and to a lesser extent by mongoose, baboons, hyenas and marabou storks) can be as high as 38% to 50% at some sites. Arrival of the egg collection/nest protection teams at nesting sites early in the nesting season can cut these losses to a minimum (perhaps down to about 10%). It is also important to protect nest sites from disturbance by humans whether they are fishermen, pastoralists or tourists. When females leave the nest site their eggs are much more susceptible to being robbed by predators. Nile monitors by day and honey badgers by night are the main egg-eaters responsible (Wakjira, pers.comm.).

Numbers of nests
Using the 2004 nest collection figures as a benchmark we can extrapolate the total likely nests available as a resource. Assuming that 262 nests represents 80% of the nests found (based on similar experience in Zimbabwe (R. Fergusson, pers.comm.)), and a further assumption that a conservatively estimated minimum of 25% of nests were dug up by predators, the total number of nests at Lake Chamo would be 394. From our observations it seems likely that an additional 10% of females nest as individuals bringing the total to 433. With the average clutch size here having been established at 45 this would be a total of 19,485 eggs. It is essential that future extrapolations be based on real total nest counts, starting with the 2007/08 nesting season (next December). In other Nile crocodile populations the adult segment consists of 53 to 63% females and using nest counts can help us calculate the total adult crocodile population (Hutton and Games, 1992).

DISCUSSION

BACKGROUND AND HISTORY OF CROCODILE USAGE IN ETHIOPIA

The demise of Ethiopia's crocodiles

The Nile crocodile was once abundant in many of Ethiopia's rivers and lakes. As in most of the rest of Africa, crocodiles were systematically exterminated here either as 'pests' or for their valuable skins. Heavy hunting for skins began in the mid-1950s. . In 1963 the French owned, Dofan Ethiopia Share Company had crocodile hunting concessions on several rivers and in 1966 Dofan was given sole hunting rights on most rivers providing they build a tannery in Ethiopia, which was done by 1968.

A total of over 47,000 crocodile skins were legally exported between 1965 and 1972, several thousand of these taken from the Rift Valley lakes (though there is no information

about Lake Chamo in particular). This legal hunting plus poaching near the border with Sudan decimated Ethiopian croc populations (Pooley, 1982; Gebre, 2000). Following the devastation of croc populations by hide hunting, habitat loss by settlement on lake shores and riverbanks became the major problem facing crocs in most of Ethiopia (Thorbjarnarson, 1992). In comparison, four out of the five major Nile crocodile populations in neighbouring Kenya markedly declined, not because of exploitation (none now) but because of human population expansion and shrinking water resources. This trend is expected to continue and the crocodile's potential as an economic resource is one of the only factors in its favour.

By 1971 the head of the Wildlife Conservation Department had already considered the Nile crocodile to be seriously depleted but they were protected only in reserves like Omo Game Park. Subsequently, in 1972 commercial hunting of crocodiles was prohibited in Ethiopia and the Nile crocodile was listed as a game animal which could be hunted under permit only. Ethiopia joined the Convention on International Trade in Endangered Species (CITES) which regulates trade in crocodile products, in 1988 and the Nile crocodile was transferred from Appendix I, the highest order of protection, to Appendix II to allow an export quota for ranched skins (referring to crocs raised from wild collected eggs). The initial quotas approved by CITES were 9370 for 1990 and 8870 for 1991-92. Current quotas are from 9,000 to 12,000 skins per year for export based on the ranching programme, though total skin sales since 1984 were less than 8,300.

The dramatic recovery of crocodiles in Lake Chamo

The Lake Chamo crocodiles were not spared and when hunting ceased here in the early 1970s, numbers were low. The earliest record, an aerial survey by Andeberhan, 1977 (in Bolton, 1984) recorded the presence of 148 crocodiles of all sizes. Bolton did a census in 1984 and counted 360 crocodiles of all sizes. Subsequent surveys by the Ethiopian Wildlife Conservation Office counted 1321 crocodiles of all sizes in 1986 (Tadesse, 1988) and 1183 of all sizes in 2004 (Wakjira et al, 2004). These were all daylight surveys from boats and using the correction factor of 1.8, based on Gebre and Wakjira's 1996 sample night survey results, the total population of crocodiles in Lake Chamo in 2004 was estimated to be about 2130. The remarkable recovery of the Lake Chamo Nile crocodile population was due to several factors: the cessation of hunting, the relaxed attitude of fishermen and lakeside people here toward crocodiles and the fact that no one eats crocodile meat or eggs here. However, as elsewhere in Africa where the gill net fishery has grown to unsustainable proportions, this is a dire threat to the continued existence of a healthy population of crocodiles here.

Crocodile numbers

A crocodile census is at best only a estimate of total numbers and its accuracy is dependent on many factors, one of the most important being water levels at the time of the census. This is especially true in a habitat such as Lake Chamo which is largely edged by extensive tracts of vegetation including reeds and acquatic grasses which can hide a good proportion of the population, particularly the small ones. More important than total numbers for assessing crocodile productivity in a habitat is the number of mature, nesting females in the population and it is on this segment that the survey was concentrated by

assessing past nest collection data and physically searching for and mapping the nest sites around the lake.

Over the years there have been several estimates of the Lake Chamo crocodile population which has been from 2,000 to over 4,000. One Crocodile Specialist Group report states "The estimated population (in Lake Chamo) in 1987 was 4175. During the same year, 316 crocodile nests were found around the lake" (Thorbjarnarson, 1992). **Based on our observations, a provisional total population of crocodiles in Lake Chamo in 2007 is below 2000, with 350 to 500 mature nesting females, or about 17.5 to 25% of the population.**

People's attitudes

Local people's feelings toward the crocodiles here are refreshingly tolerant and laid back. The fragile rafts (made from the balsa-like 'sokke' tree, *Aeschynomene elaphroxylon*) used by the fishermen who lay their gill nets on the darkest nights (fish can see the net by day or on moonlit nights they say), could be smashed like match sticks by some of the larger male crocodiles, exceeding 5m in length, if they chose to do so. But the fishermen say their only worry is getting in the way of a mother hippo protecting her young (and some did relate some harrowing stories of such encounters). Large numbers of fishing eagles seen around the lake are perhaps indicative of the relative health of the lake but the huge numbers of marabou storks hanging around the fishing camps possibly indicate an unnaturally large population, bolstered by the (very visible and smelly) 1000 kg of waste (50% of the catch weight) discarded by the fishermen on the lake shore in filleting their catch for market.

Table 3. DAY SURVEY CROCODILE CENSUS, LAKE CHAMO/ABAYA (NO ZONATION)

Year	L. Chamo	Notes	Who	L. Abaya	Survey
Jun 1973	--	Breeders	Bolton	110	Boat
Apr 1977	148	-	EWLCO	134	Aerial
Jun 1983	102	Breeders	Bolton	-	Boat
Apr 1984	360	Breeders	Bolton	-	Boat
1985	533		Tadesse	-	Boat
1986	1321		Tadesse	-	Boat
1987	1228		Tadesse	-	Boat
Jan 1995	683		Gebre/Wakjira	91	Boat
Feb 1997	476	> 1.5 m	Graham/Gebre	-	Aerial
Feb 2004	1183		Wakjira et al	-	Boat
Sep 2005	313	Zones 6,7,8	Wakjira et al	-	Boat
Jun 2006	378	Z – 1,2,4,7,8	Whitaker		Boat
Jan 2007	346		Whitaker et al		Boat

NOTE: Because of the different methods employed in these surveys and inconsistency in reporting, it is difficult to interpret anything concerning trends beyond the fact that the total population has obviously increased since the surveys of the 1970s

Table 4. DAY SURVEY CROCODILE CENSUS, LAKE CHAMO, BY ZONES WITH CORRECTION FACTOR OF 1.8 BASED ON NIGHT COUNTS (from Bolton, 1984;Wakjira et al, 1996,2004;Whitaker, 2006; Whitaker et al, 2007)

Zone	1984	1984 CF	1996	1996 CF	2004	2004 CF	2006	2006 CF	2007	2007 CF
I	107	193	134	241	136	245	193	347	86	155
II	23	41	179	322	131	236	50	90	57	103
III	30	54	48	86	34	61	-	-	28	50
IV	51	92	121	218	53	95	16	29	6	11
V	33	59	78	140	38	68	-	-	-	-
VI	79	142	31	56	15	27	-	-	-	-
VII	37	67	75	135	228	410	58	104	38	68
VIII	-	-	17	31	548	986	61	110	131	236
Total	360	648	683	1229	1183	2128	378	680	346	623

NOTE: A Correction Factor (CF) of 1.8 was derived from comparing day and night counts carried out in 2004 (Zone 2 only) and in 2007 (all 8 Zones).

While this kind of census cannot give an accurate absolute total crocodile population figure, if consistently done it can indicate population structure, spatial distribution and trends. Carrying out spotlight censuses, when a larger % of the crocs are visible, can add to the accuracy of the counts and provide a CF to use to adjust the day counts closer to a real population figure. Annual census surveys and nest counts will form the basis for scientifically based management and conservation of what is perhaps Ethiopia's last significant crocodile concentration, a national heritage of great ecological/scientific importance and commercial value.

Table 5. DAY SURVEY CROCODILE CENSUS, LAKE CHAMO, BY ZONES AND SIZE CLASSES FOR 1984 AND 2004 (Bolton, 1984; Wakjira et al, 2004)

		Survey year, numbers, and sizes of crocs											
		< 1 meter		2-3 meters		3-4 meters		4-5 meters		> 5 meters 1984 = 2 and size not classified in 1984 = 52		Totals	
Zone	Shoreline distance (km)	1984	2004	1984	2004	1984	2004	1984	2004	1984	2004	1984	2004
I	4	4	5	50	47	51	61	2	13	2	10	107	136
II	18	9	6	1	62	4	54	-	9	2	-	23	131
III	15	20	-	5	7	-	21	-	6	5	-	30	34
IV	2	-	-	-	22	32	25	-	6	19	-	51	53
V	15	5	2	17	15	-	17	-	4	11	-	33	38
VI	29	20	-	33	4	36	6	-	3	15	2	79	15
VII	12	10	25	-	60	-	105	-	35	-	3	37	228
VIII	21	2	71	4	204	1	110	-	132	-	31	-	548
Totals	116	72	109	110	421	124	399	2	208	54	46	360	1183

NOTES: Between 1984-2004, observed "density" of crocs has increased from 3.1 crocs/km to 10.2 crocs/km, respectively, indicating a dramatic population recovery. Results of the 2006 and 2007 day counts (Tables 3 and 4), however, tell another story and point to the need for regular monitoring specifically at low water periods, using both day and night counts.

Variability in census results—nest surveys essential

Because of the variable results from total count census procedures day/night/aerial (so obvious in the above tables, and see below), with all the complications of biases, lake levels and season, it is necessary to employ other census techniques to achieve more accurate population assessments and trends. One of these is to monitor the crocodile population by collecting as complete as possible data on the production base: the number of nests/eggs produced in consistent annual surveys, which will show changes in the density and distribution of crocodiles as they occur. This has been used at Lake Kariba in Zimbabwe for decades, where croc ranchers are allowed to collect all the eggs they can find, providing a cheap and effective method of monitoring the production base, based on which realistic quotas can be set (Hutton, et al, 1992). Counting nests is one of the strategies also successfully used in commercial crocodilian programmes in countries like Papua New Guinea and the United States.

To further illustrate the extreme variability in croc counts we only need to look at day survey counts in ecological Zones 7 and 8 of Lake Chamo for six years (see map, Figure 1 in the Appendices for Zonal delineation):

1984 37 crocodiles
1996 92 crocodiles
2004 776 crocodiles
2005 245 crocodiles
2006 119 crocodiles
2007 169 crocodiles

The 'missing' juvenile crocodiles

A feature of the Lake Chamo crocodile population structure, consistently noted in recent surveys and anecdotally, is the apparent paucity of the smaller size classes (only 0.05% in our survey and 8.2% for the four surveys reporting size classes). In studies of other croc populations it is found that both resource partitioning (young crocs feed largely on insects, frogs and small fish), vulnerability to predation from a wide range of predators and the propensity for cannibalism, requires hatchling, yearling and juvenile crocs to choose separate habitats away from the adult/subadult population. The extensive swamps that border up to 90% of the lake shore (with over 50m width in some areas) provide alternative habitat suitable for small crocodiles. However, these dense stands of reeds and grasses do not allow easy observation of what they may contain and aside from a few observations to this effect, without further study it can only be surmised that this is where the juveniles are.

Though some studies indicate that juvenile crocodiles may make up 50% of the total numbers in a habitat (Games, 1992) or 33.6% (Zilber, in Hutton, 1992), in other Nile crocodile population studies as low as one per cent of the total animals visible (counted) were in the under one meter size classes (Olivier Behra, pers.comm.). Visibility bias may be a major factor in explaining the 'missing' juveniles, but there likely to be other factors at work. It is noted that most of the nesting areas on the southeastern shoreline have been deserted in recent years due to disturbance, and these are the ones that were closest to the extensive swamps of the southern tip. It is further noted that many of the present major nest sites (for example Sagen, Gandulo, Gadabonke, Belte and Gandjulle in particular have very little suitable habitat nearby for yearlings and juveniles to hide and feed in, probably resulting in 'natural' mortalities of close to 100%. In support of this supposition, Modha (1967), counted 57 nests in 1966 and 31 nests in 1967 on the shores of 'Crater Lake C' on Central Island in Lake Rudolf (with an average clutch size of 33 there, at least 2000 hatchlings should have emerged) but surprisingly found no young, despite arriving in May, within a month of the peak hatching season! In other studies, survival rate of Nile crocodiles to maturity has been estimated to be as low as 2% (Games and Hutton, 1992).

This is mere speculation, but recent over exploitation and apparent extinction of a once abundant Lake Chamo fish, *Labeo horie*, could negatively impact the juvenile segment of the crocodile population if it was an important food item of smaller size classes.

Size classes

In past surveys there is a lack of consistency in the recording of the size classes of crocodiles observed. This means, unfortunately, that it is difficult to get a good idea of trends in the age/size classes of the croc population over the three decades that surveys have been sporadically carried out. The following are the observed trends derived from four past and present survey results:

Juveniles (<1.5m) – 0.05%(2007) to 20% (1984)(average for four surveys: 8.2%)
Subadults/small adults (<3.0m) – 20% (1996) to 35.5%(2004)(average for four surveys: 29.5%)
Adults (3-4m) – 28.5%(1996) to 43.9%(2007) (average for four surveys: 35.1%)
Large adults (4-5m) – 0.05%(1984) to 23.8%(1996) (average for four surveys: 14.3%)
Extra large adults (>5m) – 2.5% (2007) to 4.2% (1996) (average for three surveys: 3.5%)

Two obvious inferences that can be made from these figures is that the visible juvenile population is much less in 2007 (0.05%) as compared to 1984 (20%) and that large adults are much more abundant in 1996 (23.8%) as compared to 1984 (0.05%). This would be expected from a recovering population that had been hammered for skins till the early 1970s and has had 30 years to recover.

The important size classes we should record while carrying out censuses are:
a) **juveniles** (< 1m) and **subadults** (< 2.5m) in order to understand juvenile survival rates and recruitment to the population by smaller size classes
b) **adults** (>2.5m for females, >3.5m for males) to estimate number of potential breeders (53 to 63% of the population will be females)
c) **large adults** (>4m, usually males).
It is also worth noting the number of crocs over 5m in length, the **supersize** mature male component of the population which do a large percentage of the breeding and are the ones the tourists want to see.
The recording of size classes is an area where observer bias, based on individual experience and ability to estimate the size of a crocodile spotted by eye or with binocular at varying distances, can result in reporting very different size structures within the population.

SUMMARY OF FINDINGS

1. **Crocodile numbers**:
By analyzing results of previous surveys and carrying out daytime and nighttime surveys on Lake Chamo (and the Nechsar National Park shoreline of Lake Abaya), findings by previous workers confirm that the lake contains a healthy population of Nile crocodiles (our provisional estimate: up to 2000 individuals), including some of the largest on record for the species. There are perhaps 350 to 500 breeding adult females capable of producing 15,000 to 20,000 eggs annually but these provisional figures need confirmation by further study. This mission high-lighted just how little we know about the population dynamics of the Lake Chamo crocodiles and that ongoing management demands a strong research component.

2. **Utilization of the resource/Arba Minch crocodile ranch**:
Crocodile egg collection and rearing the young for skins and meat is a proven conservation/management strategy that can guarantee crocodile survival, provide local income, community benefits and earn valuable foreign exchange. The Arba Minch Crocodile Ranch, set up in 1984 for this purpose, has not lived up to expectations but has the potential to fulfil the stated conservation objectives and benefit local communities. It is also a major tourist attraction just waiting to happen.

3. **Nesting areas**:
A total of 23 past and active nesting areas were surveyed and it was noted that the important, southeastern shore nest sites, adjacent to swampland hatchling and juvenile crocodile habitat have been deserted, apparently due to intensification of fishing and lakeside grazing activity. In other areas crocodiles are using what appear to be sub-optimal sites for nesting, possibly because they were driven from traditional sites. It was further noted that many nest sites do not have nearby hatchling/juvenile crocodile habitat, probably leading to a very high mortality of the smaller size classes and limiting recruitment.

4. **Nesting ecology**:
The majority of female crocodiles nest communally, with up to 100 nests at a single location. There is high predation on the nests (as high as 50% at some locations) by Nile monitor lizards and other predators. In a sample of two nests, the clutch sizes, eggs dimensions and weights were within normal limits for the species elsewhere in its range. Eggs are laid in the dry months of December and January with hatching about 90 days later in March and April, coinciding with the arrival of rains (the best time for hatchlings to find food). It was observed that unseasonal rain and rising lake levels will flood a number of traditional nesting sites.

5. **Hippos**:
These mammals, now extremely scarce in the rest of Ethiopia, are in urgent need of protection from reported poaching in the southern end of the lake and disturbance by fishing. Valuable as fertilizer producers for the fishery, they are an essential component

of the 'Africa Experience' for tourists to Lake Chamo and their cohabitation with crocodiles is one of the wonders of the animal kingdom that never ceases to amaze people.

6. **Lake tourism**:
At present this is a somewhat disorganized, dodgy experience for the tourist with no safety standards, planning or purpose, other than to go to the 'Crocodile Market' and back again, as soon as possible. A well organized set up could well make these boat trips on the lake the experience of a lifetime. The Lake Chamo crocodiles need to be promoted for what they are: some of the most spectacular giant crocodiles on the planet.

7. **The role of Nechsar National Park and African Parks**:
Patrolling and protection on the 41 km of northern and northeastern shoreline within NNP (about a third of the total shoreline but only 8.5% of the lake's surface) has stopped most of the illegal fishing along the protected shoreline. This will help save crocodiles and hippos in some of the main concentrations for both the species on the lake and provides at least some respite for fish stocks which can breed in peace on this small part of the lake. Development of lake tourism around the giant crocs of Lake Chamo will have spinoffs that can reach far into the local communities.

8. **Threats:**
a) The fishery:
Lack of regulation enforcement, illegal fishing gear and unsustainable growth of the fishing industry has resulted in overfishing, the dwindling of the main target species to almost non-viable levels and the apparent extinction of one of them. The use of gill nets is death to crocodiles, especially the tough-cord 'gancho' net which can drown even the biggest crocodiles, and does. We found two dead adult female crocodiles and another we found alive, tangled in a gill net, which we released. The death rate could be as high as 10-15% of the adult population every year according to one estimate (much higher than a likely recruitment rate!).
b) Cattle grazing:
With the increase in cattle grazing, many areas previously used by crocodiles for basking and nesting have been deserted. Forcing crocodiles to suboptimal habitats can have catastrophic effects on the population as a whole leading to increased nest predation, denying hatchlings/juveniles the habitats required for their survival and so on.
c) **Lakeside agriculture**:
For the same reasons mentioned above, cultivation which extends right to the lakeshore can have drastic effects on crocodile behaviour, recruitment and survival. Droughts due to climate change and other effects will likely increase this threat which is another reason why it is so important to monitor, interpret and map the critical crocodile nesting/basking/feeding and juvenile habitats on a regular and systematic basis.

9. **The role of the Department of Agriculture and Rural Development**:
The Department is aware that expansion of fisheries is not feasible and that regulations such as licensing, taxation, mesh size rules must be enforced. As the responsible agency

for the lake outside of NNP, the Department does not have the resources and manpower to adequately patrol the over 300 km ^{2} lake area to enforce regulations and badly needs assistance to manage the fishery resource sustainably.

10. **The role of Bureau of Agriculture & Natural Resources Development, Southern Nations Nationalities and People's Regional Government**:
This is the agency which has the responsibility for the natural resources of the region and needs technical assistance regarding the management and sustainable use of the crocodile resource of Lakes Chamo and Abaya. Regulating the egg harvest and assuring community benefits from the croc ranching operation and lake tourism are a few of the key issues which the Bureau, in collaboration with Zonal authorities, African Parks and appropriate NGOs needs to address.

11. **The role of the Arba Minch University Department of Applied Biology**:
Though a fledgling department, being a specialist hydrology institution and proximity to one of the most dynamic populations of the Nile crocodile in Africa gives them a special advantage to help design and participate in ground-breaking studies on lake ecology, using the crocodile as the flagship species.

12. **The role of the Wondo Genet College of Forestry and Addis Ababa University:**
With the recent starting of a BSc Wildlife course it is obvious the WGCF Wildlife staff and students with a special interest in and aptitude for field work would be the perfect candidates to help develop and implement studies on all aspects of crocodile biology in support of a dynamic crocodile management plan to secure the future of the species and the entire lake's ecology and potential for tourism and sustainable use in the bargain. Similarly, the Department of Biology, AAU has an interest in, the experienced staff and wherewithal to participate in lake ecology studies, recognizing the uniqueness of the Lake Chamo situation. Habtamu Assaye, Graduate Assistant, WGCF, accompanied us on the day and night surveys and we donated about 2000 pages of crocodile literature and reprints to the WGCF library to help motivate interest in the field.

13. **Stakeholders and beneficiaries**:
The collaboration of the agencies referred to above will be needed to put together the components of research, protection, resource development and marketing. Together with the involvement of appropriate NGOs,(such as the Dutch NGO, SNV, which is already working for the welfare and development of the fishermen and lake shore farmers and pastoralists), this is a dynamic team which can turn what is now a virtually untapped resource into what could be a crocodile and fisheries management programme to rival the best.

14. **Trophy hunting for crocodiles and the role of Ethiopian Rift Valley Safari**:
The killing of large adult males, which perhaps make up less than 2.5% of the population, is likely to negatively impact crocodile breeding in Zone 7, the largest breeding group outside of the NNP. Also, considering the extreme vulnerability of these large males to drowning in gancho nets which are set at night when crocs are feeding and on the move

(world record size skulls of 9 of them are on display at AMCR and NNP Hq.), loss of these biggest crocs will also negatively impact lake tourism.

15. **Lake Abaya**:
During a survey of the 55km shoreline of Lake Abaya within the Nechsar National Park it was found that there is considerable fishing activity with long lines and gill nets (including the deadly 'gancho' net). The nesting beach where 29 nests were found in 1989, has no evidence of nesting in recent years and only 8 crocodiles were observed (3 of them at the boat landing). This picturesque portion of the lake with great tourism potential and significant crocodile habitat is in urgent need of protection and control of fishing if any crocodiles are to survive at all.

CONCLUSIONS

Considering that Lake Chamo represents one of the last large concentrations of Nile crocodiles in Africa and certainly the largest in Ethiopia, there is a strong argument for the establishment of an imaginatively conceived and aggressively pursued programme of crocodile conservation and management based on sustainable use of the egg resource and tourism. To date the Lake Chamo (and to a lesser extent, but nonetheless important Lake Abaya) crocodile resource and its potential has been squandered due to lack of research and management inputs, a situation that can be simply remedied given sufficient will and effort by the major players/stakeholders and recognition of the cost/benefits for the local people and the country as a whole. The stage is set with a collaborative mechanism already in place involving the Regional Bureau of Agriculture and Natural Resources Development, the Zonal Department of Agriculture and Rural Development and African Parks. Support from donor agencies and NGO involvement are an obvious next stage. This report suggests directions and activities that will further the stated goals of crocodile conservation and management for the benefit of local communities and for the overall sustainability of the Lake resources.

One key issue is of course the fishery. Gill netting and crocodiles do not go well together. The observation of two dead adult female crocodiles (very likely drowned in the infamous gancho nets set for Nile perch) and one adult female caught in a net (which we were able to release before it drowned) during our day and night surveys carried out over fifteen days, indicates an unacceptably high rate of adult breeding croc mortality due to gill netting in the lake. If we seriously want to ensure the survival and growth of the crocodile population for sustainable harvest of the eggs and for the enhancement of tourism, urgent action must be taken to enforce existing fisheries regulations and to bring about changes in fishing techniques, including a complete ban on gancho nets.

RECOMMENDATIONS

Introduction

The following recommendations for Lake Chamo and Lake Abaya are based on the findings during the 25 day field visit to the lakes, perusal of past and present recommendations and discussions with the main stakeholders here. The implementation of these recommendations will require considerable more research and technical inputs, guidance for which is available through the long experience of members of the Crocodile Specialist Group. **It is strongly recommended that the Zimbabwe model of egg collection and crocodile ranching be studied and where appropriate applied to the Ethiopia context.** The potential for developing a successful programme that will guarantee the sustainable use of the crocodile resource (and the fishery) of these two lakes and earn enough money to benefit the local communities is considerable, but will require commitment, energy and a productive collaboration of the major stakeholders who are already working together.

A. Managing the Crocodile Resource

1. **Research**

Conservation and management of wild species is necessarily based on good science. We as yet know very little about the population dynamics, trends, spatial distribution, breeding and feeding ecology of crocodiles on Lake Chamo and Lake Abaya. A first step toward the sustainable management of the Nile crocodile in these lakes is to initiate a research programme which answers these basic questions. Research can be supported by such agencies as the Earthwatch Institute, Oxford, England, collaboration with international universities, technical inputs from the IUCN/SSC Crocodile Specialist Group and the staff and student resource potential of the Wondo Genet College of Forestry and Arba Minch University. A list of suggested priority areas of research is given in the Appendices.

2. **Population census and monitoring and the restocking programme**

While censuses have been carried out over the years, it is essential that from now on annual systematized day/night censuses are carried out at lowest water (variable according to weather, rains in the surrounding mountains) and that a total nest count is undertaken at the start of the annual nesting season each December. This is to be a collaborative exercise of the Arba Minch Crocodile Ranch (Southern Regional Bureau of Agriculture & Natural Resources Development), African Parks and the Gamogofa Zonal Department of Agriculture and Rural Development. Imperative that a sustainable monitoring system for the croc pop be established. A consistent system of survey methodology and mapping is needed that will show changes in density and distribution of crocs as they occur, areas of disturbance, changes in nesting and other habitat.

It is further recommended that census and monitoring be extended to the Omo River which reportedly has a significant but unknown crocodile population with the potential for an egg collection and ranching project to benefit the local people.

It is of prime importance that the harvest of eggs from the lake shores is carefully monitored and that results of the trends in the population structure guide the crocodile restocking programme (5% of the collected stock reared to >1m for release back to the wild), a requirement for crocodile ranching operations under the Convention for International Trade in Endangered Species.

3. **Design, relocation and upgrading of the Arba Minch Crocodile Ranch**
The existing plans for development and relocation of the AMCR (by A. Graham and A. Gebre) need to be updated with the best international scientific advice and a decision taken on the takeover, investment and management of this key element of the whole crocodile management scheme and how it can also benefit fishermen and others. Rather than repeat their recommendations, hard copies of the two development and relocation plans are being filed with this Project Document at the African Parks office, Addis Ababa. It is recommended that Dr. R.A. Fergusson, Regional Chairman of the IUCN/SSC Crocodile Specialist Group for Africa be invited to assist the development of a working plan for the crocodile industry in Ethiopia which can based on the over three decades of industry experience in Zimbabwe.

The AMCR also has tremendous potential as a local tourist attraction and this aspect must be built into the Development Plan for the Ranch.

It is further recommended that the establishment of any more crocodile ranches be put on hold until a policy and framework is established that will guarantee sufficient returns to the local communities to keep them interested in protecting crocodiles as resource they have a significant stake in. New ranches, if and when permitted to develop would have to prove their capability initially with small numbers of eggs/hatchlings before being allowed to enter into large scale ranching (as is done in Zimbabwe).

4. **Community participation and benefits from the crocodile management programme**
There is an estimated potential for the collection of over 10,000 crocodile eggs per year from the shores of Lake Chamo and an unknown resource potential from Lake Abaya. But it is vital that the killing of adult crocs in nets and hunting be contained.

Based on socio-economic surveys, meetings with stakeholders to gain an understanding of what the people aspire to and want, a scheme is to be established by which primarily fishermen, and where practicable, lake shore dwellers (agriculturalists) are given the responsibility to protect the crocodiles and their nesting sites. In return for this they will receive direct payment for the eggs and hatchlings collected for the ranching operation based on a value calculated for the eggs and an equitable distribution according to the number of eggs found in the areas under their protection. A Community Crocodile Management Trust can be established to operate this programme which can also consider dividends for these stakeholders from profits accruing from the ranching scheme. Crocodile ranching needs to be recognized as multi-sectoral land use under agricultural and rural development schemes with the appropriate aid and support normally ascribed to

this vital aspect of country development. The fact that it has a great advantage over destructive, non-sustainable forms of land use is an important consideration.

A scheme for encouraging Community Crocodile Ranches, developed with technical and management guidance, donor aid, micro-finance/loans and African Parks partnership, is another option that holds great promise in directly involving local people in utilization of the crocodile resource. This scheme will use the tremendous (50%) wastage inherent in the filleting of fish for the market as an ample supply of croc feed and can be buffered (when food is scarce or the skin market depressed) by the AMCR.

5. **Crocodile tourism and 'Living with Crocodiles' education programmes**
A shoreline of 41 km of Lake Chamo (8.5% of the lake area) lies within the Nechsar National Park boundary including the so-called Crocodile Market, a gathering place at the North end of Lake Chamo for dozens of Nile crocodiles which have been habituated to humans and can be closely approached. This is a must for every visitor and is already a main tourist attraction. So far, this reptilian spectacle has not received the kind of international attention it deserves. The Lake Chamo crocs, some of which exceed 18 feet (5.5m), are possibly the largest Nile crocodiles in Africa and certainly amongst the largest crocodiles in the world that can be easily viewed and photographed!

There are very few places in the world where one can view such huge wild crocodiles, in complete safety, from so close. A one to two hour boat ride is available to visitors, but the dock, facilities and guides leave much to be desired. Investment into infrastructure, training of guides in safety and imparting information and making the boat ride a more comfortable, exciting and enjoyable experience will considerably enhance the attraction of Nechsar National Park.

Hippos are also part of the tourists' 'Africa experience', and a number of these remarkable 'river horses' can be seen, again in safety and at close range. Careful, ecologically sensitive tourism development could include a lakeside restaurant run by fishermen with management advice, featuring specialties of the lake (eventually including crocodile kabobs) and the design, promotion and sale of local artifacts.

In addition to tourism, knowledge about the life history of the Nile crocodile and the concept of 'Living with Crocodiles' needs to be made available to the local communities in the form of posters, pamphlets, film shows using portable LCD projection and extension work (demonstration/talks) via schools, colleges and community meetings. An appreciation of the role of crocodiles in the ecology and as an economic resource needs to be instilled if these reptiles, which have historically always had very bad PR, are to continue to be tolerated.

6. **Trophy hunting of the giant crocodiles of Lake Chamo**
Although it is acknowledged that conservation benefits are possible from trophy hunting, there are several reasonable arguments against hunting of big crocodiles in Lake Chamo, including the fact that an unknown number of big adult males and females are already drowning in gill nets each year and because of our almost total lack of knowledge of

crocodile population dynamics here. Perhaps the most cogent of all reasons is the importance of these huge male crocodiles (to our knowledge unrivalled anywhere else in Africa and which have taken perhaps 50 years to reach these impressive sizes) to the genetic input and tourism industry on the lake.

Large crocodiles over 5m in length make up perhaps only about 2.5% (50 animals) of the population in Lake Chamo. In the considered opinion of this consultant, and generally shared by a majority of stakeholders questioned on this issue, it is felt that the trophy hunting concession for crocodiles on Lake Chamo could at this time be detrimental to the goals of crocodile conservation and development of tourism here and that it's better that exploitation of the crocodile population be limited to egg collection until we understand crocodile population dynamics, spatial distribution around the lake and tourism potential.

7. **Crocodile Conservation and Management/Research Coordinator**
There are few wild animal resources in the world with as much profit potential and for which there is a huge body of expertise as crocodiles. It is conservatively calculated that an optimally organized Arba Minch Crocodile Ranch alone could earn a gross income of over USD1.5 million per year based on the present known egg collection potential from Lake Chamo alone. There are a number elements that need to be established and coordinated for this to happen however and the most cost effective way to do it is to appoint a Crocodile Conservation and Management/Research Coordinator, with possible support for the post from a donor agency interested in the development of wildlife resources for community benefit and long term ecosystem conservation and sustainability.

B. Managing the Fishery Resource
1. **Regulating the fishery in Lake Chamo and Lake Abaya**
Though primarily the responsibility of the Gamogofa Zonal Department of Agriculture and Rural Development, the impact of the fishery in both lakes on crocodiles is the single most important impediment to the sustainability of what could be literally a million dollar industry in terms of leather and meat exports and local tourism. This means that other stakeholders such as African Parks and the Southern Regional Bureau of Agriculture & Natural Resources Development need to assist in fishery management and implementation/enforcement of regulations. These are the measures (most of them as listed in the Department's 2006 overview by Bimrew Tadesse) which need to be implemented as soon as possible:
a) personal/non-transferable licensing of each fisherman
b) taxing fishing effort
c) permanent and temporary closed areas to protect crocodile nesting beaches, juvenile habitat and fish spawning areas to allow stocks to recover
d) fishing gear specifications and enforcement to protect recruitment of fish stocks
e) immediate ban on the use of 'gancho' nets which are now the major cause of deaths of the adult breeding stock of crocodiles and have been proven to contribute to the drastic decline of the Nile perch fishery and the virtual extinction of *Labeo horie*

2. **Managing the fishery and crocodile resource**
The future of the sustainable management of the lake fishery and the crocodile resource are closely interlinked. The tragic decline of fish stocks here is typical of many areas where there has not been adequate inputs of research and regulation. Uncontrolled increase in numbers of fishermen, decrease in net mesh size, lack of research and management inputs by the key profiteering fish buyers/exporters and lack of vision of the future of the industry are all factors mitigating against a sustainable future for fishing. This has obvious negative impacts at every level, for the fishermen, the middlemen, the big buyers/exporters and for Ethiopia as a whole which needs to earn foreign exchange.

The collaboration of the various stakeholders in an aggressive plan to study and manage both the fishery as well as the crocodile resource will reap significant benefits if implemented now, before there is a further deterioration in the situation. While smaller gill nets, set for tilapia, catfish and other species do not represent such a serious threat to adult crocs as do the gancho nets, their use is affecting recruitment of the smaller size classes of crocs to the future breeding population. This needs to be studied and other, crocodile-friendly fishing methods need to be researched and promoted in the interests of both the fishery and crocodile management.

3. **Alternative employment for fishermen**
The majority of the lakeside dwelling people are pastoralists and farmers and not interested in fishing. There are about 20 ethnic groups of people involved in fishing, many of them people from the Highlands and others attracted to the occupation due to lack of employment or other income generating activities. Many fishermen express the desire for alternative occupation and/or resettlement which has already been carried out for 150 families by the Government Resettlement Programme for poor and landless people and by tourism projects for rehabilitating illegal fishermen in collaboration with African Parks. With the growth of tourism and the development of a community based crocodile industry it will be possible to reduce dependency on what is now a diminishing resource. Aquaculture is another area which has been successful in other parts of Africa, especially tilapia farming, often in association with plantation crops such as banana.

C. Evolving a Long Term Management Plan
While the summary of findings and recommendations given above will provide guidelines to start with, the formulation of a long term management plan will require a number of research data and technical inputs that can only be derived in time. Fortunately some of the data has already been collected during past surveys and egg collection, but much baseline data still needs to be established for a sustainable plan. The following is an outline of what has to be done:

Introduction and rationale for crocodile ranching
1. People are more likely to support crocodile conservation programmes that offer them tangible benefits rather than a tangle of legal prohibitions.

2. Sustainable use can only work if wild populations can be demonstrated to have an economic value (thus the ranching option rather than captive breeding and closed cycle farming).
3. The use of crocodiles by egg collection is surplus harvesting. If the eggs at Lake Chamo were not removed, most would die in the egg or as juveniles. Only an estimated 2 to 5% might survive to adulthood.

Parameters for a long term management plan
1. History of utilization -- included in this report as: Background and History of Crocodile Usage in Ethiopia.

2. Biological background – while we have a considerable body of knowledge about the Nile crocodile in other parts of Africa, there has been very little work done here. This is a list of assumptions, based on data collected by research, that will comprise the major components of a management plan:
a) natural mortality and that due to anthropogenic causes (gill netting)
b) differential mortality in the various age goups and in males and females
c) males grow faster than females and reach a larger maximum size
d) eggs are laid in December/January and hatching is in March/April
e) number of eggs laid depends on characteristics of the female population (ie. female size:clutch size)
f) females start breeding at 2.5m in length at age 12
g) 20 to 40% of the eggs are eaten by predators (mainly the Nile monitor)
h) 80% of surviving eggs will hatch
i) sex ratio of the adult population includes 53 to 63% females
j) adult population is >1000

The outputs from these assumptions on which management decisions will be taken, based on monitoring and study, adjusted according to periodically different results are:
a) population structure by sex and size group
b) size structure of breeding female population
c) total number of eggs laid
d) overall hatching rate
e) numbers of crocodiles that need to be released to maintain/increase the population

3. Economics – the egg harvest, with egg levies paid to fishermen and other involved communities, converted to crocodiles successfully raised to cropping size, minus overheads, results in profits which need to be apportioned with conservation of the resource, community benefit and sustainability as the main goals.

4. Monitoring – this is the key research component that will be a permanent feature of the crocodile management plan, which will help maximize yields and maintain a healthy population, long after other basic research into crocodile biology has been done.

5. Legislation – adequate protection of the stock is essential if crocodile exploitation is to considered as a long term land use. In Lake Chamo the protection of crocodiles from

being drowned in gill nets is the uppermost priority, immediately followed by protection of the nesting, basking and key habitats for juveniles. The feasibility of new categories of land use such as Community Conservation or Community Wildlife Management Areas is being discussed and need to be implemented without further delay to bring the people of the area on board the Crocodile Management programme.

APPENDICES

Contents of Appendices

Technical terms of reference for the crocodile consultant

Background

The actual value of the Nile crocodile population in Lake Chamo has never been fully appreciated in the past. However, R.Whitaker's June, 2006 observations on various aspects of the lake's croc population, including its potential for community based tourism development, based entirely on the crocodile and fishery resources in the lake has attracted the attention of African Parks (AP) and responsible government agencies, alike.

AP understands the importance of Lake Chamo crocodiles, especially for developing sustainable tourism in and around Nechsar National Park (NNP). For this reason it attaches particular significance to the need for promoting the potential of the lake's crocodile population for a dynamic community-based sustainable use and tourism development project, as suggested by Mr. Whitaker.

This calls for conducting a field assessment of the lake ecosystem, in order to bring together all essential information on the crocodile population size/dynamics/ecology, spatial distribution, seasonal movements, reproductive biology and ethology and based on the findings to formulate a management plan for the conservation and sustainable utilization of the potential of L. Chamo for the benefit of NNP and the local communities. The work is planned to be completed in two successive phases as described below.

The mission will involve the technical expertise from IUCN/SSC Crocodile Specialist Group, Honorary Steering Committee Member, R. Whitaker in the field mission and in developing the 'management plan document' to ensure an ecologically sound and sustainable utilisation of the crocodile population via tourism, hunting, egg collection for ranching (skins and meat) in the area.

Main Objective

- To develop a field ‘programme document' (project document) to plan for the ecologically sound sustainable utilisation of the crocodile population (through tourism, hunting, egg collection, etc...) in the area with the participation of the local people.

Major tasks

Phase I

1. Conduct a series of consultative meetings with key stakeholders: Federal Wildlife Department (EWCD), Wondo Genet College of Forestry (WGCF), Tourism Parks and Hotels Commission of Southern Region (Awassa), African Parks Nechsar NP project (APNNP), Arba Minch Crocodile Ranch (AMCR), 3 Fisheries

Cooperatives in Arba Minch (AMFC) and the Gamo-Gofa Zone Fisheries Desk (GGZFD), with a view to developing shared understanding on the need for effectively utilizing the potential of lake Chamo crocodiles (*6 days*).

2. Conduct a preliminary field survey of the crocodile populations in the lake to determine abundance/population size, age/sex structure, spatial distribution, and main nesting grounds and estimate the egg-harvest potential (*10 days*).
3. Give lecture on the biology of Nile crocodiles to the students, pursuing first degree programme in Wildlife and Tourism Management in the WGCF (*2 days*).
4. Prepare technical guidelines/work-plan for follow-up monitoring and study of the crocodile population in the lake (*7 days*).
5. Prepare and give initial technical training to a group of technical experts, drawn from key stakeholder institutions (GOs, CBOs/NGOs etc) responsible for the conservation and sustainable utilization of the crocodiles and other natural resources in the L.Chamo environment (*4 days*).
6. Based on the findings of Phase I, prepare management plan document including research/conservation/management/education/community programmes.
7. Develop, in collaboration with the WGCF (Awassa and Arba Minch Universities), a research programme on the ecology and management of the crocodile population in L. Chamo.
8. Develop a training and or awareness raising programme for the boat operators, local tourist guides and visitors.

BRIEF DESCRIPTION OF LAKE CHAMO

Lake Chamo is roughly oval in shape with a North/South maximum length of about 33.5km and maximum width about 15.5km, characterized by a gently sloping shoreline (though there are some steep lakeside escarpments) with extensive emergent and sub-emergent vegetation. Dominant species include *Typha augustifolia*, *Phragmites sp., Juncus sp.*, tall aquatic grasses such as *Loudetia phragmitoides* and bushes such as *Sesbania sp*. and *Balanites sp.* (Duckworth, et al, 1992). There are several small islands at the north end of the lake: Jantra, Alako, Sharashanto and Kaiafer, the largest being Gandjulle, an important crocodile basking and nesting area. A shoreline of 41 km of L. Chamo (over a third of the shoreline but only 8.5% of the lake area) lies within the Nechsar National Park (compared to 55 km of shoreline of L. Abaya, about one sixth of the shoreline and only 4.8% of the lake within NNP).

Lake Chamo is apparently shrinking and has a present area of 316 km ^{2} with a shoreline of 108-116km (though many current reports cite an area of 550km2) (Awulachew, S.B. 2005). The maximum depth is 14m with an average of 6m. It is situated at an altitude of 1110 m/msl, has an average annual rainfall of 900mm, with an average maximum temperature of 30.3 degrees C and an average minimum temperature of 17.4 degrees C.
Rainy seasons: April-May and September-October
Dry seasons: June-August and November-March

Lake Chamo is highly alkaline with a pH of 9.0 to 9.23 and a high primary productivity with a phytoplankton biomass averaging 75mg/m3 (compared to Lake Abaya's of 4.4mg/m3).

The overflow from adjacent Lake Abaya into Lake Chamo via the Kulfo River has not occurred since 1980. Similarly, the overflow out of Lake Chamo via the Sagen (Meo) River (and eventually South to Lake Chew Bahir) has not occurred since then. The result of a greatly reduced inflow of water via the two previously perennial rivers, the Kulfo and the Sille (which have now been largely diverted for agriculture), plus increase of drought periods possibly due to climate change, has been a 40% increase in salinity in 40 years "which seems linear and unabated and could damage the lake ecosystem" (Awulachew, S.B. 2005). Lake Chamo is characterized as eutrophic which could be favourable for cyanobacteria, resulting in periodic bluegreen algae blooms. There have been isolated cases of fish and zebra deaths blamed on toxins produced by such blooms (Awulachew, S.B. et al. 2000).

Small annual streams that drain into Lake Chamo include: Wezeka, Arguba, Doyso, Geda Okolo, Genta Kenshema, Sego-ein, Walesa, Waneta, Abulo and Geda Bonke. Besides the Sille and Kulfo rivers, the Sego-ein and possibly others are seasonally important gathering spots for piscivorous birds and crocodiles.

Other important lake fauna include hippos (117 counted by us during our daytime lake perimeter survey), and large numbers of water birds including fishing eagles, marabou storks, egrets and pelicans. Nile monitors (important predators on crocodile and bird eggs) are visibly common as are baboons.

THE FISHERY ON LAKE CHAMO

Bolton (1983) reported that the commercial fishery at Lakes Chamo and Abaya was then confined to long lining for Nile perch and the large catfish Bagrus, with an annual catch of about 120 tons. In the mid-1980s a foreign advisor introduced gill netting in Lake Chamo which at first raised the fish catch to spectacular levels but then resulted in a drastic decline. The introduction of the thick-twine 'gancho' gill net specifically for Nile perch in 1993/4 led to a rapid but brief increase in the catch which then to its virtual disappearance from the catch between 1998 and 2001.

Though the Nile perch (rate paid to fishermen is currently Etb 35/kg) may be slowly recovering, the present catch represents less than 10% (4.3% according to the Fisheries Cooperative Association) of the annual total fish catch of a little over 2000 tons (of which 50% is wastage after filleting). About 90% of the catch is tilapia (rate currently paid to fishermen Etb 15/kg) with catfish (rate currently paid to fishermen Etb 22/kg) comprising a small portion of the commercial catch (3.1% according to the FCA). The total value of the Lake Chamo fishery for 2005/06 was reportedly about Etb 17,144,520 (USD 2,143,065) for an average annual income for each of the estimated 2000 fishermen (plus their dependents) of about Etb 8,512 (USD 1,071) (Tadesse, 2006).

The majority of the lakeside dwelling people are pastoralists and farmers not interested in fishing. There are about 20 ethnic groups of people involved in fishing, many of them people from the Highlands and others attracted to the occupation due to lack of employment or other income generating activities. At present the fishery is open to anyone without restriction (except for the 44km closed area of shoreline within the NPP). This, and the use of unsustainable methods like the steady decrease in mesh size, have led to over-exploitation and the inevitable decline of species like *Labeo horie* (2000 tons in 1999 and now 0% of the catch!) and the Nile perch.

Many fishermen express the desire for alternative occupation and/or resettlement which has already been carried out for 150 families by the Government Resettlement Programme for poor and landless people and by tourism projects for rehabilitating illegal fishermen in collaboration with African Parks (Tadesse, pers. comm.). Other opinions however are that fishing is still lucrative enough to poor, landless people and that even if they have local alternative livelihoods they will fish at night to supplement their income (on a good night a fisherman may make USD25-35, a very significant income here). Ethio Fisheries, PLC seems to think that there is a future for the fishery here as they are setting up a processing and icing unit here for fish to be transshipped to Addis Ababa by reefer truck and then exported to the Middle East and to Italy.

The Gamogofa Agriculture and Rural Development Department is aware that there is no scope at present for expanding the Lake Chamo fishery and that enforcement of existing and proposed regulations such as net mesh size, licensing, taxes, closed areas/seasons and fishing gear modifications is urgently necessary. This is the Department responsible for patrolling, protecting and enforcing fishery regulations in the large lake area outside the NPP but cannot be effective due to lack of resources, funds and man-power (Tadesse pers.comm.).

Gill nets and crocodiles

Gill nets and crocodiles do not mix well. Hutton (1992), quoting Parker, says that the 50% decline in the Lake Turkana (Kenya) population of the Nile crocodile between 1968 and 1988 coincides with the growth of the gill net fishery there. In Lake Kariba (Zimbabwe) it is reported that "Uncontrolled netting in many parts of the lake has led to the reduction or disappearance of crocodiles from these areas. Most were undoubtedly killed in the nets" Games and Hutton, 1992).

It has also long been recognized that the introduction of the braided twine, so-called 'gancho' gill net in the early 1990s has been a disaster for adult crocodiles in Lake Chamo which become entangled in the thick cords and drown (Gebre and Wakjira, 1996;Wakjira et al, 2005). A number of huge male Nile crocodile skulls (the largest on record in the world for the species) can be seen at the Arba Minch Crocodile Ranch and at the NNP headquarters which were all allegedly crocs drowned in gill nets.

The number of breeding adults lost to gancho nets every year can only be speculated on but one estimate is that 10 to 15% of the adult population is lost each year (Gebre, pers.comm.). During our survey, two adult female crocodiles of over 3m were found dead

(and photographed) apparently by drowning in nets. On the final day of our lake survey we encountered what was presumably an adult female crocodile at the Gandulo nesting beach (within NPP) entangled in a gill net which we freed before she drowned. Unknown numbers of juvenile crocodiles are drowned in the smaller gill nets set for tilapia. Gill nets, combined with shoreline disturbance at basking and nesting areas by fishermen and pastoralists need to be dealt with urgently if the crocodile resource is to be effectively protected and managed. **There is no evading the fact that fishing methods have to be compatible with crocodile movements and behaviour if there is to be any future for these reptiles in Lake Chamo.**

The apparent anomaly here is that though the fish catch is dramatically declining there is no immediately visible indication that the crocs are suffering as a result. This could be because subadult and adult crocs mainly feed on tilapia as in Lake Turkana (Graham, 1968), which seem to still be plentiful. However, there are reports that some large crocodiles appear emaciated and the total disappearance of species like *Labeo horie* could mean that young crocodiles are deprived of the fry of that species, contributing to the observed apparent scarcity of smaller crocs, an area of limnology and croc feeding ecology that deserves study.

THE ARBA MINCH CROCODILE RANCH

Introduction

As defined by CITES, crocodile ranching refers to the collection of eggs and/or hatchlings from the wild and rearing them to culling size in captivity. Following the recommendations of FAO Consultant Melvin Bolton (1983), the Arba Minch Crocodile Ranch (AMCR) was set up in 1984 under the Ethiopian Wildlife Conservation Office (later, in January, 1997 it was taken on by the Bureau of Agriculture and Natural Resource Development). The location chosen by the authorities was about half a kilometer from the southwestern shore of Lake Abaya though there was historical evidence of flooding at this site in 1967 and 1977. Two heavy rainy seasons in 1996 and 1997 resulted in the submergence of the Ranch with disastrous results. It is therefore imperative that the Ranch be shifted to higher ground (Gebre, 2000).

Egg collection and incubation in styrofoam boxes and heating using charcoal burners (and later electric bulbs) was tried in 1985/86. From 1987 onwards eggs were left in natural nests and hatchlings collected after the 90 days of incubation. Bushes were cleared and fishermen's camps removed from known nesting sites a month before laying time to 'attract' the females. Nests were located and stones piled on them to detract predation by Nile monitors and other egg eaters. Hatchling calls are listened for in early March and the baby crocs removed to the nursery pens at the Croc Ranch. This method is described as the simplest and most cost effective way to produce healthy hatchlings (with a reported average of 80% hatching rate, which is close to the wild hatch rate reported by Games and Hutton (1992) for Zimbabwe) as compared to the more rigorous and demanding task of collection of eggs and incubating them (Hailu, 1990).

Synopsis of AMCR
Area: 3 hectares
Capacity: 9,000 crocodiles (hatchlings to 5 year olds)
Staff: 31 including 18 maintenance men and 5 scouts
Feed: Horsemeat (@Etb2.73/kg) and fish waste (@Etb0.80/kg) (hand processed)
Feeding rates: Twice a week for smaller crocs, once a week for larger crocs.
Problems: High mortality of hatchlings and yearlings in particular (total mortality over 60%); high incidence of 'red spot' disease (bacterial infection); crowding/slow growth rates; no veterinarian; inadequate budget; high percentage of Grade III and reject skins; untreated effluent drains to Lake Abaya; flooding potential.

Every 5-10 years CITES requires the ranch to restock 5% of captive crocs to the lakes which was done in 1986 when 460 1-1.5m crocs reared at the ranch were released, 200 in lake Abaya (of which, interestingly, 90 homed back to the ranch on Abaya's shores and others were killed as they approached fishermen to be fed) and 260 in Lake Chamo. (Hailu, 1994;Gebre, pers.comm.)There have been no releases since then. This is an important requirement that needs to be fulfilled with attention given to the fact that the majority of crocs released should be females and should be done in suitable habitats for them, away from the concentrations of adults.

Table 6. EGG COLLECTION DATA, ARBA MINCH CROCODILE RANCH (Data courtesy Assegid Gebre, Manager, AMCR)

Year	No. Nests	No. Eggs	Average clutch size	Hatched	Hatchlings to ranch	Hatchlings released
1985	4	129	32	72	72	Nil
1986	72	3176	44	2713	2713	Nil
1987	206	5521	27	4928	2622	2306
1988	132	4103	31	3510	2587	923
1990	265	7752	29	6244	6045	199
1991	74	2749	37	2121	2005	116
1997	242	5663	23	4011	4011	Nil
2001	58	2572	47	2120	2000	120
2004	262	11840	45	9400	8000	1400
Total	1607	53124	--	42755	37195	5559

NOTES: Years not entered means no egg collection done that year.
Years like '87, '90, '97 seem to have wrong nest counts resulting in low clutch size averages. Clutch sizes range from 25 to 70 eggs (depending on size of female) with the 2004 figure of 45 eggs probably representing the actual average for the population. In other parts of Africa, average clutch sizes for the Nile crocodile range from 33 to 63 eggs.

Number of skins sold

1. Hawk Trading	(1984-1995)	5596	($699,464) @$125.00 per skin
2. Bale PLC	(1996-2006)	2535	($ 65,088) @$ 26.67 per skin
Others		145	
Total		8276	($764,552)

Crocs on ranch now (Feb, 2007)	3646
(2973/2 year olds, 673/5 year olds)	
Total	11922

Stock mortality

Total hatchlings to ranch:	37195
Less skins and current stock:	11922
Mortality:	25273 (67.9%)

This is a very high mortality by any standards and emphasizes the need for consultative management and financial inputs to improve the situation. In comparison, for the successful Lake Kariba (Zimbabwe) egg collection and ranching exercise, stock mortality averages have been 10% for hatchling and18.5% overall up to 1992. (Games and Hutton, 1992).

Potential for the AMCR

Hutton, (1997) writes: **"The (AMCR) farm has great potential with large numbers of hatchling stock easily available, very cheap fish and red meat for feed and low labour costs. Even conservative projections show that it could easily fund all protected area operating costs in the country's Southern Region and, in fact, with other wildlife revenues would result in large surpluses that could be applied to community development programs."**

Graham and Gebre (1997) produced a draft Management Plan for AMCR which details the problems and solutions. With updating and consultative inputs this document provides an excellent framework to start with and much of what is outlined below is derived from and corresponds with their recommendations (a copy of their plan is on file at African Parks).

The AMCR (and/or other proposed crocodile ranching operations in the area) is indeed the primary key to the success of the Lake Chamo crocodile management programme for generating income for conservation and community activities. However, the ranch has to be run at a high rate of efficiency with consultative management inputs at every stage and adequate infrastructure investment. Since the whole operation has to be relocated to higher ground to mitigate the problem of flooding, the best advice on pen design, water ingress, pen cleaning and effluent treatment, feed and its preparation, veterinary care, and slaughter/skin handling and preservation needs to be obtained prior to the shift.

It is beyond the scope of this consultancy to present a detailed analysis of the crocodile skin industry or to project the costs of running the AMCR at a high rate of efficiency. However some general statements can be made and extrapolations presented to demonstrate the potential profitability of a ranching operation with a well conceived infrastructure and adequate financial and technical inputs.

Firstly, it is assumed that the AMCR has several options in order to bring it up to speed:
a) to be placed under the operation of or in collaboration with an appropriate NGO

b) formation of a Crocodile Ranchers Trust or Company consisting of local stakeholders to run the ranch
c) inviting a PLC on board with a commitment to involve and aid local communities (fishermen in particular) who form the major stake-holders in the resources of Lake Chamo.

The mechanisms of community involvement can be complex and require the inputs of NGOs with the wherewithal to carry out socio-economic surveys, meetings with stake-holders and a management advisory authority comprised of the regional/zonal authorities, the Federal wildlife conservation authorities and African Parks who are already in collaboration. Secondly, it is assumed that donor and/or investment measures will be taken to ensure that the ranching operation is planned and executed at the highest level of efficiency using the best international expertise available to accomplish the job.

Crocodile ranching based on egg collection has become a fine-tuned industry in other parts of Africa and the world and this expertise is available for every stage of the operation including: egg collection/incubation, pen design, veterinary and rearing techniques, humane slaughter, skinning/preservation techniques and marketing strategies. And thirdly, it is assumed that the egg harvest will be based on adequate studies on the population dynamics of the crocodiles, including regular monitoring of trends.

Egg collection and harvest potential
To demonstrate the potential of optimum and efficient usage of the egg harvest from the adult female Nile crocodile population of Lake Chamo several more assumptions are made:

1. That the Ranch will be relocated and reconstructed according to optimum design plans with trained staff and an efficient infrastructure (a Project Proposal for Ranch relocation has already been prepared by Gebre, 2000 and needs updating and consultative inputs).
2. That the egg collection potential for Lake Chamo alone (with Lake Abaya as an additional but unknown source for eggs for the ranching scheme) could be as high as 19,000 eggs per year.
3. That the 'natural hatch' system will in future be replaced by early egg collection and incubation at the Ranch.
4. That 13,000 hatchlings would be produced with a total stock mortality of no more than 23% per year.
5. That the growing period from hatchling to culling size (33cm commercial belly width, corresponding to a total length of about 150cm) will be not more than 4 years.
6. That an agreement is entered into with a reliable international crocodile skin trader who can be guaranteed at least 50% of unblemished grade 1 and 2 skins.
7. That current market values for Nile crocodile skins (dependent on a whole array of factors, including sizes, numbers, quality, freight) averaging from USD 2 to 5 per cm of belly width, according to grade, remain the same. (Note: Current prices being paid by an Ethiopian buyer are abysmally low: from USD 0.35 to 1.70 per cm of belly width).
8. That current costs of running the farm: salaries, feed costs, logistics remain the same.

9. That gill netting/crocodile conflict will be mitigated and the resource guaranteed protection from this and other negative anthropogenic influences.
10.That the AMCR will be developed as a significant tourist destination.

If these assumptions are met, the gross annual skin income (from year 4 onward) from the rearing of a conservative 10,000 crocodiles can be broken down into the following rough extrapolations which can be used as a general guide but do not pretend to any precision (considering market fluctuations, rates of inflation, running costs, who pays shipment costs and so on):
Grade 1 - 5,000 skins of 33cm belly width = 165,000 cm @USD5/cm = USD825,000
Grade 2 - 2,500 skins of 33cm belly width = 82,500 cm @USD4/cm = USD330,000
Grade 3 - 2,500 skins of 33cm belly width = 82,500 cm @USD2/cm = USD165,000
(But note that there is little or no international market for Grade 3 skins)

Crocodile meat
Crocodile meat is a specialty protein export that has a reportedly steady market from western countries, particularly Europe. Current rates are unknown but could range in the vicinity of the local price paid for Nile perch fillets, conservatively USD4.00/kg. The average fillet weight of meat from a 1.5m captive reared crocodile is about 4kg. The annual slaughter of 10,000 crocodiles would yield 40,000 kg of meat with a value of at least USD160,000.
(But note that meat can only be exported to Europe with considerable investment in a modern abattoir, following international standards in veterinary care and public health. Since Ethiopia is already a large fish and meat exporter this should not be difficult to achieve.)

There are fears that marketing crocodile meat could stimulate local usage (at present virtually non-existent) leading to poaching. However, the whole concept of the crocodile management programme for Lake Chamo is that the resource would be well protected by virtue of successfully involving the local community and using a portion of the proceeds from the industry for this. Local use of crocodile meat for the growing tourism industry in addition to export is definitely a proposal worth considering as long as good protection of wild crocs can be guaranteed.

Ancillary products and cottage industry
Crocodile skulls (cleaned and bleached), teeth for necklaces/key chains, strips of hornback skin (not generally used in the fine leather industry) for belts, hat bands, key chains and other handmade artifacts can contribute to the local economy as local artisans can fashion imaginative and ethnic looking products for the rapidly growing tourist market. These ancillary products are difficult to put a value to but could yield in excess of USD100,000 per year (or considerably more) with profits going directly to local people.

AMCR as a major tourist attraction
Tourists love to see crocodiles close up. They would have the chance to see wild crocodiles on the Lake Chamo boat ride but at AMCR they could have a real educational experience, hold a baby crocodile, watch crocs feeding and learn about the life history of

these fascinating animals. Both Ethiopian and foreign visitors would be attracted to well set up, pleasingly landscaped exhibits and would be happy to pay for the opportunity. Foreigners could pay USD 5 for the chance to see a well maintained croc ranch (at present close to 5,000 visit the NNP yearly and this will go up), and local people could buy a Etb 5 ticket to see the crocodiles. This could easily become the regular Arba Minch local picnic spot, serving the purpose that zoos and botanical gardens do in other places. This could generate USD 25,000 per year and more for ticket sales alone.

Estimated annual value of the crocodile resource

Thus it can be seen that at the current estimated rate of exploitation the crocodile egg resource at Lake Chamo has the potential to realize a gross income of at least USD1,605,000 per year from year 4 onwards. Assuming that a more vigorous protection and management of the wild crocodile resource will maintain the upward population trend seen in the lake (a 9.5% annual growth in the breeding population was seen in the Nile croc population in the Okavango, Botswana), and based on complete annual nest censuses, this income could very likely double within 10 years. **It is important to emphasize that the death of each adult female crocodile by drowning in gill nets can be calculated to be a loss of up to USD 100,000 as her lifetime egg production potential of over 1000 eggs is removed from the resource base.**

CITES commitments

As for any country which is a signatory to the Convention on International Trade in Endangered Species, Ethiopia has basic responsibilities which must be met to continue to be eligible to export Nile crocodile skins and other products derived from crocodiles to other member nations. In general, Ethiopia needs to ensure the following in order to comply with CITES requirements:

1. That the crocodile population(s) being exploited are adequately studied, including regular monitoring and conservation measures taken to guarantee sustainability of the resource.
2. That a ranching programme, based on collection of wild eggs/hatchlings be scientifically conceived and operated with minimum stock mortality, high standards of health, housing and humane slaughter maintained.
3. That all the regulations on reporting (results of population monitoring, harvests and exports), skin tagging and other requirements are fulfilled.
4. That a release programme, putting back an adequate number of captive reared crocodiles at a size when optimum survival is likely to ensure sufficient recruitment for sustainability and population growth, is established and implemented. Note: the CSG/Africa Chairman cautions that we first need to answer the question of what is happening to the juvenile crocs in L. Chamo and if necessary, mitigate negative human impacts (R. Fergusson, pers.comm).

THE LAKE CHAMO CROCODILES AND TOURISM

Nechsar National Park

Last year, Ethiopia, the Horn of Africa country, hosted around 227,000 tourists, earning $156 million in foreign exchange, compared with the $134.5 million earned from 184,000 visitors the previous year, according to ministry of tourism figures, and it is assumed that about half of these visit the southern region. In addition, the government aims to promote Ethiopia as one of the top 10 tourist destinations in Africa by 2016, hoping to reap $650 million a year in much-needed foreign exchange. With 353 different species of birds, the endemic Swayne's hartebeest, leopard, lion, wild dog, greater kudu, bushbuck, waterbuck, gazelle, dik-dik, wart-hog, baboon, colobus and vervet monkeys, impressive reptiles like the Nile monitor and spectacular scenery, Nechsar National Park is a prime tourist destination which promises to lure even more visitors as facilities are developed (Bake, 2006).

'Crocodile Market'

A shoreline of 41 km of L. Chamo (8.5% of the lake area) lies within the Nechsar National Park boundary including the so-called Crocodile Market, a gathering place at the North end of Lake Chamo for dozens of Nile crocodiles which have been habituated to humans and can be closely approached. This is a must for every visitor and is already a main tourist attraction. So far, this reptilian spectacle has not received the kind of international attention it deserves. The Lake Chamo crocs, some of which exceed 18 feet (5.5m), are possibly the largest Nile crocodiles in Africa and certainly amongst the largest crocodiles in the world that can be easily viewed and photographed!

There are very few places in the world where one can view such huge wild crocodiles, in complete safety, from so close. A one to two hour boat ride is available to visitors, but the dock, facilities and guides leave much to be desired. Investment into infrastructure, training of guides in safety and imparting information and making the boat ride a more comfortable, exciting and enjoyable experience will considerably enhance the attraction of Nechsar National Park. There are several major crocodile nesting sites within the area of the boat ride, and though these sites should not be disturbed they can be pointed out and trained guides can describe the fascinating details of what good parents crocodiles are.

Hippos are also part of the tourists' 'Africa experience', and a number of these remarkable 'river horses' can be seen, again in safety and at close range with minimum disturbance to the animals (many with calves at the time of writing), on the short boat ride to the Crocodile Market and back. When rains bring a flow of water (and a concentration of fish) into the lake via the Kulfo River, flocks of pelicans and a number of other aquatic birds crowd the mud flats along with the crocodiles creating a spectacular sight. Fishing eagles are common and Egyptian geese, ducks, storks, herons and egrets usually visible. Careful, ecologically sensitive tourism development could include a lakeside restaurant run by fishermen with management advice, featuring specialties of the lake (eventually including crocodile kabobs) and the design, promotion and sale of local artifacts.

Visitors are fascinated with the local fishing boats which seem so risky. Though fishing is banned within the National Park (and gill netting rightfully so), subsistence fishing with hook and line might be allowed for local lakeside dwellers, giving them the right to catch food for their families and offering tourists a chance to see and photograph another aspect of local colour.

TROPHY HUNTING OF CROCODILES AT LAKE CHAMO

From what I was told, the Ethiopian Rift Valley Safari (ERVS) company was granted a 5 year concession (from 2005) to hunt up to 6 large adult crocodiles per year in the southwestern part of Lake Chamo, well outside of the National Park area (corresponding to ecological Zones 6,7 and 8 (Bolton, 1984). While this area (and the very picturesque Bolle Bay in particular) supports perhaps 45% of the adult crocodile population on the lake, including some of the largest adult males, it is also the most important crocodile breeding area outside the National Park and contributes perhaps 25% of the total eggs produced each year (over 100 nests detected in Little Bolle Bay alone in 2004 by the AMCR staff). Hunting is not permitted during the breeding season, April to December, and the ERVS quota was only partly filled with seven large male crocodiles being killed by their clients, including one giant of 18 feet seven inches (5.57m) in June, 2006.

The granting of the crocodile hunting concession was approved by the Zonal Authority (and subject to an annual review based on crocodile census results) who represents the interests of the local community around that section of Lake Chamo and it is has been stated that the activity is sustainable and that it contributes economic benefits to Government and the local community. ERVS are well known for their commitment to conservation and the local communities, however, aside from the hunting fee paid to the Government, it is unclear how the local community benefits in this case. In other populations of the Nile crocodile, large males sometimes represent a distinct danger to people and livestock and their control makes positive conservation sense. However in Lake Chamo crocodiles killing humans and their livestock is at present not an obvious problem. If a ‘problem crocodile’ is identified however, it should definitely be removed in the interests of conservation and continued tolerance by graziers and fishermen.
There are several reasonable arguments against trophy hunting of big crocodiles in Lake Chamo including the fact that an unknown number of big adult males and females are already drowning in gill nets each year (nine of Africa’s largest known Nile crocodile skulls on display at AMCR and AP Headquarters are said to all be victims of gancho nets) and because of our almost total lack of knowledge of crocodile population dynamics here. Perhaps the most cogent of all reasons is the importance of these huge male crocodiles (to our knowledge unrivalled anywhere else in Africa and which have taken perhaps 50 years to reach these impressive sizes) to the genetic input and tourism industry on the lake. Large crocodiles over 5m in length make up perhaps only about 2.5% (50 animals) of the population in Lake Chamo. In the considered opinion of this consultant, and generally shared by a majority of stakeholders questioned on this issue, it is felt that the trophy hunting concession for crocodiles on Lake Chamo could at this time

be detrimental to the goals of crocodile conservation and development of tourism here and should not be continued without a detailed study and evaluation.

NEW CROCODILE RANCHES PROPOSED/UNDER CONSTRUCTION AT LAKE CHAMO

In a recent development, a four hectare and a ten hectare site have been provided by the local Rural Development Office to Blane, PLC and Malaku, PLC respectively (near the northwestern shore of Lake Chamo) to set up crocodile ranches. These have apparently been licensed by the Zonal Investment Office, but as far as can be ascertained, have not been cleared with, nor permits issued by the Natural Resources, Wildlife Conservation or African Parks authorities. The promotion of an industry dependent on wildlife resources needs to be carefully planned, keeping in mind the serious commitment to consider the Lake Chamo crocodiles as a sustainable resource for the betterment of local conservation and community benefit.

Blane, PLC has requested the AMCR for 3,000 hatchlings from this year's egg collection (outside the NNP area) but their facilities are neither near ready nor are they anything close to being well designed to rear crocodiles. The Crocodile Farmers Association of Zimbabwe provides guidance to and very pragmatically allows their new farmers to start with 300 eggs or hatchlings, only permitting prospective croc farmers to have larger numbers in subsequent years if they can maintain a stock survival average of 80%. Considering the high mortality rates consistently recorded at Ethiopia's only crocodile ranch, AMCR, this is the kind of model that needs to be established here. Because there is no clear management plan for crocodiles in Ethiopia as yet and also considering the country's commitments under CITES, it would be best to move slowly and carefully in estimating the potential for and encouraging more crocodile ranches here.

NEST SITE LOCATIONS AT LAKE CHAMO

Nest sites (based on ecological zonation as per Bolton, 1984 and revised by us)
Zone 1 (Nechsar National Park) GPS coordinates for the below listed sites are given in Table 8 in the Appendices. 2004 figures are approximate and provisional.
Chamo Markeptave (near Fisheries and A.P. Boat Landing) – up to 35 nests collected in 2004. Much of the 80m, flat, black sand/grassy shoreline nesting area submerged in December, 2006 by unseasonal rains. Five nest holes observed with evidence of predation. Excellent juvenile habitat adjacent to the nesting area.

Kulfo Island (banks just West of the Kulfo River mouth) – up to 45 nests collected in 2004. Most of the 60m black sand shoreline (edged by vegetation) submerged now (since before the nesting season) with a layer of silt from the Kulfo River overflow, and no evidence of nesting. Intensification of farming and cattle grazing here is already a likely detriment to crocodile nesting in this very significant crocodile area within the NNP (with considerable suitable habitat for juveniles).

Crocodile Market –up to 15 nests collected in 2004. Some nesting on the 120m black sand bank behind the area where large numbers of crocs bask at low water but much of the nesting habitat was submerged in December, 2006 (and remains so). Here too there is plenty of habitat for juvenile crocs.

Zone 2 (NNP)
Gandjulle Island (northern and eastern shores only) – up to 20 nests collected in 2004. Sloped, black sand/gravel prime nesting area, about 350m long and not subject to flooding at high water, with a consistent population of 40 to 60 adult crocs. One of the most important nesting areas in the lake though there is very little alternate habitat suitable for juveniles except for some patches of reeds and water grasses on the northwestern shore.

Gadabonke (near Arfaide Game Scout camp) – a small area of black sand and grass surrounded by boulders. 12 nests collected in 1988 but not since then. Evidence of old nests (shells and excavations) and presence of several adult crocodiles. Disturbance by Scout Camp could be a detriment to nesting here. There is good habitat for juveniles here.

Sandaka (small cove with heavily vegetated banks) – nesting in the past here but no evidence now.

Zone 3 (NNP)
Belte is a strip of dark sandy beach, much of it grass-covered), heavily vegetated and an important place for crocodiles in an otherwise mainly rocky, wind-prone zone with very little suitable habitat for juveniles. 48 nests were collected here in 1988, but not since, and some evidence of nesting now.

Zone 4 (NNP)
Gandulo (Gint Camp) is a 107m strip of black sand beach with little vegetation – 16 nests collected in 1989 and 29 nest holes observed in 2006 (Whitaker,2006), considerable evidence of nesting now but no significant habitat for juveniles.

Sagen/Meo is a 150m long, wide light sandy beach with little vegetation and once the site of the only river that drained from Lake Chamo (but not since 1980). 58 nests were collected here as late as 2000. Up to 15 nests collected here in 2004 but surprisingly little evidence of nesting now. Recent disturbance by fishermen could be to blame. There is minimal habitat for juveniles here.

There is a small pool about a km inland from the lake on the now dry Meo riverbed. Now there is evidence of a single nesting female there and one recent nest, dug up by predators. When the river was flowing this would have been one of the most important juvenile croc habitats on this part of the lake.

Zone 5
Gollole (Nos. 1 and 2) consists of several strips of fine light sand 20 to 50m in length, with sparse vegetation. 60 nests collected here in 1988 and up to 15 collected in 2004.

Some evidence of nesting, but highly disturbed by fishermen till last year. This important area of fine sandy nesting beaches is not within the NNP and needs to be protected. From here southward there is significant habitat for juvenile crocs but the proliferation of gill nets negates this.

Tashala consists of former beaches now completely covered by vegetation with a fish camp near by. 20 to 50 nests collected here in the past but no evidence of nesting now.

Alfacho was formerly an important concentration of crocs but is now heavily disturbed by graziers and fishermen. An unknown number of nests found here in the past.

North Gatra is a grassy area with sand underneath, few trees, an exposed beach when the lake is low and a fishing camp nearby. Up to 26 nests collected here in the past, but there is no evidence of nesting now.

Gatra is also grassy with sand underneath, few trees and fishing camps on both sides. Up to 40 nests collected here in the past, but no nesting evidence now.

Suga was a major concentration of crocodiles in the past and now a heavily fished area with several large fishing camps. 25 nests were collected here as late as 1997 and the southernmost nesting area detected on the eastern shore of the lake, important because it is part of one the swampiest areas of the lake, ideal for juvenile crocodiles.

Zone 6
This is a primarily swampy (in some place the reeds, bullrushes and grasses form a belt perhaps 100m wide) and heavily fished area with considerable agriculture and pastoralists. There have been no nests detected in this Zone but considering the swamp's proximity to former nesting habitats on the southeastern shore (now mostly occupied by fishermen) and importance as habitat for juvenile crocodiles, it needs intensive surveying and protection.

Zone 7
This zone is without doubt the most important crocodile breeding area outside of the National Park-despite considerable disturbance by fishermen and pastoralists-and most urgently in need of protection. It consists of two bays, both locally called Bolle. For convenience, we have differentiated one as Little Bolle, which is a small and moderately disturbed, very beautiful bay with limited habitat for juvenile crocs and the southernmost nest sites on the western shore. The other we've called Big Bolle, which is large with a heavily disturbed shoreline containing a large area of swampland. A high (38%) overall predation rate on croc nests was observed here in the 2004 egg collection season, the Nile monitor being the likely main perpetrator (Gebre, pers.comm).

Little Bolle No.1 is a black clay, gravel and grassy embankment, an important crocodile basking bank and now mainly submerged. Up to 4 nests found here in the past.

Little Bolle No.2 is a very steep open area with stony gravel, high above the water line and it's use by nesters, even though seemingly not optimal, may have been intensified by this year's submergence of other nesting banks. About 14 nests were collected here in 2004. High level of predation noted .

Little Bolle No.3 is a black clay/gravel 'beach', bordered by shoreline reeds and other vegetation at the extreme northeastern end of the bay (good juvenile croc habitat). This is the most important nesting area in Little Bolle Bay with about 64 nests collected here in 2004, (about 70 this year) with a high level of predation noted. Being low on the shoreline it could be prone to submergence in years of high rainfall and high lake levels.

Little Bolle No.4 is a steep, stone and gravel landslide from the escarpment, seeminglyt not ideal for croc nesting, but the only option on an otherwise rocky shoreline. About 12 nests collected here in 2004 and high predation noted.

Little Bolle No.5 is another landslide which created a sandy/gravel site on an otherwise very rocky substrate shoreline. About 42 nests were collected here in 2004 and this is the most concentrated nesting ground observed on the lake with nest holes often just half a metre apart.

Big Bolle is a large, heavily disturbed area with fishermen and graziers. On the southern shore of the bay there are several small areas with sand/gravel banks suitable for nesting with adjacent swampy habitat perfect for juveniles along the western shore) but the presence of fishing camps would deter crocs from nesting here in large numbers. Up to 15 nests have been found in the past and there is some evidence of recent nesting.

Zone 8

This zone has never been adequately surveyed for nesting though there are at least two important concentrations of crocs here. Nesting has been reported near the Mazoria (Sagoein) river mouth in cornfields which were once the lake shore below Badena hill (which was once an island). Intensification of farming here is a detriment to crocodile nesting. The other concentration of crocs in this zone is at the mouth of the Sille River which should be surveyed for nesting sites. The shoreline of this zone has significant swamp vegetation suitable for juvenile crocodiles.

Nest location/collection data from past records and interviews

NOTE: Numbers of nests do not reflect total nesting effort for the year but only those which were collected, which depended on the number the AMCR decided to collect that year and the timing of when the collectors arrived at the nest sites (late arrival means high rates of predation and difficulty in finding nests).

Table 7. Previous nest location/collection data

	1987*	1988*	1989*	1990*	1997*	2000*	2004**
Gololle	32	60	49	16	--	--	--
Belte	15	48	20	--	18	--	--
Meo/Sagen	44	16	29	29	73	58	20
Gadabonke	--	12	--	--	8	--	--
Gandjulle I.	--	23	43	17	17	--	20
Suga	--	--	37	--	25	--	--
Gandulo	--	--	16	--	--	--	--
Abaya Beach	--	20	29	--	--	--	--

(During the Feb. 2007 survey there was no sign of recent nesting at this L.Abaya site)
* From the record books at the AMCR
**From interviews with AMCR staff, figures are approximate.

Table 8. Nesting location coordinates at Lake Chamo (decimal degrees)

REFERENCE NO.	ZONE	N	E	NAME OF SITE
1	IV	5.85417	37.63194	Sagen
2	IV	5.87207	37.63088	Gandulo
3	VII	5.77076	37.46776	Little Bolle1
4	VII	5.77072	37.46776	Little Bolle2
5	VII	5.76918	37.46838	Little Bolle3
6	VII	5.77287	37.47181	Little Bolle4
7	VII	5.77287	37.47181	Little Bolle5
8	VII	5.78132	37.46533	Big Bolle
9	II	5.93017	37.57867	Gandjulle Island
10	V	5.75318	37.55821	Suga
11	V	5.79046	37.61294	Alfacho
12	V	5.82037	37.63299	Tashala
13	V	5.83233	37.63682	Gatra
14	V	5.84788	37.63425	Gollole #1
15	V	5.85766	37.63583	Gollole #2
16	IV	5.85756	37.63573	Meo
17	III	5.93074	37.63731	Belte
18	II	5.96990	37.59542	Sandaka
19	II	5.96989	37.59549	Gadabonke
20	I	5.92581	37.53671	Chamo Markeptava
21	I	5.91354	37.54983	Kulfo Island
22	I	5.91570	37.55736	Crocodile Market

Sampled nest details, Lake Chamo
Two nests were sampled during our surveys which fall within the ranges of findings at other Nile crocodile locations in Africa (Modha, 1967; Pooley, 1982, etc).

Nest No. 1 Location: Gandjulle I. Clutch size: 24
Distance from water: 4.4m Distance from next nest: 5m Height above water: 80cm
Egg size average: 68.9X45.4mm Egg weight average: 104gm

Nest No. 2 Location: Gandulo Clutch size: 42
Distance from water: 10.9m Distance from next nest: 2m Height above water: 1m
Egg size average: 74.1X47.3mm Egg weight average: 122gm

RECORD NILE CROCODILE SKULL LENGTHS FROM LAKE CHAMO

Length is measured from nose tip to rear of occipital platform and these skulls, mainly salvaged from adult males which were drowned in gill nets in Lake Chamo over the past several years, apparently exceed in size the largest on record in museums around the world. The ratio of skull length to total length of the crocodile for these outsized animals is not clearly known, but could be about 1:8 to 1:9, based on a few examples of large crocodiles where the total length was taken. This means that the largest of these crocodiles were in the range of 5.5 to 6.2m (18 to 20feet), making them among the largest Nile crocodiles ever recorded.

At African Parks HQ:
1. Skull length: 69.2cm
2. Skull length: 68.9cm

At Arba Minch Crocodile Ranch:
1. Skull length: 68.6cm
2. Skull length: 67.9cm
3. Skull length: 67.3cm
4. Skull length: 67.0cm

NILE CROCODILE BIOLOGY NOTES

Staff at the Arba Minch Crocodile Ranch have been collecting data on crocodile nesting for more than 20 years and though most is unpublished, it is a valuable beginning to what will hopefully become a full-fledged Lake Chamo crocodile breeding biology database. Their summarized data, together with what we know about Nile crocodiles from research carried out in other African countries, is noted below to provide a general outline of the biology of the species at Lake Chamo:

Mating season: September/October
Nesting season: December/January (driest season)
Hatching season: March/April (onset of rains)

Size/age of female at sexual maturity: 2.5m/12 years
Size/age of male at sexual maturity: 3.5m/15 years

Maximum length/age of female: 4m/60 years
Maximum length/age of male: 6m/80 years

Range and average clutch size: 25-70 eggs, average: 45 for Lake Chamo

Clutch size increases and is directly proportional to female size/age

Average fertility in nests: first nesters 20 to 50%, reaching 80 to 90%

Nest losses to predators (mainly Nile monitors) which peak at laying/hatching times: 38 to 50% (or more)

Food:
Hatchlings: acquatic and terrestrial insects (many of which impact fisheries by eating fish eggs and fry), tadpoles, small frogs

Juveniles: insects, frogs, small fish

Subadults: frogs, fish, birds

Adults: fish, birds, mammals, reptiles

Population recruitment: An adult population of 1000 males and females is likely to require only about 100 to 200 new members each year to replace those dying naturally (Graham, 1976). However, since an unknown (but possibly large) number of Lake Chamo adults are dying unnaturally in nets each year, recruitment would have to compensate for these losses.

Table 9. REVISION OF ZONE START/END POINTS ON LAKE CHAMO

ZONE	Relative position	Km Shoreline[1]	BEGINS AT:		ENDS AT:		
-	-	-	N	E	N	E	Major features within zone
I	North	8.9	5.92888	37.53331	5.93090	37.57001	Chamo Markeptava, Fish. Boat Landing, Crocodile Market, Kulfo Is. nesting banks, Kulfo R. (NNP)
II	North	10.4	5.93090	37.57001	5.95278	37.60319	Gandjulle Island, Gadabonke, and Sandaka nesting banks, smaller islands (NNP)
III	Northeast	14.5	5.95278	37.60319	5.88053	37.62981	Belte nesting bank, smaller is. SE of Gandjulle I. (NNP)
IV	East	4.7	5.88053	37.62981	5.83878	37.63581	Gandulo, Meo, and Sagen nesting banks (NNP)
V	Southeast	14.1	5.83878	37.63581	5.76098	37.56815	Suga, Alfacho, Tashala, Gatra, and Gollole nesting banks
VI	South	19	5.76098	37.56815	5.75945	37.47108	Southernmost portion of lake
VII	Southwest	10.9	5.75945	37.47108	5.79818	37.47931	Little/Big Bolle group of nesting banks
VIII	West/Northwest	21.8	5.79818	37.47931	5.92888	37.53331	Sagoein and Sille R. mouths

[1] will vary with season and year according to lake levels

[2] GPS locations were taken with a UTM 37-N projection, Adindan datum, in decimal degrees, future croc surveys should use these parameters for comparison with current work but may need correction since lake levels will vary After setting the GPS to appropriate local time, Projection (UTM Zone 37) and Datum (Adindan) tracks ("bread-crumb" trails) were enabled on the GPS, at a recording interval of every two-five minutes to record day and night survey routes while waypoints were used to mark specific locations of interest, such as fishing camps, nesting banks, and river mouths. Shapefiles (compatible with ESRI's ArcView) of fish camps, nesting sites, and day/night survey routes are given on CD. Time between the GPS and a digital camera was synchronized, and digital photographs were taken of shoreline habitat, so as to be able to relate location on the lake to a picture of the habitat at a later date. An attempt was made to develop a land cover classification of the shoreline (with 200 meter buffer zone) based on a Landsat ETM + image captured in 2000, but because the satellite imagery represented conditions in January 2000 with a higher different water level than in January 2007 this was not possible.

Table 10. Differentiation of shoreline habitat based on potential utilization by hatchlings for feeding/refuge areas

Lake	Habitat	Km	% of Shoreline
Chamo	HM	83.7	80.3
-	HM2	9.6	9.2
-	R	11.0	10.6
Abaya	HM & NB	41.2	78.9
-	R	11.0	21.1

- HM= Hatchling habitat; reeds dominate
- HM2=Hatchling habitat; reeds secondary to larger water tolerant shrub
- R=Rocky shoreline (unsuitable hatchling habitat)
- NB= Current/potential nesting banks

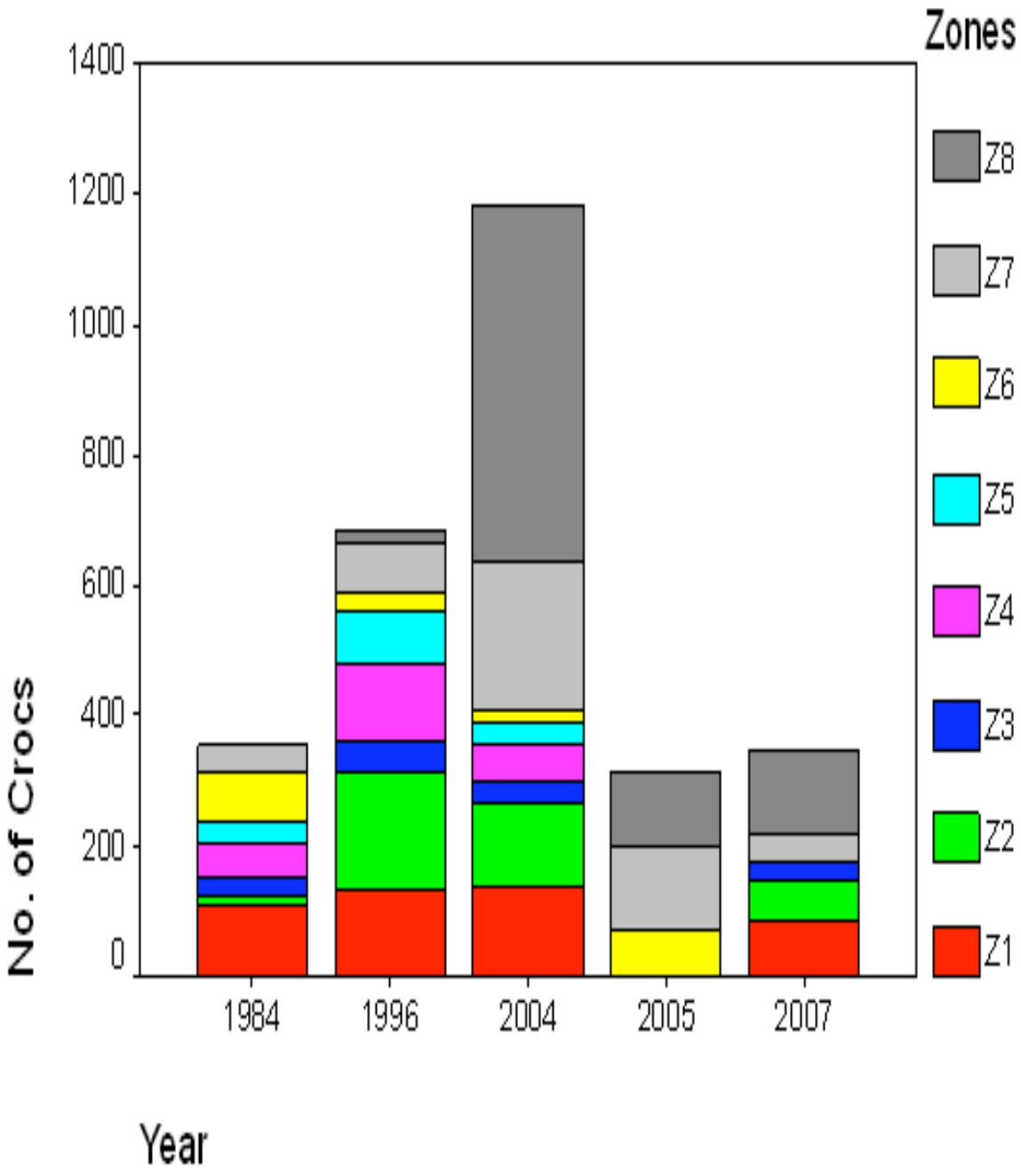
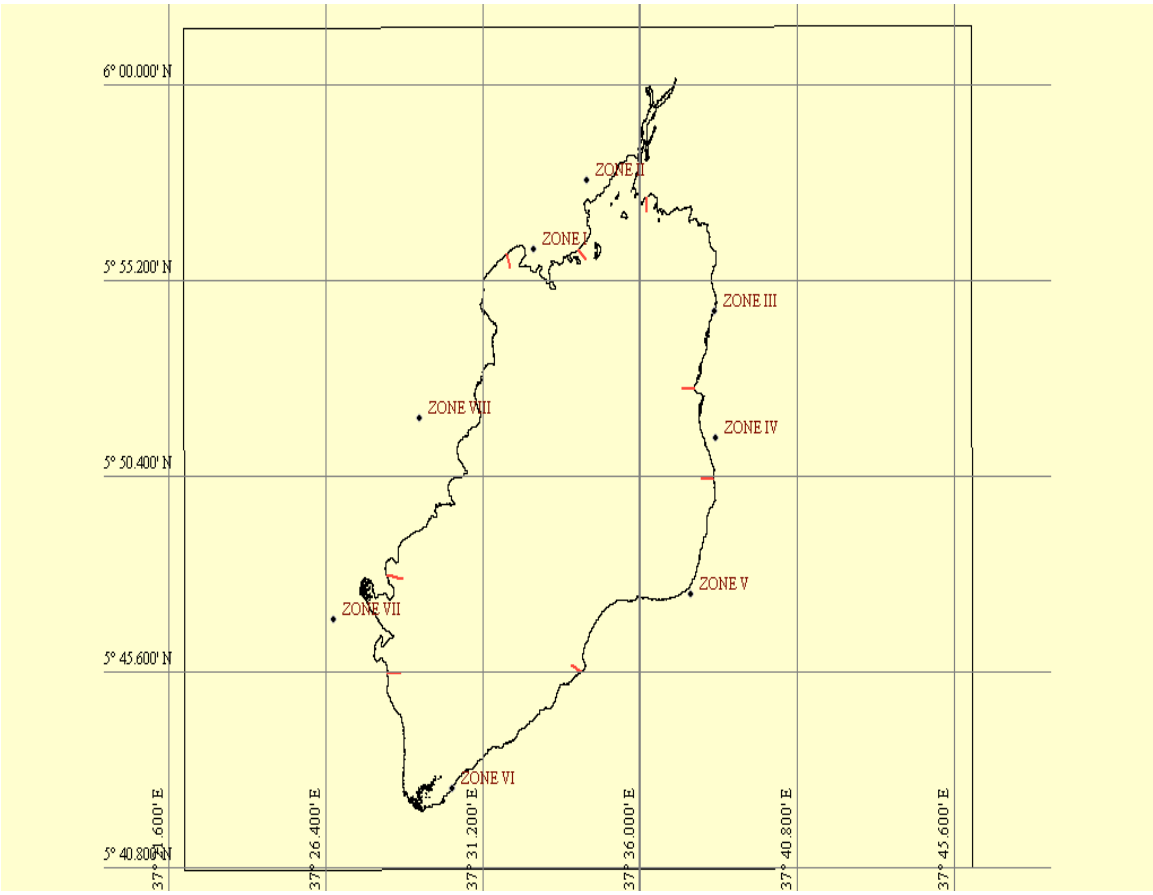


Figure 1. Comparison of day survey census by zone between 1984 – 2007



Zone	Number of crocs seen in daytime*	% of crocs seen in daytime	Number of fishing camps	% of fishing camps	Number of nest sites	% of nest sites
I	155	24.8	1	5.9	3	13.6
II	104	16.7	0	0	3	13.6
III	50	8.1	0	0	1	4.5
IV	11	1.2	0	0	3	13.6
V	0	0	4	23.5	6	27
VI	0	0	4	23.5	0	0
VII	68	10.9	2	11.8	6	27
VIII	236	37.82	5	29.4	0	0
Total	624	-	16	-	22	-

Figure 2. Summary of zones (demarcated by red lines on map), number of crocs seen in daytime with CF applied, number of fish camps, and number of nest sites.
*With correction factor of 1.8 applied and rounded to nearest number

CROCODILE RESEARCH REQUIREMENTS

A. Research on the Wild Nile Crocodile Population

Below are suggested areas of priority research (**in bold type**), to form a basis for the management plan for Nile crocodiles on Lakes Chamo and Abaya. Section A. refers to research on the wild population and B. refers to studies to improve captive husbandry knowledge/practice to be conducted on site at the Arba Minch Crocodile Ranch (AMCR). The role of the proposed Crocodile Conservation and Management/Research Coordinator (see Recommendations) would include design, analysis, supervision, and incorporation of these research results into formats suitable for use by the management authorities.

1. **Population biology**
a. Size specific partitioning of habitat use
b. Using mark-recapture to assess survival, growth, and movements of the various size classes
c. Remote measurements of crocs to estimate size (including aerial surveys)
d. Estimates of croc size based on clutch size, scat width, nest depth
e. Mapping basking sites, monitoring seasonal/annual changes/disturbances

2. **Reproductive biology**
a. Loss of nesting habitat and nesting in marginal habitats
b. Pesticide levels in eggs
c. Temperature regimes of nests, impacts on sex ratios and egg survival
d. Identifying individual females to ascertain nest site fidelity
e. Nest predation and predator identification
f. Nest site distribution compared to nearest available hatchling habitat
g. Nest studies: distance to water/tree line, nest depth, distance between nests, % flooded/other losses, clutch fertility, egg sizes, mapping nesting banks and changes that occur during incubation
h. Nest site habitat manipulation (brush and grass clearing) and results thereof
g. Percentage/degree of nest protection and crèche formation by females and relation to survival of hatchlings

3. **Anthropogenic impact related studies**
a. Study Kulfo/Sille/Sagoein river mouths for seasonality, fish spawning, temperature, concentrations of crocs, hippos, and birds
b. Impact of agriculture and associated soil runoff on river flow into lake
c. Loss of large numbers of crocodiles by drowning, size classes and net types, net placement, time of day/night
d. Spatial association between fishing camps and nest sites respective to nesting effort
e. Impact of cattle grazing/cattle camps on existing/potential nesting sites
f. Human and livestock/crocodile conflict
g. Crocodile friendly fishing methods and impact on fish catch/effort

h. Quantitative analysis of fish catch over time (tonnage and species wise occurrence); changes by increasing protected/closed areas
i. Soft rearing and soft releases (minimizing human contact) to determine avoidance behaviour and survival of releasees; marking/tagging and monitoring

4. **Special interest/management related studies**
a. Blood/internal/external parasites
b. Impact of seasonal/annual variation in lake levels and associated shoreline on visibility of crocs
c. Social and basking behavior studies (daily and seasonal variation)
d. Feeding ecology employing fecal analysis and stomach pumping; prey preference in different size/age classes
e. Shoreline land use/land cover mapping using remote sensing data and GIS
f. Facilitating land use decisions using GIS and stakeholder inputs
g. Hippo and crocodile distribution and behavioural/ecological relationships

B. Research on the Captive Population of Nile Crocodiles at AMCR, Related to Ranching

1. **Veterinary science**
a. Blood chemistry
b. Post mortem database
c. Disinfectant trials
d. Skin quality: bacterial infection, scrapes, scars, nematodes
e. Vitamin D3/calcium deficiency/sunlight
f. Nutrition analysis (on croc feed)

2. **Egg incubation**
a. Developing simple, cost-effective incubators (using solar and green-house systems) for early collection of nests and transport to Ranch hatchery
a. Developing a embryonic staging scheme for aging Nile croc nests
b. Trials with varying temperature, media, hydric environment to improve hatching success
c. Crocodile egg chemistry changes through incubation
d. Temperature Sex Determination (TSD)

3. **Management / Development**
a. Design of natural/root-zone filtration system for effluent outflow from ponds
b. Development of landscaped Ranch area, exhibits, a good interpretation/education centre/gift shop for visitors

C. Research and Surveys on Crocodile Occurrence and Status in other Lakes and Rivers in Ethiopia

Pooley (1982), listed the places where crocodiles were still to be found in Ethiopia up to 1980, mentioning that most populations were already depleted or completely extirpated

by commercial hide hunters by then except in the Omo River. Below is a list of the places he mentioned which might be re-examined in the hopes that crocs have survived in some of them and recovery programmes could bring them back to resource status for ranching and/or tourism:
Rivers: Webi Shebeli, Daina Parma, Ganale Doria, Omo, Baro, Gilo, Akobo, White Nile, Blue Nile, Dedessa, Belles, Anger, Awash, Alurero.
Lakes: Dipa, Hertale, Cadobassa, Murle, Ba.

NOTES:
Omo River
A 1987 aerial survey of about 100 km of the Omo River in Omo National Park revealed relatively high densities of crocs (259 crocs over 1.5m total length on one bank only). In the year 2000, a rainy season (post-hatching) night survey by boat on 87 km of the Omo River revealed an unspecified number of adult crocs plus "several thousand" hatchlings, mostly in the seasonal Lake Dipa adjacent to the river (Assegid Gebre, pers.comm.).
In a daytime sample survey of 30km (of the 157.5 Omo river stretch) of the Murulle Controlled Hunting Area a total of 128 crocodiles of all sizes were seen, for a density of 4.26 crocs/km (Wakjira, pers.comm.). These observations indicate that there could be considerable potential for a crocodile ranching project to benefit local people of the area, using the waste from the large nearby fishing industry. This should be examined as early as possible.

The Coordinator of a PACT, Ethiopia project in Gambella region reports that crocodile attacks are a serious problem in the Baro River and assistance in solving the problem has been requested (Jody Henderson, pers.comm.).

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