Population and Habitat Viability Assessment (P.H.V.A.) Workshop for Gharial

REPORT

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EXECUTIVE SUMMARY

From 16-18 January 1995 a Population and Habitat Viability Assessment (P.H.V.A.) Workshop for Gharial was held at Jiwaji University, Gwalior. It was attended by an assembly of wildlife field managers, captive management specialists, gharial researchers, university professors and NGO's / NGI's.

Twenty years ago — in 1975 a Crocodile Project was initiated in India. This programme included conservation of three threatened species of crocodilians, including gharial a species of immense scientific interest. After two decades of conservation and significant progress, some researchers and wildlife officers felt that the work lacked a well-defined direction. There were accompanying concerns about the actual success of the conservation measures so far implemented, and the fate of the species in the near and distant future. Recent decisions to terminate supplementation of wild populations withdrew active assistance towards recuperation, of the species. Concerned researchers and managers felt that a systematic assessment of the current status of the species following the years of harvest, supplementation and other management strategies was necessary at this time.

After consultation with leading crocodile experts and institutions of the country in states like Orissa, U.P., Tamil Nadu and M.P., the PHVA for Gharial was initiated by the School of Studies in Zoology at Jiwaji University which has been involved actively in research activities and conservation of this species since ten years. The Madhya Pradesh Forest Department came in as a co-organiser. The Ministry of Environment and Forests, Government of India agreed to sponsor the Workshop. The Zoo Outreach Organisation/ CBSG, India agreed to facilitate the Workshop.

Population and Habitat Viability Assessment, developed by the Conservation Breeding Specialist Group, SSC, IUCN, is a process for assessing extinction risk for a species and for developing management recommendations to enhance long-term survival. PHVA workshops are conducted in the range area of the species in collaboration with wildlife agencies of the area. Also included in the PHVA process was an evaluation of the status of the species in captivity, projected plans for re-introduction, and issues requiring collaborative research.

In this Workshop issues and concerns of gharial were discussed in a combination of small working group sessions alternating with plenary discussions. The Working Groups were: Census and Distribution Group, Habitat Group, Modelling Group, Threats Group, Captive Management and Disease Group, Education/ Awareness/Human Interaction Group, Trade Group, and Reintroduction Group.

The Census and Distribution Group reviewed the information collated by the researchers and field managers. In the past two decades about 4000 gharial have been released into 12 rivers in four states under the "Grow and Release'' programme in which eggs were collected and hatched and hatchlings reared to sizes which increased the probability of their survival. While there is every indication that this Programme has made the species secure in certain areas, there was a conspicuous lack of information in other areas.

This Working Group recommended that the Annual Census be done in every area, using a more standardised methodology, and taking the help of local people and other volunteers for whom briefing sessions, and literature would be organised. It was also recommended that a Central

Coordinating Unit be established which would provide a mechanism for better interaction between the different states and agencies involved in conservation activities for gharial.

The Habitat Group defined the various components (with particular emphasis on prey availability) that make up an "ideal" habitat, which constitute the criteria by which suitable reintroduction sites could be identified in the future. Sites which fall outside protected areas but are felt to be highly suitable and stable or those which migrant gharials are trying to recolonise, should be protected under the Wildlife (Protection) Act. International cooperation for better management of metapopulation is recommended for habitats extending across international borders.

The Modelling Group simulated gharial populations over a wide range of sites and under various conditions. The three populations — Chambal, Mahanadi and Katheriniaghat—are in different degrees of stability. The Chambal population is stable and can even withstand a yearly small harvest for genetic supplementation of other populations if there is need. A review of the Chambal population is recommended before five years and after collection of some more information. The Mahanadi. population, while appearing relatively stable, suffers from a larger number of more potentially catastrophic threats. Extensive studies need to be done on these threats and the population needs to be thoroughly assessed again before five years with additional data. The Katheriniaghat population is very small and unstable, and requires continuous supplementation in order to be sustained at all. Genetic studies for diversity and for variability are crucial for all populations.

The Threats Group identified 10 direct and 8 indirect threats and identified that gharial populations of Mahanadi River was the most seriously threatened. It was felt that the Ramganga population least affected by such threats. It was noted that threats to gharial in unprotected areas such as fishing sand mining, river side cultivation and industrial pollution can be controlled best by education/ awareness activities. It emerged from the Modelling exercise that inbreeding could be a more serious threat than previously considered.

The Captive Management and Disease Group assessed the ability of existing captive facilities to breed and rear gharial for future, either for supplementation of wild or for provision to zoos for exhibition and education. They concluded that all these facilities taken together could generate a spatial capacity to propagate as many as 4000-5000 animals per year if required. In this scenario, a coordinated, scientific breeding programme is necessary. The Group recommended that the zoos holding gharial should create or upgrade gharial enclosures so as to be more educationally relevant and more mindful of the welfare of the animals. Those zoos which are identified as breeding or holding units for conservation may be suitably improved.

The Trade Group assessed the request of some agencies for an. opinion on the opening of trade based on utilisation of Gharial**.** The Group felt that conservation of Gharial would not be improved by opening of trade and in fact could be seriously damaging. The Group affirmed other effects of opening trade also, e.g. that it would convey a wrong signal for conservation of wildlife in general, offend the cultural and religious sentiments of a large portion of the population, and even contradict Article 5/A of the Constitution of India.

The Reintroduction Group endorsed the contention of the Census and Distribution Group as well as that of the Modelling Group that regular supplementation should be maintained without significant reduction. However, it was felt that the age of the animals when released and the sex ratio may need to be redefined according to scientific research input. Frequent and consistent monitoring to determine habitats in which populations had responded favourably to supplementation with captive reared animals is recommended**.**

The Education Group identified several target groups, including the people who are most affected by gharial conservation, e.g. fishermen**.** They suggested methodology suitable for each, target group and recommended a drastic upgrading of public education with respect to gharial conservation. The PHVA participants agreed that lack of public education had been a major lacuna in the Crocodile Conservation Programme.

AMALGAMATED RECOMMENDATIONS OF P.H.V.A FOR GHARIAL

General

A National Action Plan should be prepared under the auspices of the central coordinating unit incorporating sub-plans for each major river system. Comprehensive management plans should be prepared with recommendations for these areas as well as for Protected Areas that already exist for gharial and these plans implemented to minimise irreversible limiting factors.

A second PHVA for gharial should be held within three years, after some of the recommendations have been implemented and more facts about the biology of the species have emerged.

The research base of every range state of Gharial needs to be strengthened and additional resources made available for this in view of the importance of the species and its habitat. On grounds of logistic advantage and presence of trained and experienced manpower, the Zoology Department at Jiwaji University, Gwalior should be encouraged to grow as a National Centre for Gharial research, with Gharial rehabilitation Centre at Deori (Morena) being revived as a vibrant field research station.

The Government of India, the range states of gharial, and the zoos and captive rearing centres holding gharial should utilise the occasion of the 20th anniversary of the Crocodile Project to highlight the success of the project, the need to continue protection of gharial and the importance of gharial to the aquatic ecosystem. Government of India should mark this anniversary in an elaborate manner, bringing out posters and brochures reviewing the Project and suggesting future directions.

Population Biology (Modelling)
General recommendations for all three populations:

1. Systematic monitoring of all gharials is to be carried out to record longevity, age of first reproduction**,** sex ratio and other basic biology.

2. DNA finger printing is recommended for all populations to better understand the genetic make up and the effects of population battle neck.

3. If the populations have retained sufficient genetic diversity between them, Katerniaghat and Mahanadhi populations are supplemented with gharials from Chambal.

4. Effects of threats must be studied in detail so as to reduce the causes and the impact of these threats.

i) Chambal population

1. Subpopulation within the Chambal population must be studied for migration by monitoring their movements to understand the dynamics of the population.

2. Harvest of eggs should be done giving due consideration to the requirement of other populations. The Chambal population can withstand a harvest of maximum 500 eggs every year.

ii) Katerniaghat population

1. Continuous supplementation is recommended to insure viability of the population.

2. Gharial juveniles of minimum age 4 years and above should be released to reduce post release mortality.
3. Monitoring of the juveniles must be carried out once they are released.

iii) Mahanadi population

1. Continuous supplementation of the Mahanadi population over the last 19 years has in fact helped the population avoid total extinction. Although continuous supplementations were carried out, however, the population has not stabilized. Even though the simulation model showed no extinctions in the populations, high degrees of threats can push this population to extinction. Supplementation must continue to be carried out.

2. Studies on threats and their effects must be made in detail. This will help understand the actual role such threats play on the dynamics of the population and also help reduce this cause.

Census and Distribution

Annual census must be conducted. Habitat status with respect to basking and nesting sites should be surveyed at the time of annual census and possible occurrence of changes monitored by compiling habitat field maps.

All participating state agencies should have effective coordination. Annual census by different agencies should be well coordinated and a permanent central, coordinating unit should be created.

Comprehensive maps showing distribution of gharial (i) historically, (ii) before initiation of the project, and (iii) current population strength should be prepared and made available to census agencies. These should be updated on the basis of census results.

A brief brochure dealing with census techniques should be prepared for distribution to the agencies and individuals associated with the census with the idea of optimising

survey and census techniques. The possibility of making these more accurate can be explored, in workshops to be conducted periodically.

NGO's and other interested individuals should be motivated to participate in survey and census work and a network of participants to conduct annual census of gharial throughout its country wide distribution built up. A briefing session should be organised in sector levels for all the participants before census.

Habitat

Availabilty/status of habitat be assessed by trained surveyors on the basis of identified qualifiers. Such habitats outside protected areas which are identified as highly suitable and stable, or those that gharial migrating out of P. A.'s attempt to recolonise be protected under the Wildlife (Protection) Act.

Habitat extending across international borders necessitates international cooperation for management of metapopulations which occur in such habitats. Several important gharial populations are affected by impediments arising from lack of coordination between India, Bangladesh and Nepal.

Threats

Identify community nesting areas and provide protection to the nests to reduce the risk of predation. As there are many gharial in unprotected areas, threats such as fishing, sand mining, riverbed cultivation and industrial pollution can be controlled best by education/ awareness activities.

The computer modelling exercise indicated that a lack of heterozygosity resulting from inbreeding may be a problem in some populations. Also very little is known about the age structure of the populations. As no genetic management has been considered in release programmes to date, it is strongly recommended that managers take cognisance of genetic and demographic factors.

Operation of irrigation and hydro-electric structures should be examined for possibilities in their modification to facilitate proper Gharial management and the construction of migration routes for river life are incorporated into the planning of future projects.

Trade

Although there is no significant trade in gharial, it is still important to educate the local people in and around gharial habitats. This will promote awareness to stop illegal local trade, which takes place from time to time for non-tannery products such as eggs, meat and medicinal biomaterial. Training of enforcement officers (customs, local policemen and forest dept.) to help them in identifying derived products should be done.
Although there has been substantial pressure from international bodies for opening up trade in crocodilian products in line with the conservation strategy of sustainable use, it was strongly felt by the Workshop participants that opening of trade in India, at least at present, is not justified. It would create unwanted results which, on balance, would negate any economic or social benefit generated by opening of trade, especially for gharial.

The requests which have come from within India for opening up of trade in crocodilian products in recent years stem in part from the surplus animals which exist with different agencies which bred them in anticipation of need. Zoos and rearing centres should therefore rear only such numbers of gharial as are required for exhibition or supplementation. In the case of accidental surplus accumulated “in good faith” and not required for conservation due to unavoidable circumstances, the Government of India may consider undertaking support of the animals for the rest of their natural lives.

Reintroduction

Releases for supplementation should be made at a standard optimum size. This exercise should be supplemented with scientific research input accompanied by frequent and consistent monitoring.

Releases must strictly adhere to the accepted norms of release except when there are species-or habitat-specific variables which require different norms.

As a result of the modelling exercise which was done on. Katerniaghat populations as well as scrutiny of results of 20 years of supplementation of wild populations with captive reared animals, the view of the group was that long-term survival of gharial could not be assured without continued supplementation.

Captive Population / Disease Group

Individual identification marking of gharial should be done using a standardised code to facilitate planned captive breeding. Preparation of a studbook should be carried out and maintained with available gharials in zoos/gharial rearing centres.

It is recommended to have detailed investigation with the help of disease diagnostic laboratories to come to definite conclusion about the disease responsible for mortality and to find out the proper prescription for cure.

Detailed investigation with the help of disease diagnostic laboratories should be carried out to arrive at definite conclusions about diseases and causes of mortality. Better management practices which include prophylactic measures may be undertaken as well as proper prescriptions for treatment, developed with collaboration between veterinary institutions and captive rearing centre's.

The number of hatchlings to be reared should be decided strictly according to the requirement of the stock intimated by the concerned authorities responsible for reintroduction programmes,

Rearing procedures for hatchlings should be standardised and these standards strictly maintained to ensure maximum production of gharials from eggs produced in captivity. Contemporary research has opened up possibilities of controlling sex ratios of crocodilians produced through temperature controlled incubation. This technique should be investigated with the objective of improving gharial management *in situ* through supplementation if so required.

Education

The PHVA participants agreed that lack of public education had been a major lacuna in the success of the crocodile conservation programme. It was felt that a major initiative should be directed towards specific target groups important to gharial conservation, such as fishermen and others who might have been affected by the gharial programme. Emphasis should be given on the utility of gharial for sustaining the health of the river system and the perilous consequences of its disappearance.

MODELLING

Introduction

One method for understanding the factors affecting the population extinction process is to use population models. A model is a basic tool used to represent or describe, in a simplified and abstract form, a particular process of interest. In the case of the PHVA, modeling is a tool that mimics the processes, by which populations propagate themselves from one year to the next.

A Simulation Model: stochastic population simulation model is a kind of model that attempts to incorporate the uncertainty, randomness or unpredictability of life-history and environmental events into the modeling process. Events whose occurrence is uncertain, unpredictable, and random are called stochastic. Most events in an animal's life have some level of uncertainty. Although we cannot predict exactly what events an individual will experience during its life, we may have a general idea of the range of possibilities for these various events. Similarly, environmental factors, and their effect on the population process, are stochastic - they are not completely random, but their effects are predictable within certain limits.

A simulation model of an animal population mimics actual demographic and genetic events, such as deaths and births, in an explicit time dimension. Both time steps and individuals are usually simulated as discrete and finite. When stochasticity is included in a simulation model, each run may be a unique sequence of events, with different end results in all runs. So, to be able to present both a reliable expected average result, as well as an estimate of expected variations in the result, we need to run the simulation many times, often several thousand times.

Events that are random or stochastic need to be described in terms of both their average value (mean) and their variance, or standard deviation (a measure of the distribution which values can take around their mean). The Vortex computer model, which is the one we use for PHVAs, incorporates factors with uncertain outcomes (stochastic factors) by randomly making a decision about what will happen within the limits as specified by the variance associated with that factor.

There are a host of reasons for why simulation modeling is valuable for the PHVA process. The primary advantage, of course, is to simulate scenarios and the impact of numerous variables on the potential of population extinction.

Population modeling supports consensus and instills ownership and pride during the PHVA process. As groups begin to appreciate the complexity of the problems, they have a tendency to take more ownership of the process and the ultimate recommendations to achieve solutions. Modeling also forces discussion on biological aspects and specification of assumptions, data, and goals. The lack of sufficient data of useable quality rapidly becomes apparent and identifies critical, factors for further study (driving research), management, and monitoring. This not only influences assumptions, but also the group's goals.

Modeling can be used as a tool to create credibility by using technology that non-biologically oriented groups can use to relate to population biology and the "real" problems. The acceptance of the computer as a tool for performing repetitive tasks has led to a common ground for persons of diverse backgrounds.

Population modeling explicitly incorporates what we know about dynamics by allowing the simultaneous examination of multiple factors and interactions - more than can be considered in analytical models. The ability to alter these parameters in a systematic fashion allows testing a multitude of scenarios that can guide adaptive management strategies.

Finally, the tool of population modeling can be a neutral computer “game” that focuses attention while providing persons of diverse agendas the opportunity to reach consensus on difficult issues. The outcome of population modeling can be of political value for people in governmental agencies by providing support for perceived population trends and the need for action. It helps managers to justify resource allocation for a program to their superiors and budgetary agencies as well as identify areas for intensifying program efforts.

The VORTEX model analyzes a population in a stochastic and probabilistic fashion. It also makes predictions that are testable in a scientific manner, lending more credibility to the process of using population modeling tools. This model is designed specifically for use in the stochastic simulation of the small population/extinction process. It has been developed in collaboration and cooperation with the PHVA process. The model simulates deterministic forces as well as demographic, environmental, and genetic events in relation to their probabilities. As do all models, VORTEX has its limitations which may restrict its utility in some cases. In this PHVA every attempt was made to compensate for such limitations and create scenarios to reflect the potential problems of various populations of this species.

POPULATION MODELLING *

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The gharial population simulation models were constructed with input from researchers and field managers working at the gharial sites and rearing centres. Data was also gathered from published literature before and during the gharial supplementation programme started by the Government of India. In some cases where old data differed from that of the more recent studies, a consensus was sought from all the field workers present at the workshop.

Mostly, studies on the Chambal population were taken as a basis on which the biology was worked out. Models were run on a 386, 486 and pentium IBM compatible processor. VORTEX Version 7 was used to construct the models.

The gharial populations were identified to survive in three locations, viz: River Chambal, Katerniaghat and Mahanadi and cases of rare sightings were reported from Ganges, Brahmaputra, Gandak and Narayani rivers. The Chambal population is the largest with an estimated 1100 individuals. Mahanadi is next with 200 individuals and Katerniaghat finally with 54 individuals. Sightings of “a huge male”, “two females and a male”, “one gharial of unidentified sex’’ in other rivers such as Ganga and Brahmaputra were reported by a few researchers. Gharials were once known to inhabit these rivers but have now become extinct. These rivers, however, could have a few individuals along areas of favourable habitat. Flooding of the Chambal causes gharials to wash away towards the main river -Ganges. Some individuals that survive the turbulent waters might have found suitable habitat in parts of Ganges.

Simulation models were run for the three populations of gharials separately.

Basic scenarios

Sex ratio at birth

Studies have indicated that there is a female biased sex ratio at birth in gharials, as in other crocodilian species. The participants were of the view that it varied from 3 to 5 females to every male. Scenarios were run with sex ratio 1:4 and 1:3. Low ratio of 1:2 and 1:1 were also tried in certain cases. Temperature regulation during incubation determined the sex of the hatching.

Life expectancy

There is no record of longevity of gharial in the wild or in captivity. Only one female gharial lived up to 29 years in captivity. The oldest crocodilian in captivity was a mugger that lived up to 45 years. Based on the participants’ view of life span, a low of 40 years and a high of 80 years were tried in the models. Life expectancy of gharial according to some participants was more than 100 years.

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* Dr. Seal was kind enough to read a preliminary report of the modeling and suggest corrections for setting up the model more accurately.

Age of first reproduction

Captive gharials are known to mature at an earlier age of 8 years for females and 10 years for males. However, gharials in the wild mature at a later age. Population scenarios were modelled with age of first reproduction for females at 10 and for males at 13. An additional scenario of lower female age of first reproduction at 9 was also modelled.

Population studies in Katerniaghat showed gharial to mature at a later stage in that river.
Therefore, in case of Katerniaghat population, a scenario of female age of first reproduction at 13 and for males at 17 was modelled.

Mahanadi population was modelled more on the lines of Chambal.

Female fertility

All adult females in the breeding pool reproduce every year. Scenarios with 90% and 92% female fertility were modelled. Breeding records of Gharial from Nepal indicated female fertility rate at 50% annually. This scenario was modelled in almost all the cases.

Male fertility

Territoriality among male gharials has been noticed and the harem system is rather strict. A very limited number of males mature from sub adulthood to adulthood. Fierce fighting with rival males usually results in the death of the weak one or the subdued male moves away from the aggressor. All mature males are known to breed. Bachelor groups in gharial have not been observed.

Clutch size

A minimum of 15 eggs per clutch to a maximum of 65 eggs per clutch have been observed in the wild. Eggs collected from the wild and reared at different rearing centres have been recorded. Frequency of clutch size of 35-45 is the maximum while the frequency of clutches with over 50 eggs is less.

No. of eggs/clutch	Frequency
16-35	20%
36-45	50%
46-65	30%

For the model, a clutch size of 40 was chosen. A smaller size of 30 was also modelled in certain cases. One of the researchers in Chambal noted that recently more number of clutches with 55 and more individuals was recorded. Hence the scenarios were also modelled for 60 eggs per clutch.

Mortality

Juvenile mortality is very high in Gharial. Up to 95% mortality is recorded for juveniles of the age group 0-1 years. Flooding is the main cause for this mortality. Large clutch sizes make up for the high rates of mortality. Juvenile mortality up to the age of 4 years is high. Subadult and adult mortality are very low.

Different scenarios were modelled with varying mortality rates. In all the cases 90% mortality for 0-1 age class was modelled. Standard deviation (SD) for the mortality was entered as 3% for 0-1 age class.

Catastrophe

Environmental catastrophe such as flooding is the main cause for high mortalities. This phenomenon affects only the hatchlings and very young juveniles. The young gharial is washed away to tributaries and creeks where they die due to unfavourable conditions. This factor however is considered in the mortality rates (high juvenile mortality) and is not modelled as catastrophe.

Untimely and sudden opening of flood gates of check dams along the river is a threat to gharials living downstream. Predation from humans and dogs are very negligible. Fishing is also negligible and only accidental. Agricultural practices near river banks is one of the major causes of habitat destruction. All these factors together constitute a major threat and have been modelled as a single catastrophe. A catastrophe with a frequency of 10% with varying effect on survival from 10-55% have been modelled.

For the Mahanadi population, a higher effect of catastrophe has been modelled. This is because of egg collection and high degree of pollution in the river. The model is still conservative as compared to that found in Mahanadi.

Initial population size

The initial population size for Chambal has been modelled for 1100 (present count) and 100 (number at the beginning of the gharial supplementation project). The models were constructed with initial number of 100 odd animals to see the effect of management (harvest/ supplement) on the population structure for the last 20 years. Katerniaghat population was modelled at 55 initial population arid Mahanadi at 200 initial populations.

Carrying capacity (K)

According to researchers at Chambal the habitat is still suitable for an increase in gharial numbers. Since fishing is also minimal, an adequate prey-base is present to hold about 2500 gharials (an estimate that is more than double of the present numbers).

According to the nesting sites observed over a period of time, the numbers of nests have stagnated for the last 3-4 years. Some feel that this might be due to the carrying capacity-limit of 1100 the population has already reached.

Researchers point out that though there is stagnation, the nesting sites have the capacity to hold 12-15 nests of which they are holding only 4 or 5 on an average at present. The prey-base according to them is also adequate for more individuals.

The simulations for Chambal were modelled with a carrying capacity of 1000 and 100 as initial population and with 2500 as carrying capacity to see the effect it had on the population growth. For initial population of 1100, the carrying capacity was 2,500.

Populations of Katerniaghat were fixed a carrying capacity of 100 which was what the researchers thought the habitat could hold. In the case of Mahanadi, it was set at 500.

Harvest

For the models where populations went extinct in a short period of time, eggs were harvested for rearing. The supplementation project for gharial that was done for 18 years involved collecting eggs from the wild, incubating, hatching and rearing them at the rearing centres**.** When the hatchlings were 3-4 years old, they were released back into the river. During the last 18 years, the rearing centres developed expertise in rearing gharial eggs, such that the mortality of the hatchlings was reduced to 40%. Recently, Kukrail Gharial Rearing Centre (Katerniaghat) recorded 100% success in hatching and rearing gharial eggs.

In modeling the scenario, a number two and a half times the initial population was chosen as the number of eggs to be harvested. The model asks for the number of individual to be harvested starting from age 1. Since the eggs in this case would be considered age 'O' the initial mortality of 90% (0-1 age group) had to be calculated as the computer does that automatically to the individuals in the 0-1 age class. Ten percent of the actual number was entered as the number of eggs harvested. For example, for an initial population of 100 animals, 250 was the number of eggs to be harvested. Considering 90% mortality only 25 eggs were entered as being harvested. The scenarios modelled with harvest had the first year, last year and the interval of harvest entered.

Scenarios were also modelled with harvest not accounting the 90% mortality in one case and in another accounting just 40% mortality.

Supplementation

The eggs harvested in year one were reintroduced into the natural habitat as 3 or 4 year old hatchlings during the gharial supplementation programme. Similarly, the scenariosmodelled had supplementation of 3 or 4 year olds into the natural population. Supplementation was started from the third year of first harvest and continued every year for up to three years after harvest was discontinued.

The reason for harvest and supplementation is to reduce the 0-4 age class mortality. Since the rearing centres had achieved 60% success, mortality was brought down by more than 35% in total 4 years when the hatchlings were reintroduced.

In the scenario where 10% of the actual eggs were shown as harvested, a supplementation of 60% of the actual numbers of eggs was entered. For example of 240 eggs, 24 were shown as harvested, 144 hatchlings were supplemented into the population. This difference is to make up for the decrease in the mortality rates.

In other scenarios with no mortality included in the harvest and with 40% mortality in the harvest, supplementation was carried out accordingly.

Inbreeding

Though the Chambal population of 1100 underwent a bottleneck of 107, 20 years ago, the effect of inbreeding was assumed to be either nil or very low since the average generation time for the species is about 20 years. Further, no genetic studies have been carried out for gharial to determine inbreeding either in the wild or in captivity. Therefore inbreeding value was not adopted for the models simulated.

Results and discussion

The scenarios modelled were with the intention to study the population dynamics over the next hundred years by varying fertility rates, mortality rates, catastrophes, population size, carrying capacity, without and with management practice; and with a view to understand what best management action plan needs to he adopted if the population is to survive and retention of more than 90% of heterozygosity.

Chambal population

The scenarios modelled considered the present population structure of gharial and how different variables incorporated affect the dynamics for the next hundred years. A second set of scenarios considered the population

20 years ago. This set was also used as a counter check by verifying its outcome with the actual occurrence in nature. A third set of scenarios were considered that looked at the population 180 years ago and were run for 200 years to see the effects today. Results of all scenarios are recorded in tables 2 to 4.

Initial population size and carrying capacity

Scenarios modelled according to conditions prevailing 20 years ago had an initial population of 100. Carrying capacity for this population was fixed at 1000 or 1100 and
run for 20 years. Population with 100 as initial size went extinct in a short time. Carrying capacity of 1000, 1100 or 2500 did not matter to scenarios run without management practices to this population size.

Scenarios with starting population size of 1100 (present status) were modelled with a
carrying capacity of 2500. Parameters for the scenario were chosen on the basis of validity of results obtained for initial population size of 100 or 107. Populations were also modelled for carrying capacity of 1100.

The scenarios with carrying capacity value of 2500 and initial population size of 1100 showed a very healthy trend in population growth and stability. The populations that were modelled at initial population already at saturation stage (n & K = 1100), they remained stable over the long run. The population showing positive growth rate were truncated at the carrying capacity value.

Mortality

Different rates of mortality were applied to different runs. The 0-1 age mortality was varied between 90% and 92%. Populations with 92% mortality had a higher probability of extinction in populations of initial size 100, though when seen across different populations, this did not matter much. Similarly, the standard deviation for the above mortality was entered either as 3% or 21 %. Population with initial number 1100 modelled with higher SD showed a slower growth rate and those with 100 initial population showed higher rate of extinction. Mortalities were also varied at different age classes in different scenarios. Populations with mortality rates higher in sub adult class were subjected to higher extinctions (initial size 100) and slower growth rates (initial size 1100).

Female fertility rates

Females' fertility rates were tried at 92%, 90% and 50%. The higher the fertility rate, the higher was the stochastic growth rate. Much variation was seen in varying fertility rates only in the 1100 initial populations' scenarios. A distinct decline in the growth rate is seen with decreased fertility rate of 50% (Graph 1). Populations of 1100 however do not become extinct.

Sex ratio

Populations modelled with lower sex ratio of 1:3 showed a nominal growth rate but retained higher heterozygosity at the end of 100 years. Populations with higher sex bias of 1:4 showed a higher growth rate but lost heterozygosity faster. Difference in sex ratio did not matter as much with population of initial size of 100 since either scenario went extinct.

Harvest/Supplementation

Populations of initial size of 100 went extinct in all of the scenarios in 100 years. This population was taken as a control to test the accuracy of the model. Yearly harvest and supplementation was entered similar to that carried out in the wild for the last 19 years during the gharial supplementation programme. The scenarios modelled showed distinct rise in stochastic growth rate during supplementation (Graph 2) and a nominal but steady growth rate after the supplementation was stopped (Graph 3).

The gharial population of 107 in 1976 would have gone extinct by now or very low numbers of an unviable population size would have remained today if the management programme had not been implemented. Results of the scenario indicated extinctions without management.

Results for population size of 1100 indicated no extinctions “without a management programme. The population of 1100 is large and stable and can even withstand a small harvest every year without supplementation. Harvested eggs from this population could be used for releases into other viable habitats or other areas with small gharial populations.

Metapopulation

The Chambal population can be categorised into 3 zones of 109 km, 90 km and 24 km stretches (Fig. 1). Each of these stretches or zones has gharial populations. The number of gharial is calculated by the number of nests per nesting site in these zones. There are 15 nesting sites totally with an average of 4-5 nests per site. The number and sex of gharial was calculated according to the single population count of 1100 and proportion of adults to subadults and juveniles. The number of nests indicates about 90% of adult females.
The three zones were considered as sub-populations and modelled with migration**.** Migration downstream was taken as 5% and upstream as 2% (participants in the workshop). The panmictic population was considered as genetically one.

Even as different subpopulation, they did not go extinct in 100 years. The Chambal population considered as different populations still survives well without management practices. Harvest could still be carried out in small quantities for later release in other habitats.

The Chambal population can be considered either as a single large population or three or five different subpopulations (Fig. 1). It is not clearly understood whether migration occurs between these populations. It is speculated that there is migration downstream during floods and upstream when the water level begins to recede. However, only one case of an adult male fighting with a resident male 28 km upstream has been observed.

Fig. 1. Nesting sites of gharial along the river Chambal.

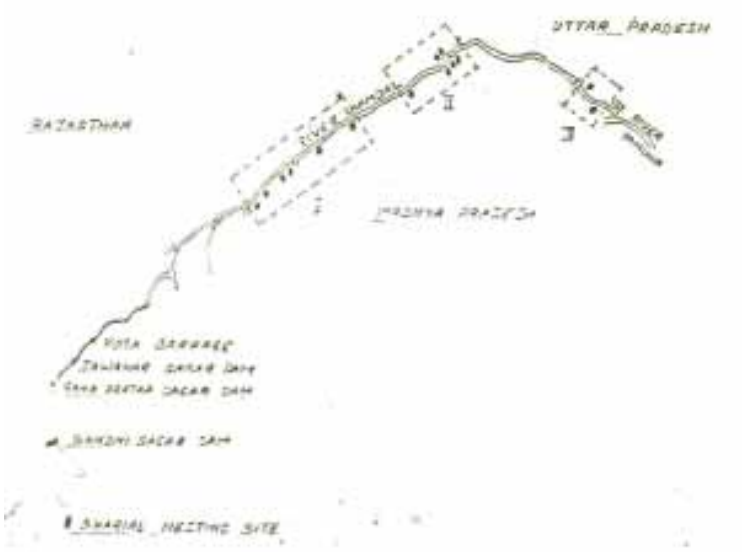


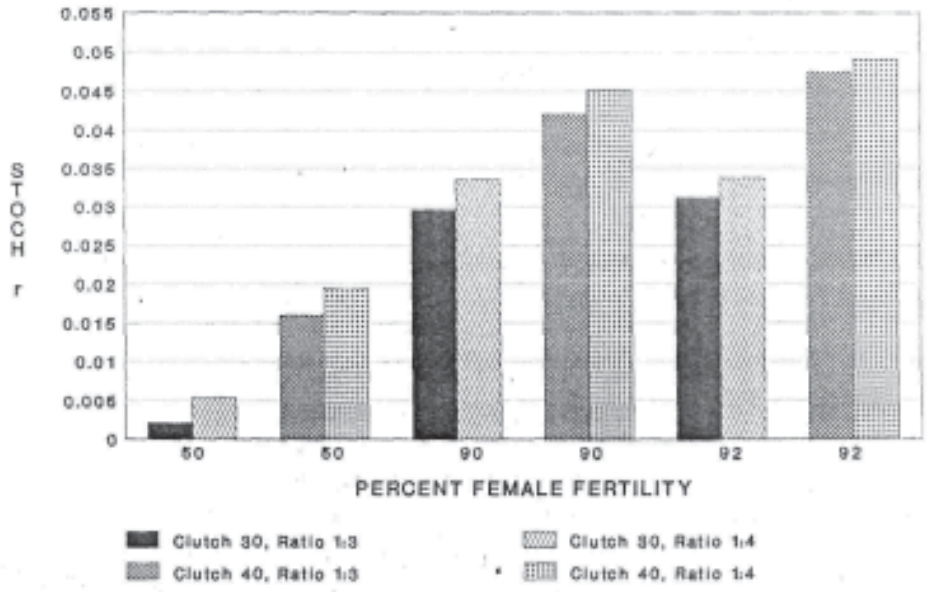
Table 1. Gharial releases in National Chambal Sanctuary during 1979 - 1987

YEAR AND MONTH OF RELEASE	PLACE	NO. GHARIAL	TOTAL NO. GHARIAL
1979 - May, November, December	Jeora	15 60	75
1980 - March	Barenda Kenjra Pureini	15 45 50	110
1981 - March, April	Kuthiana Chinnouni Sahaspura Baroli	44 83 43 83	253
1982 - January February & March	Deogarh Nadigaon Baroli Rameswar	45 50 49 43	187
1983 - January	Kenjra Keori Deogarh Pureini	24 74 50 50	198
1984 - March	Pali Pali	38 30	68
1985 - February	Barenda Barenda Barenda Pali Rameswar	20 20 20 10 20	90
1986 - February, March & April	Udi Rameswar Rameswar Rameswar	1 20 19 20	60
1987 - March & December	Rameswar Baroli Pinahat Pinahat Nandagawa	48 50 49 48 42	237
Total			**1278**

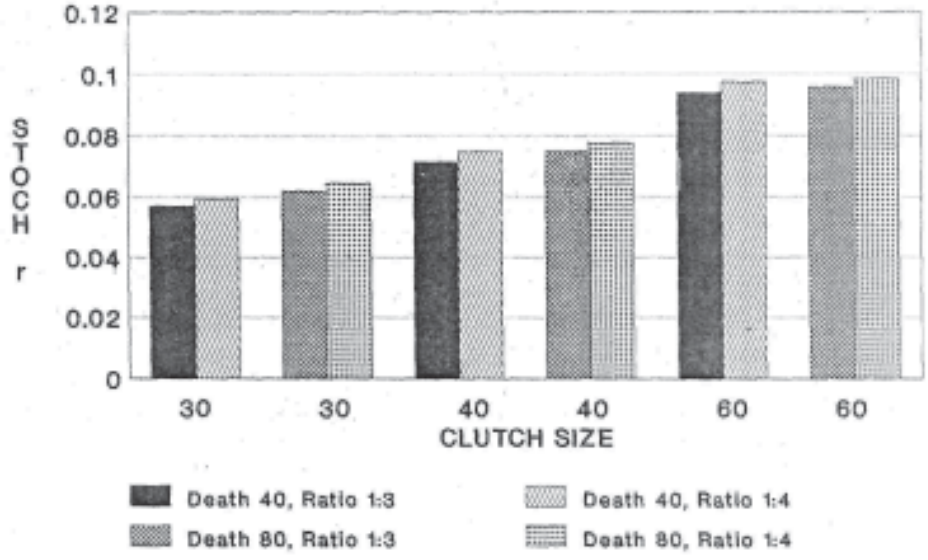
Table 2. Preliminary models for the Chambal population with initial population of 100 and a carrying capacity of 1100. The models were base on management practices (harvest and supplementation). Number of eggs harvested = 30; number of 3 year old gharial supplemented = 100 (80 females and 20 males); varying mortality schedules; female fertility at 92%, 90% and 50%.

File Name	Death	Sex Ratio M:F	CATAS S.	r (D)	P.B. Results				TE	STOCH 'r'			
										W/H		WO/H	
					PE%	N	SD	H		R	SD	R	SD
Ghar_020	80	1:4	1	.060	50.4	302	272.7	73.8	54	-.0836	.4043	.0295	.7963
Ghar_022	80	1:4	1	.060	16.6	313	276.8	82.4	130	.1435	.4504	.0306	.7876
Ghar_030	80	1:4	1	.060	14.4	308	295.5	82.1	123	.1507	.5166	.0309	.7884
Ghar_031	80	1:4	1	-.023	99.8	22	0	70.8	86	.0763	.5109	-.0649	.8755
Ghar_033	40	1:4	1	.076	16.4	310	289.1	79.9	122	.1638	.5561	.0415	.8454
Ghar_034	40	1:3	1	.072	6.0	365	332.4	91.1	90	.0590	.8988	.1579	.6177
Ghar_035	40	1:3	1	.072	0	988	135.4	95.8	-	.1599	.2705	.0712	.2464
Ghar_040	40	1:3	1	.072	0	1049	85.8	99.7	-	.1703	.2586	-	-
Ghar_041	40	1:3	1	.072	0	990	135.1	95.8	-	.1739	.2013	.1713	.2471
Ghar_042	40	1:3	1	.078	0	1046	91.2	99.6		.1736	.1997	-	-
Ghar_043	40	1:3	1	.058	0	1057	75.6	99.7		.1643	.1750	-	-
Ghar_044	40	1:3	.55	.012	0	903	221.3	99.7		.1297	.2188	-	-
Ghar_045	40	1:3	.90	.048	0	1045	89.4	99.7		.1555	.1783	-	-
Ghar_046	40	1:3	.90	.042	0	1042	87.5	99.7		.1522	.1754	-	-
Ghar_047	40	1:3	.90	.047	0	1043	92.2	99.7		.1595	.1842	-	-
Ghar_048	40	1:3	.90	.035	0	1043	85.5	99.7		.1526	.1787	-	-
Ghar_050	40	1:3	.90	.036	0	1044	87.9	99.7		.1464	.1752	-	-
Ghar_051	40	1:3	.90	.036	0	964	138.2	98.3		.1455	.1789	.0358	.2108

Graph 1. Chambal population. Stochastic growth rate and female fertility at clutch sizes 30 and 40. female fertility at clutch sizes 30 and 40.



Graph 2. Chambal population. Stochastic growth rate and clutch size at 40 and 80 years with harvest and supplementation.



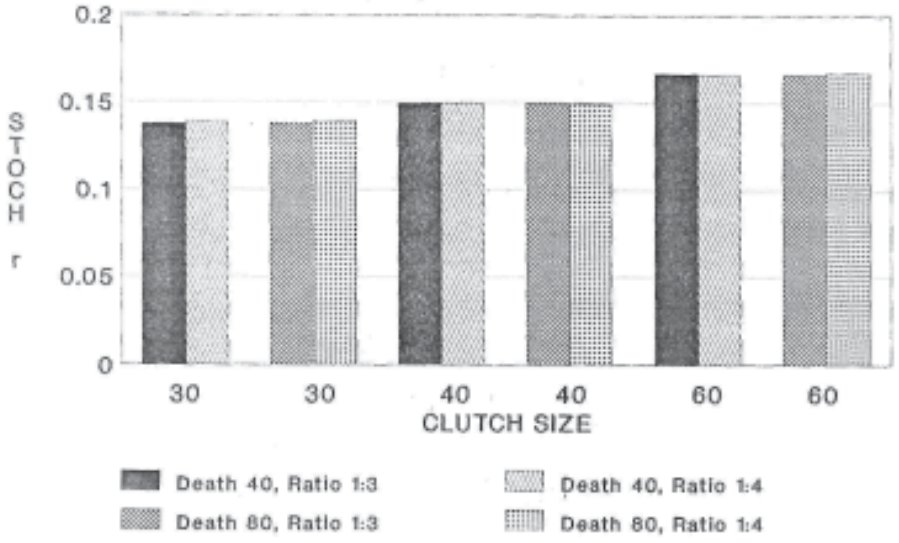
FILE NAME	DEATH	SEX RATIO M:F	CATAS S.	INI POP	K	r (D)	P.B. RESULT				STOCH 'r'			
											W/H		WO/H	
							PE%	N	SD	H	r	SD	r	SD
Clutch size 40, female fertility 92%, mortality at 0-1 age class 90%														
Ghar_241	40	1:3	1	100	1100	.072	0	985	142.9	95.8	.1494	.3318	.0714	.2471
Ghar_242	40	1:4	1	100	1100	.075	0	988	135.9	94.9	.1494	.3383	.0748	.2511
Ghar_243	80	1:3	1	100	1100	.075	0	998	136.2	95.9	.1498	.3322	.0749	.2482
Ghar_244	80	1:4	1	100	1100	.078	0	990	135.8	94.9	.1494	.3333	.0777	.2520
Clutch size 30, female fertility 92%, mortality at 0-1 age class 90%														
Ghar_245	40	1:3	1	100	1100	.057	0	992	129.8	96.6	.1378	.3083	.0570	.2311
Ghar_246	40	1:4	1	100	1100	.068	0	980	141.0	96.0	.1383	.3118	.0596	.2356
Ghar_247	80	1:3	1	100	1100	.062	0	976	133.7	96.7	.1381	.3081	.0618	.2321
Ghar_248	80	1:4	1	100	1100	.065	0	990	139..2	96.0	.1389	.3128	.0646	.2346
Clutch size 40, female fertility 92%, mortality at 0-1 age class 90%														
Ghar_249	40	1:3	1	100	1100	.094	0	994	141.1	94.2	.1665	.3638	.0938	.2682
Ghar_250	40	1:4	1	100	1100	.098	0	1005	131.3	92.7	.1654	.3729	.0975	.2722
Ghar_251	80	1:3	1	100	1100	.096	0	983	145.3	94.1	.1660	.3665	.0955	.2693
Ghar_252	80	1:4	1	100	1100	.100	0	990	149.4	92.8	.1671	.3681	.0986	.2722
Clutch size 40, female fertility 92%, mortality at 0-1 age class 92%														
Ghar_401	40	1:3	,90	1100	2500	.048	0	2260	290.0	99.0			.0475	.2075
Ghar_402	40	1:4	.90	1100	2500	.051	0	2210	299.0	98.8			.0491	.2124
Clutch size 40, female fertility 90%, mortality at 0-1 age class 92%														
Ghar_403	40	1:3	.90	1100	2500	.047	0	2152	345.9	99.0			.0421	.2080
Ghar_404	40	1:4	.90	1100	2500	.050	0	2179	307.3	98.8			.0452	.2086
Clutch size 30, female fertility 92%, mortality at 0-1 age class 92%														
Ghar_405	40	1:3	.90	1100	2500	.033	0	2162	335.0	99.2			.0311	.1926
Ghar_406	40	1:4	.90	1100	2500	.036	0	2183	301.9	99.0			.0337	.2013
Clutch size 30, female fertility 90%, mortality at 0-1 age class 92%														
Ghar_407	40	1:3	.90	1100	2500	.032	0	2142	319.4	99,2			.0296	.1955
Ghar_408	40	1:4	.90	1100	2500	.035	0	2199	298.2	99.0			.0336	.1990
Clutch size 40, female fertility 50%, mortality at 0-1 age class 92%														
Ghar_409	40	1:3	.90	1100	2500	.018	0	2057	376.4	99.3			.0160	.1769
Ghar_410	40	1:4	.90	1100	2500	.021	0	2143	336.7	99.1			.0195	.1845
Clutch size 30, female fertility 50%, mortality at 0-1 age class 92%														
Ghar_411	40	1:3	.90	1100	2500	.004	0	1352	580.5	99.1			.0020	.1639
Ghar_412	40	1:4	.90	1100	2500	.007	0	1605	548.1	99.1			.0053	.1682

Table 3. FACING PAGE. Chambal population. Age of first reproduction 10 (females) and 13 (males); harvest of 180 eggs every year for 20 years and supplementation of 100 eggs every year for 20 years, starting from the third year of first harvest (harvest and supplementation in files 241 to 252 only)

Table 4. Chambal metapopulation. Female AFR = 10; male AFR = 13; Initial population size (carrying capacity K) in the first set of tables (3 sub populations, files 001 to 004): pop. 1 = 450 (1050); pop. 2 = 550 (1250); pop. 3 = 150 (350); migration rate: upstream = 2% and downstream = 5%.; Initial population size (carrying capacity K) in the second set of tables (5 sub populations, files 011 and 012): pop. 1 = 300 (680); pop. 2 = 150 (350); pop. 3= 80 (180); pop. 4 = 470 (1070); pop. 5 = 150 (350); migration rate: upstream = 2% and downstream = 5%

FILE NAME	DEATH	SEX RATIO	CATAS. S.	r (D)	META POP. RESULT				STOCH 'r'	
					PE%	N	SD	H	r	SD
3 populations, clutch size 60, female fertility 92%, mortality at 0-1 age class 90%, migration 5% downstream and 2% upstream										
Met~001	80	1:4	1	.083	0	2333	232.8	97.8	.0882	.1718
Met~002	40	1:4	1	.081	0	2329	257.1	97.8	.0873	.1733
Met~003	80	1:3	1	.058	0	769	115.8	98.0	.0744	.2456
Met~004	40	1:3	1	.055	0	2224	285.5	98.7	.0576	.1589
5 populations, clutch size 40, female fertility 92%, mortality at 0-1 age class 90%, migration 5% downstream and 2% upstream										
Met~011	80	1:4	.90	.062	0	2219	237.1	98.1	.0667	.1311
Met~012	40	1:4	.90	.058	0	2183	203.6	98.1	.0631	.1323

Graph 3. Chambal population. Stochastic growth rate and clutch size at 40 and 80 years without harvest and supplementation.



Recommendations

1. Although the Chambal population has been studied extensively and for a long time, some of the basic biology is lacking still. Systematic monitoring of all gharials is crucial to know longevity, age of first reproduction and sex ratio.

2. Threats to the population are in the form of floods, agricultural practices, predation, fishing, etc. These must be studied in detail to understand the actual damage caused to the population. Such an understanding could be better quantified for simulation modelling.

3. The scenarios modelled with migration show no extinction. To understand completely the dynamics of the population, migration studies need to be carried out in detail.

4. The Chambal population seems to have stabilized, and is growing presently. However, to be able to better predict probabilities, monitoring and study of these populations and their movements will help in better understanding the dynamics.

5. According to the model, the population is now stable enough to withstand selective harvesting of up to 500 eggs every year for rearing and further releasing at alternate sites.

6. Gharial population upstream and those downstream may be quite close genetically because of the bottleneck the population underwent 20 years ago, and this needs to be verified by genetic testing. DNA fingerprinting is recommended for all the subpopulations to better understand genetic make up and gene flow.

Katherniaghat Population

The number of individuals in the Kathernaighat population was recorded as 54 in 1994. This figure was maintained in all the scenarios modelled.

Sex ratio

The population as studied indicate a sex ratio of 1:3 and above, being biased towards females. The sex ratio seems to play a role in the growth rate and the viability of the population. Though the deterministic growth rate increases with increased proportion of female to males (1:4), the population does sot seem to sustain itself for 100 years. The probability of extinction is higher in the higher female biased ratio of 1:4 as compared to 1:3 (Graph 4), The amount of heterzygosity retained is also higher in a population of 1:3 ratio rather than 1:4 (Graph 5).

Age of senescence

Scenarios were modelled for ages 40 and 80. The populations clearly did well with longer life span. The growth rate also has a positive increase with longer life span. Probability of extinction is higher in scenarios modelled with life span as 40 as compared to 80 (Graphs 6,7).

Carrying capacity

Two scenarios of carrying capacity were tried on the Katerniaghat population. The initial population size was retained at 55 but a carrying capacity value of 100 and 150 were modelled. The results showed that the population growth and stability depended on the habitat capability and therefore showed a greater chance of survival with carrying capacity at 150 as compared to 100 (Graphs 8, 9).

Catastrophe

The scenarios were modelled with and without catastrophe. Populations with a low catastrophe of frequency 10% (occuring once every 10 years) having no effect on reproduction but a .9 effect on survival (i.e. 10% casuality) had a higher probability of extinction compared to those populations modelled without catastrophe.

Age of first reproduction

All of the scenarios were modelled with age of first reproduction for females as 13 and for males as 17. Extensive studies and observations at Katherniaghat have led to this conclusion.

Unlike other populations such as in Chambal and Mahanadhi where the age of first reproduction is 10 and 13 in females and males respectively, the Katherniaghat population with its small numbers is even more influenced by the late ages of first reproduction.

Fertility

Three parameters have been used for the Katerniaghat population. The first scenario had 92% females producing eggs, second scenario of 90% females producing eggs and third scenario of just 50% females producing eggs.

The population is very sensitive to very mild changes in fertility rates. Reducing female fertility by 2% (from 92% to 90%) had an effect on growth rate (stochastic ‘r’) which reduced and the probability of extinction

increased. Populations with 50% female fertility went extinct in 40 years when the life span was modelled at 80 years and in 15 years when life span was modelled at 40 years.

Clutch size

There different values for clutch size were modelled. Populations modelled with 60 eggs per clutch did extremely well. Clutch size of 40 showed a nominal growth rate when catatstrophes were nil (Graph 10). With a mild catastrophe of frequency 10% and .9 effect on survival, populations modelled with 40 years life span and clutch size of 60, 40 or 30 showed a negative trend in growth. Catastrophes occuring once in ten years such as was modelled have a greater effect on populations with a smaller clutch size. When these populations of smaller clutch size were compared with the scenarios with no catastrophes there was a distinnct difference in the probability of extinction (Graph 11).

Mortality

Three sets of mortalities were modelled

1) Low mortality after age 4
2) Low mortality after age 4 but higher 0-1 age mortality.
3) High mortality with 90% & 92% mortality at 0-1 age class.

The first two cases of low mortality after age 4 was with 10% (3 SD) from class 4-5. The second set varied slightly with 92% mortality at 0-1 age class instead of 90%. The third set of high mortality had a set of values that reduced slightly for every age class beginning at 90%.

Regardless of the type of mortality, all populations went extinct as modelled. Populations modelled with higher mortality throughout and higher mortality at 0-1 age class (92%) had a higher probability of extinction.

Harvest/Supplement

The population at Katherniaghat is very small to sustain, itself in the long term. The models however conservatively constructed showed the populations to go extinct in a very short time -15 to 40 years depending on the longevity of gharial.

The gharial supplementation project by the government of India helped to conserve and aid growth of Katherniaghat population. The low numbers were able to sustain themselves due to continuous harvest and supplementation for the past 19 years (Table 5**)**

In the scenarios modelled, 100 eggs were harvested, according to the last year harvest values (table above). The value was entered as 10 (including 0-1 age mortality of 90%). The harvest was modelled every year for 50 years.

Supplementation figures were entered as 40 individuals (juveniles) 4years old released every year from the 4th year to 54th year. The ratio of individuals released depended on the ratio of the sexes in the population. The figure of 40 was to indicate 40% survival in the rearing centres. Although 60% success rate has been achieved in the centres, a mortality of 20% was considered during transportation & actual pre- and post-release mortalities

The models were all run for 100 years and with harvest and supplement for 50 years. The populations remained stable as long as this was carried out but went extinct in a short time thereafter (Table 8). Probability of extinction varies for models with varying basic scenario but on the whole extinction of the Katherniaghat population is imminent if no management action is taken.

Probability of extinction was seen to be very high for bigger clutch sizes by the hundredth year. However, the mean population size remained big for these populations. Stochastic growth rate was faster for populations modelled with bigger clutch size. Populations with higher sex ratio also showed higher probability of extinction (Graphs 12 - 19).

Graph 4. Katerniaghat population. Sex ratio and stochastic growth rate for different clutch sizes with catastrophe of 10% frequency and .9 effect on survival.

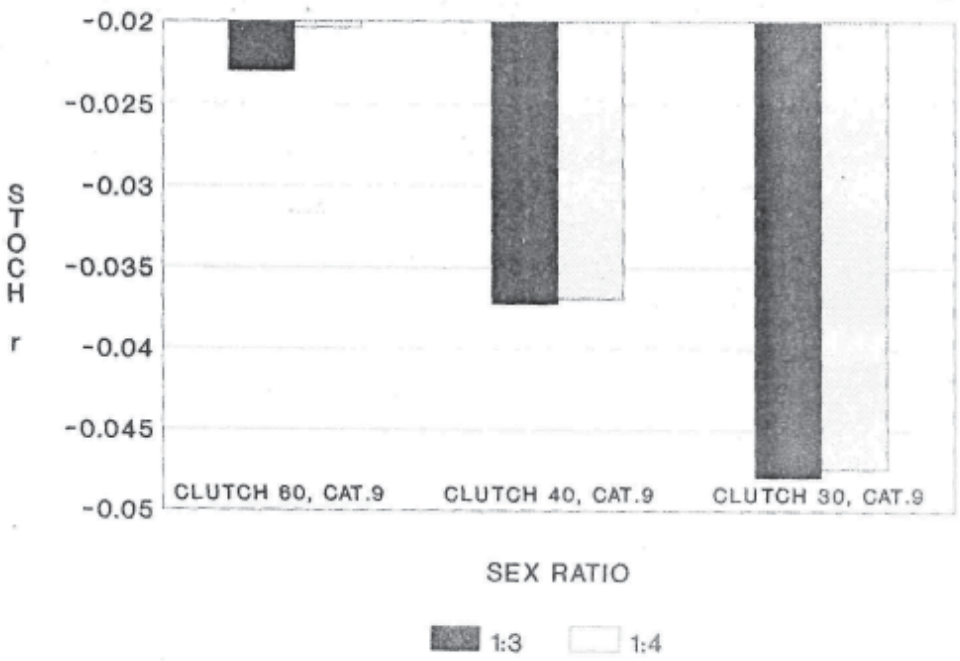


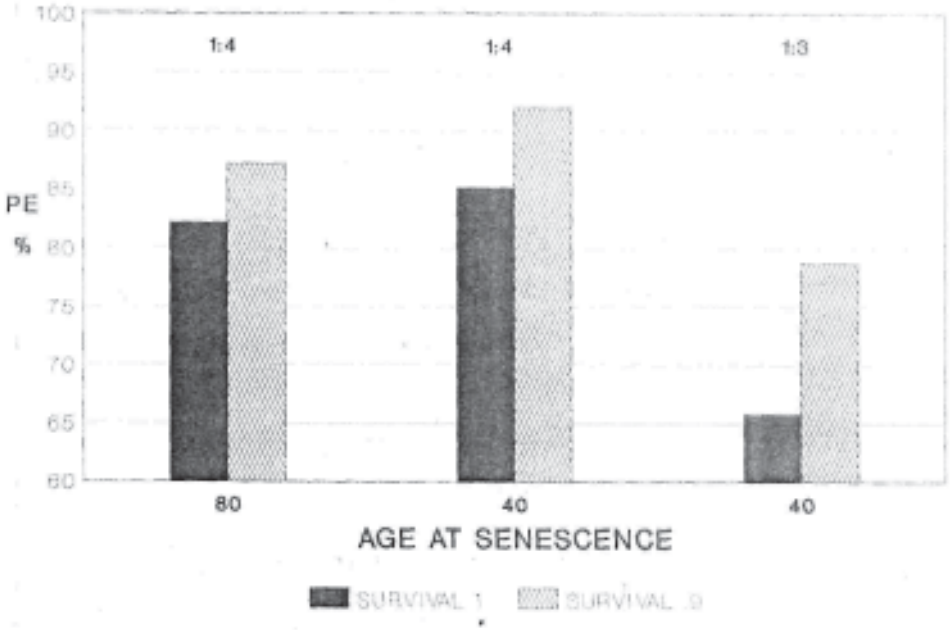
Table 5. Katerniaghat population. Harvest and supplementation carried out during the last 19 years.

	CENSUS RESULTS					WILD PRODUCTION					CLASS-WISE SUPPLEMENTS			
YEAR	**AD. MALE**	**AD. FE-MALE**	**SUB AD.**	**JUV.**	**TOT.**	**NO. OF POSS. NEST.**	**NO. OF EGGS**	**NO. OF EGGS HARV.**	**NO. OF EGGS LEFT**	**HATL. SURV. @5%**	**AD. MALE**	**AD. FE-MALE**	**SUB. AD.**	**JUV.**
1975	1	5	5	3	14	5	210	38	172	9	-	-	-	-
1976	2	8	6	12	28	8	336	215	121	6	-	-	-	-
1977	2	8	8	14	32	8	336	166	170	9	-	-	-	-
1978	2	9	9	14	34	9	378	171	207	10	-	-	-	-
1979	2	8	12	10	32	8	336	234	102	5	-	-	14	-
1980-1987						96	4032	2128	1904	95	1	-	163	-
1988	2	16	19	4	41	10	420	312	108	5	-	-	-	-
1989	3	25	5	3	36	15	525	200	300	15	-	-	-	-
1990	4	27	5	3	39	15	525	70	455	23	-	-	-	-
1991							525	65	455	23	-	-	-	180
1992	3	27	5	4	39	15	525	-	525	26	2	11	-	40
1993	3	28	4	7	42	15	525	120	405	20	2	11	-	-
1994	5	28	18	3	54	15								

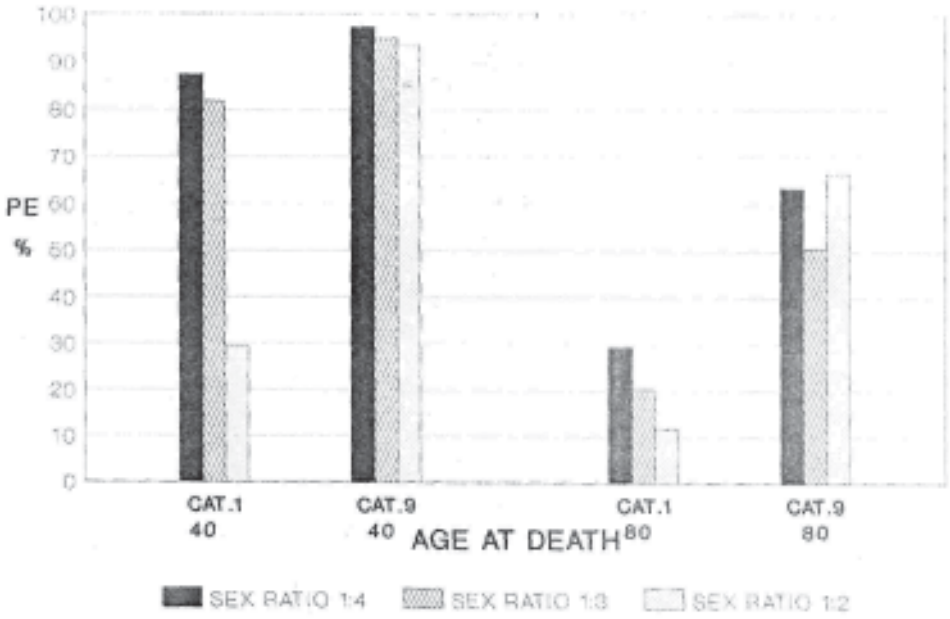
Table 6. Katerniaghat population. Single population

FILE NAME	DEATH	SEX RATIO	CATAS.	r	P. B. RESULT				TE	r (S)	SD
					PE %	N	SD	H			
Clutch size 60, female fertility 92%, mortality at 0-1 age class 90%, K = 100											
Kath~006	80	1:4	1	.058	82.2	69	29.0	45.3	75	.0270	.4021
Kath~007	80	1:4	.9	.048	87.2	67	30.4	45.7	66	.0139	.4019
Kath~008	40	1:4	1	.052	85.2	62	30.7	41.4	73	.0161	.4071
Kath~009	40	1:4	.9	.042	92.0	50	29.8	31.6	65	-.0013	.4130
Kath~010	40	1:3	1	.049	65.8	51	30.1	46.3	92	.0239	.3778
Kath~011	40	1:3	.9	.039	78.8	57	30.7	40.3	85	.0097	.3807
Clutch size 30, female fertility 92%, mortality at 0-1 age class 90%, K = 100											
Kath~012	40	1:4	1	.022	65.8	61	27.3	51.2	93	.0053	.2997
Kath~013	40	1:4	.9	.012	90.6	52	27.3	46.4	80	-.0121	.3144
Clutch size 60, female fertility 92%, mortality at 0-1 age class 92%, K = 100											
Kath~057	40	1:4	.9	.010	84.0	43	28.0	61.9	43	-.0284	.3888
Kath~060	40	1:3	.9	.008	72.6	35	23.7	63.1	53	-.0230	.3865
Kath~066	40	1:4	1	.011	83.6	43	27.4	62.3	43	-.0276	.3902
Kath~069	40	1:3	1	.009	71.6	40	26.5	64.0	53	-.0209	.3866
Clutch size 40, female fertility 92%, mortality at 0-1 age class 92%, K = 100											
Kath~058	40	1:4	.9	-.006	88.6	25	20.7	62.2	47	-.0369	.3619
Kath~061	40	1:3	.9	-.008	85.2	25	19.3	64.1	53	-.0372	.3573
Kath~067	40	1:4	1	-.005	87.2	30	22.7	65.2	46	-.0381	.3602
Kath~070	40	1:3	1	-.007	81.8	24	19.3	63.5	53	-.0341	.3584
Clutch size 30, female fertility 92%, mortality at 0-1 age class 92%, K = 100											
Kath~059	40	1:4	.9	-.017	96.4	18	14.8	56.4	44	-.0484	.3456
Kath~062	40	1:3	.9	-.019	93.8	12	7.1	59.7	50	-.0479	.3418
Kath~068	40	1:4	1	-.016	94.6	19	17.5	57.2	43	-.0473	.3435
Kath~071	40	1:3	1	-.018	93.2	15	13.5	64.9	50	-.0460	.3407

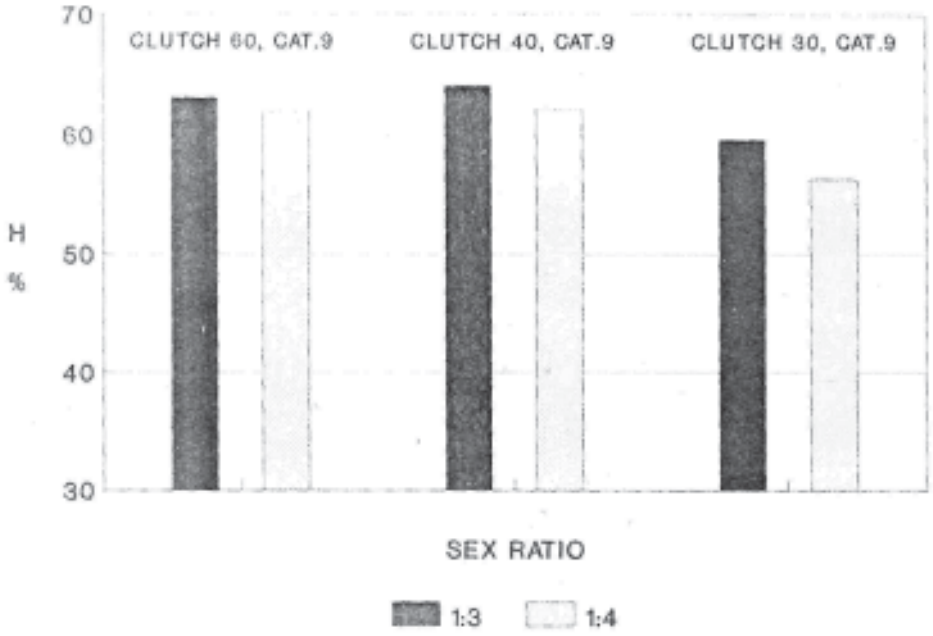
Graph 6. Katerniaghat population. Probability of extinction at different age of senescence.



Graph 7. Katerniaghat population. Probability of extinction at different age of senescence for sex ratios 1:4, 1:3 and 1:2 comparing with and without catastrophe



Graph 5. Katerniaghat population. Sex ratio in relation to heterozygosity retained at 100 years for different clutch sizes and catastrophe of 10% frequency and .9 effect on survival.



Graph 8. Katerniaghat population. Probability of extinction at different carrying capacity values and clutch sizes modelled at age 40 with 1:4 ratio.

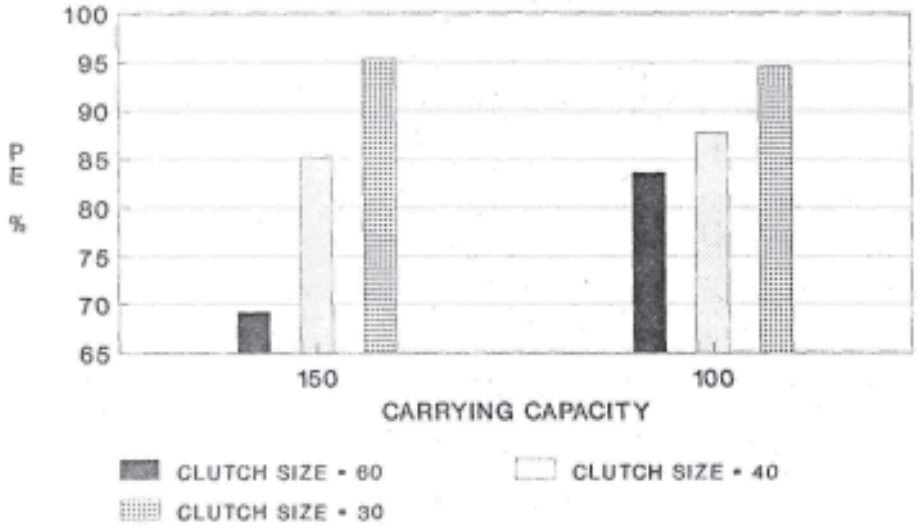
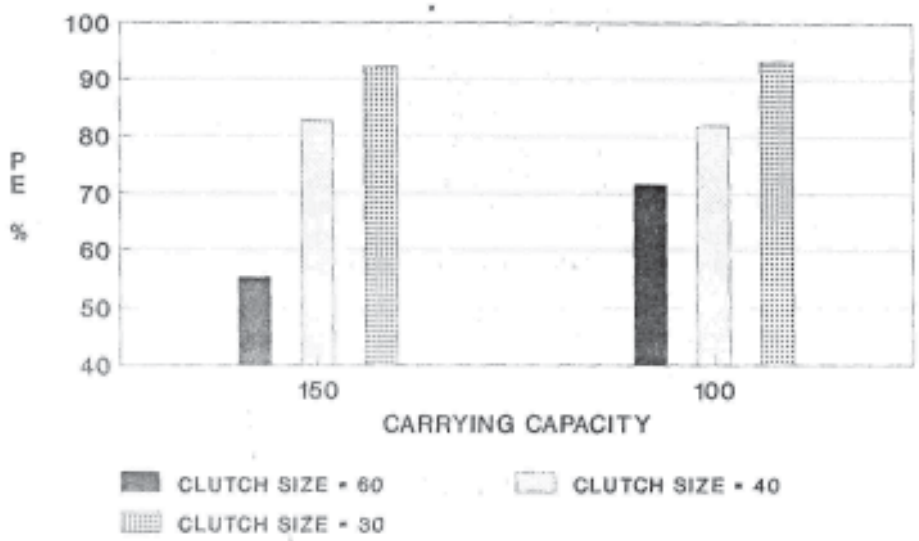


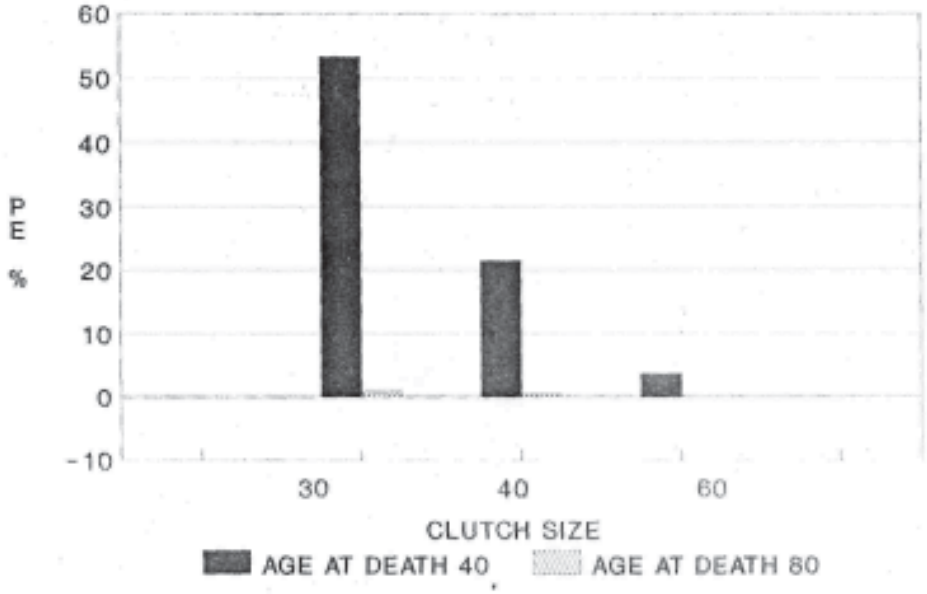
Table 8. FACING PAGE. Katerniaghat population with harvest and supplementation. Initial size = 55; carrying capacity = 100; harvest programme carried on for 50 years with 10 eggs removed every year; supplementation for 50 years starting from the fourth year of first harvest, 40 juveniles of 4 years of age (32 females and 8 males when sex ratio of population is 1:4 and 30 females and 10 males when sex ratio is 1:3) added every year. A result of population behaviour is recorded at 16 and 46 years after the supplementation programme is stopped.

	DEATH		CAT	r	P.B. RESULT									STOCH 'r'			
					70 YEARS				100 YEARS					W/H		WO/H	
					PE %	N	SD	H	PE%	N	SD	H	T.E	r	S.D	r	S.D
Clutch size 40, female fertility 92%, mortality at 0-1 age class 90%																	
Kathar-1	80	1:4	.90	.024	7	64	27.6	92.5	39.0	57	27.5	86.9	79	.1795	.1637	.0096	.3760
Kathar-2	40	1:4	.90	.014	27	67	25.7	85.3	34.6	51	29.4	81.8	81	.1797	.1880	.0027	.3767
Kathar-3	40	1:3	.90	.011	15	68	24.7	93.1	24.6	51	27.0	83.7	83	.1809	.1731	.0023	.3707
Kathar-4	80	1:3	.90	.022	15	67	25.9	93.1	19.2	63	27.1	85.0	82	.1828	.1653	.0154	.3589
Clutch size 60, female fertility 92%, mortality at 0-1 age class 90%																	
Kathar-5	40	1:4	.90	.032	13	65	30.0	90.9	42.0	54	30.6	79.7	66	.1801	.2367	.0105	.4515
Kathar-6	80	1:4	.90	.038	4	57	30.8	90.7	39.8	63	26.6	80.7	77	.1817	.0031	.0180	.4607
Kathar-7	40	1:3	.90	.029	9	60	28.3	91.5	28.0	56	29.6	80.1	78	.1860	.1738	.0133	.4340
Kathar-8	80	1:3	.90	.036	6	62	26.1	91.1	28.0	66	29.8	81.9	81	.1854	.1828	.0213	.4339
Clutch size 60, female fertility 50%, mortality at 0-1 age class 90%																	
Kathar-9	40	1:4	.90	.006	0	65	26.7	92.7	37.0	43	25.5	85.9	-	.1780	.1943	-.0002	.4092
Kathar-10	80	1:4	.90	.017	5	64	27.7	92.7	18.0	54	24.6	86.4	73	.1801	.1811	.0063	.4071
Kathar-11	40	1:3	.90	.003	2	58	26.0	93.2	38.0	42	27.8	81.8	83	.0025	.1805	-.0066	.4218
Kathar-12	80	1:3	.90	.015	3	62	23.2	92.7	22.0	54	27.8	85.7	81	.1804	.1848	.0092	.4135
Clutch size 30, female fertility 92%, mortality at 0-1 age class 90%																	
Kathar-13	40	1:4	.90	.002	1	71	24.6	93.7	29.0	48	26.8	83.8	83	.1770	.1554	-.0037	.3412
Kathar-14	80	1:4	.90	.014	2	71	24.0	93.6	18.0	61	24.5	86.4	79	.1784	.1595	.0088	.3266
Kathar-15	40	1:3	.90	0	2	68	26.0	93.4	26.0	44	24.8	83.5	86	.1785	.1547	-.0061	.3438
Kathar-16	80	1:3	.90	0.12	4	69	24.0	93.9	16.0	64	27.3	86.7	79	.1790	.1554	.0084	.3395
Clutch size 30, female fertility 50%, mortality at 0-1 age class 90%																	
Kathar-17	40	1:4	.90	-.022	3	68	19.4	95.1	28.0	27	16.0	84.6	88	.1748	.1563	-.0249	.3277
Kathar-18	80	1:4	.90	-.004	3	71	22.3	95.2	23.0	4	23.3	89.8	81	.1749	.1501	-.0053	.3245
Kathar-19	40	1:3	.90	-.024	0	66	22.0	95.7	27.0	28	19.8	85.9	87	.1721	.1611	-.0265	.3233
Kathar-20	80	1:3	.90	-.005	2	70	23.0	95.4	13.0	51	24.2	89.1	80	.1743	.1578	-.0044	.3238
Clutch size 40, female fertility 50%, mortality at 0-1 age class 90%																	
Kathar-21	80	1:4	.90	.004	6	65	26.1	94.6	41.0	44	25.3	84.9	89	.1751	.1570	-.0044	.3290
Kathar-22	40	1:4	.90	-.003	5	62	23.3	93.9	48.0	38	19.6	86.0	83	.1783	.1502	-.0101	.3245
Kathar-23	80	1:3	.90	0	5	69	27.4	95.1	42.0	37	19.7	85.8	75	.1734	.1593	-.0100	.3222
Kathar-24	40	1:3	.90	-.024	3	59	22.2	94.7	50.0	29	17.4	87.1	80	.1760	.1550	-.0301	.3231

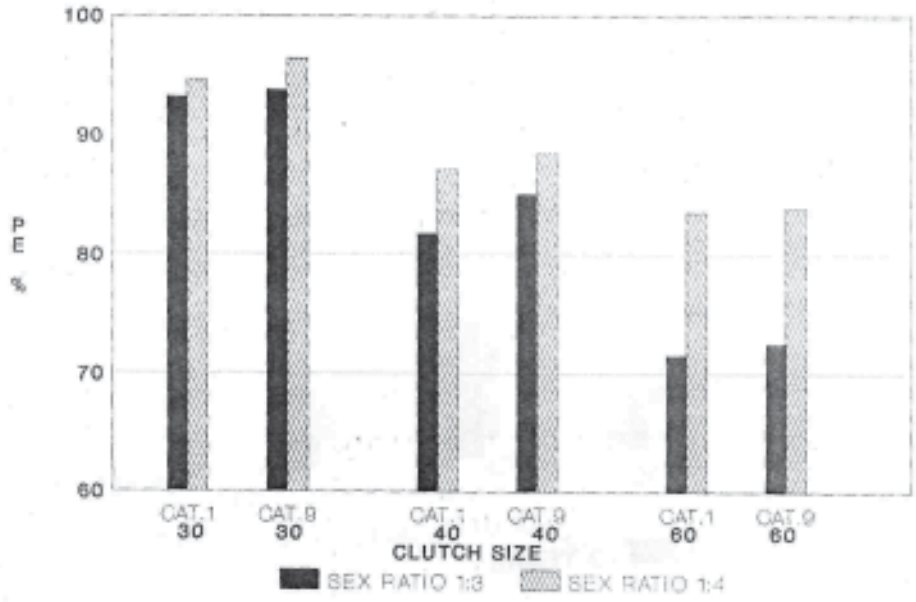
Graph 9. Katerniaghat population. Probability of extinction at different carrying capacity values and clutch sizes modelled at age 40 with 1:3 ratio.



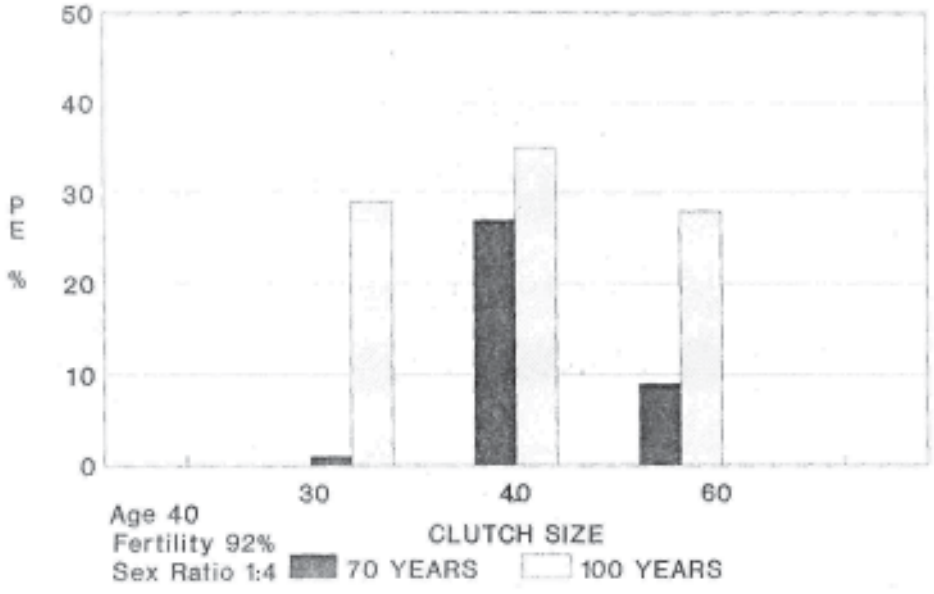
Graph 10. Katerniaghat population. Probability of extinction at different clutch sizes comparing ages 40 and 80.



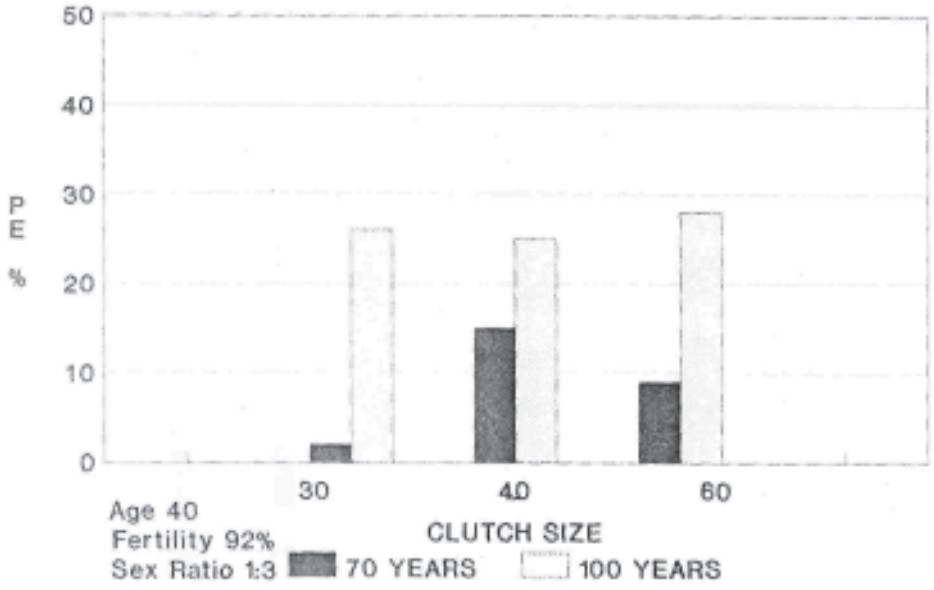
Graph 11. Katerniaghat population. Probability of extinction at different carrying capacity values and clutch sizes modelled at age 40 comparing values with and without catastrophe



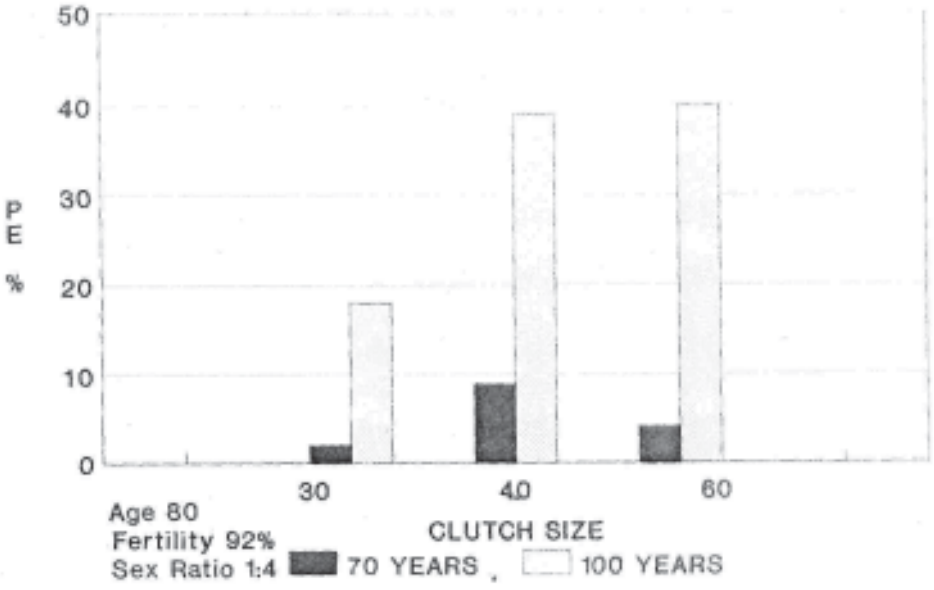
Graph 12. Katerniaghat population. With harvest and supplementation. Probability of extinction at 16th and 46th year after the last supplementation modelled for age 40, ratio 1:4 and fertility 92%.



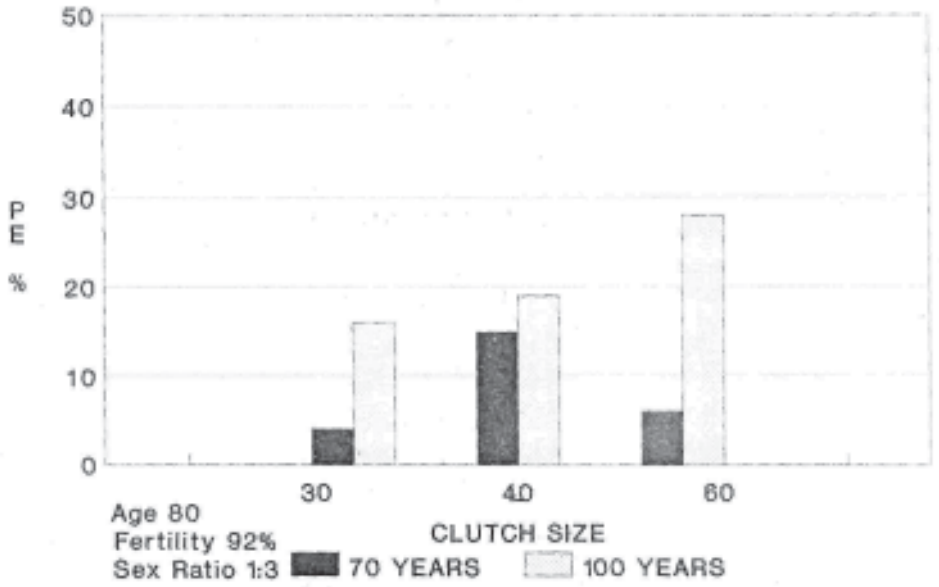
Graph 13. Katerniaghat population. With harvest and supplementation. Probability of extinction at 16th and 46th year after the last supplementation modelled for age 40, ratio 1:3 and fertility 92%.



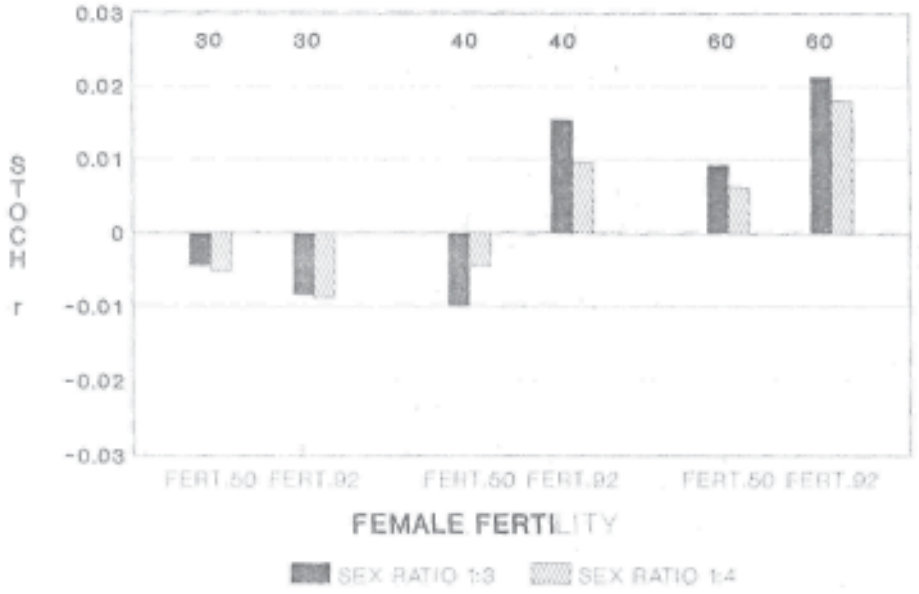
Graph 14. Katerniaghat population. With harvest and supplementation. Probability of extinction at 16th and 46th year after the last supplementation modelled for age 80, ratio 1:4 and fertility 92%.



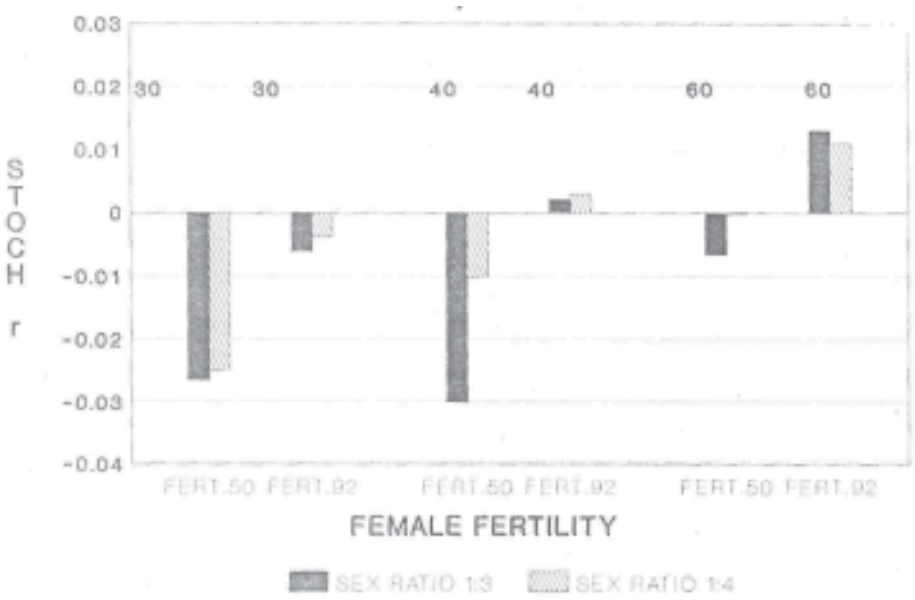
Graph 15. Katerniaghat population. With harvest and supplementation. Probability of extinction at 16th and 46th year after the last supplementation modelled for age 80, ratio 1:3 and fertility 92%.



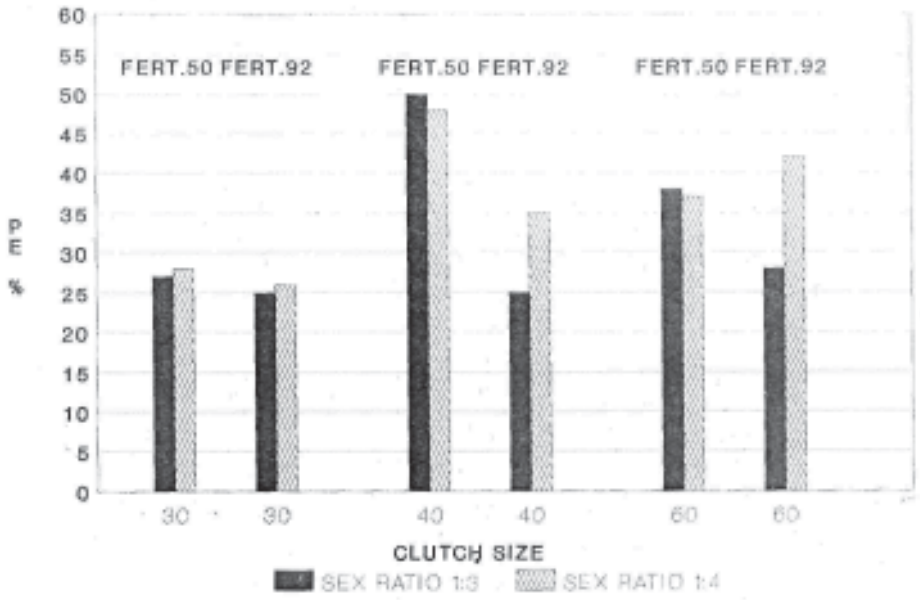
Graph 16. Katerniaghat population. With harvest and supplementation. Stochastic growth rate post supplementation as compared with female fertility and clutch sizes for populations modelled at age 80



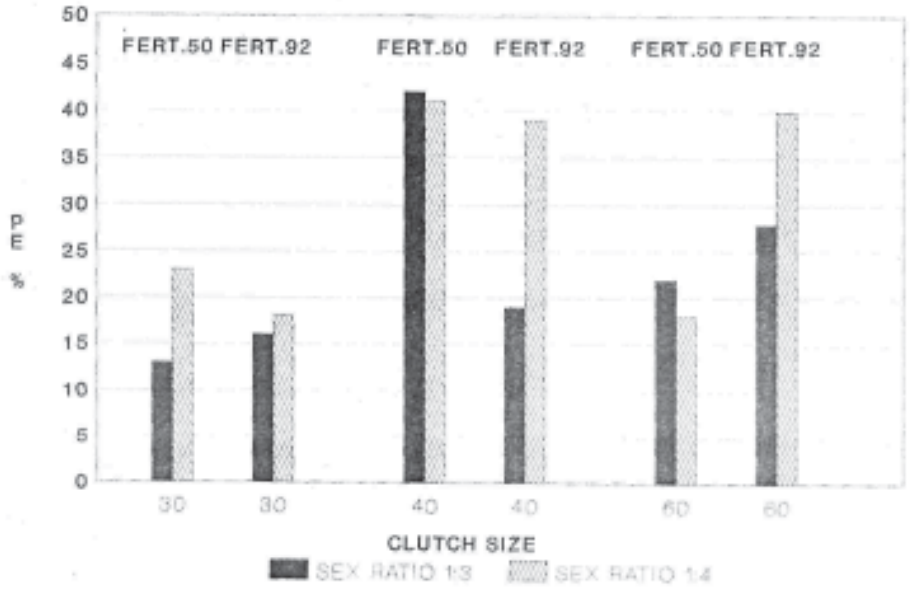
Graph 17. Katerniaghat population. With harvest and supplementation. Stochastic growth rate post supplementation as compared with female fertility and clutch sizes for populations modelled at age 40



Graph 18. Katerniaghat population. With harvest and supplementation. Probability of extinction post supplementation as compared with female fertility and clutch sizes for populations modelled at age 40



Graph 19. Katerniaghat population. With harvest and supplementation. Probability of extinction post supplementation as compared with female fertility and clutch sizes for populations modelled at age 80



Recommendations

1. Continuous supplementation should be carried out for the Katemiaghat population since the number of individuals are too small to be viable on their own. The carrying capacity of the habitat is also small for the population to remain stable once the numbers reach that.

2. Scientific monitoring of the population must be carried out once the juveniles are released.

3. Genetic studies of the population should be made to assess the degree of inbreeding the population has undergone. Genetic typing of certain identified individuals representing different age classes should be carried out.

4. If the population is not mixed with releases from Chambal or Mahanadhi, genetic affinity must be tested and such releases should be made to retain enough heterozygosity

5. Hatching and rearing gharial young in the rearing centres has reduced mortality dramatically. Releasing younger juveniles results in high mortality in the wild. To avoid this, gharial of age 4 years and above should be released.

Mahanadi Population

Initial population size and carrying capacity

The Mahanadi population was modelled at an initial population size of 200 based on the estimated number in the wild. All scenarios were modelled with a carrying capacity of 500 as suggested by the participants.

Age of first reproduction

Age of first reproduction for males was kept at 13 and that for females was modelled at 10 and 9. The value of 9 was tried because researchers from Mahanadi felt that the females matured earlier by a year. The scenarios modelled with female age of first reproduction at 9 showed a faster growth rate (stochastic r greater than 4%) than the scenarios modelled with female age of first reproduction at 10 (stochastic r lesser than 2%) (Graphs 20 - 22).

Life span and sex ratio

Two parameters were tested for age of senescence - 40 years and 80 years. Populations with longer life span showed a faster growth rate. Sex ratio of 1:4 with a female bias showed a faster growth rate as compared to a lower ratio of 1:3. However, population with 1:3 sex ratio retained greater genetic heterozygosity.

Mortalities

Mortality schedules were tried, as in other populations, Higher mortality at 0-1 age class decreased the growth rate by 2% and the models showed a few extinctions over 100 years.

Female fertility

Female fertility was varied at 92%, 90% and 50%. Lower fertility rates reduced the trend in growth. Not much of variation was observed between the rates 90% and 92% (Graphs 21 - 26). Populations with 50% fertility had a considerable decline in growth rate and combined with a low clutch size of 30, the probability of extinction increased

Clutch size

Three clutch sizes of 30, 40 and 60 were modelled. Clutch size of 60 showed a healthy growth compared to other two. The clutch size of 40 showed a nominal but steady growth rate indicating an optimum size for a clutch. Populations with a clutch size of 30 showed poor growth rate or when modelled with low fertility rates, showed a negative growth (Graphs 21 -26).

Catastrophes

The Mahanadi population is prone to various threats such as pollution, fishing, egg collection, floods, effluents, habitat destructions, etc. which cannot be quantified easily Researchers feel that these threats especially toxic wastes released in the river causes major damage to the population although they have no way at present to substantiate their fears. Therefore catastrophe was modelled with a conservative estimate as occuring once in 10 years (10%) and having a multiplicative effect of either ,55, .75 and .9 on survival (i.e., survivorship being 55%, 75% and 90% in a population due to catastrophe). The results showed the population to be able to withstand all of the above catastrophes. The growth rate, however, was affected (Graph 27).

The Mahanadi population was supposed to be larger a few years ago but has considerably reduced even with supplementation. This is because of threats due to high pollution, egg collection and fishing.

The Mahanadi population on the whole is more stable in the simulation models than it actually is in the wild. The results in this model showed no probability of extinction for the population but showed change in growth rates. Since the model was constructed very conservatively, a very careful look at the scenarios and the results must be taken.

Obvious depletion in population numbers in the wild has been noticed and it has been attributed to manmade environmental variations. Since these variations could not be adequately quantified as catastrophes, the actual scenario was difficult to assess. However, extrapolating with the existing scenarios of the present wild population and habitat and reading the modelling results on Mahanadi population, recommendations have been worked out.

Graph 20. Mahanadi population. Stochastic growth rate for different clutch sizes at 1:3 and 1:4 ratio and ages 80 and 40. Age of first reproduction for females 9 and for males 13.

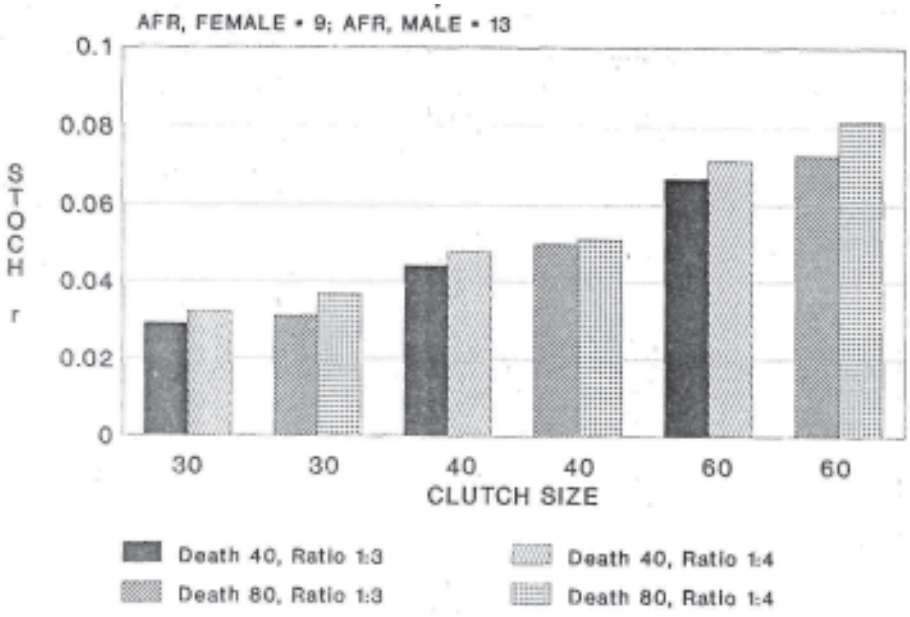


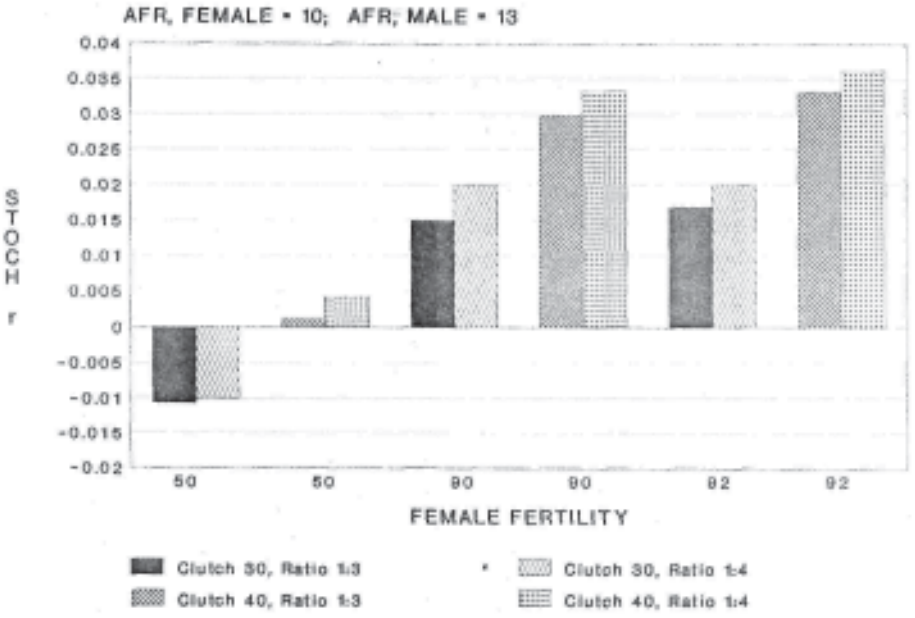
Table 9. Mahanadi population.

FILE NAME	DEATH	SEX RATIO	CLUT-CH	r (D)	P.B. RESULT					STOCH 'r'	
					PE%	N	SD	H	TE	r	SD
Female fertility 92%, mortality at 0-1 age class 92%, female AFR 9, Male AFR 13											
Maha~003	40	1:3	40	.047	0	440	66.2	90.9	-	.0441	.2160
Maha~004	40	1:4	40	.050	0	436	65.7	88.7	-	.0478	.2202
Maha~005	80	1:4	40	.053	0	438	65.1	88.9	-	.0509	.2198
Maha~006	80	1:3.	40	.050	0	443	63.1	91.2	-	.0497	.2164
Female fertility 92%, mortality at 0-1 age class 92%, female AFR 9, Male AFR 13											
Maha~007	40	1:4	60	.074	0	450	62.9	84.6	-	.0713	.2393
Maha~008	80	1:3	60	.076	0	453	60.0	84.1	-	.0728	.2395
Maha~009	40	1:3	60	.070	0	446	63.9	97.7	-	.0668	.2369
Maha~010	80	1:4	60	.084	0	454	59.8	84.7	-	.0815	.2385
Female fertility 92%, mortality at 0-1 age class 92%, female AFR 9, Male AFR 13											
Maha~011	40	1:4	30	.034	0	429	67.9	90.9	-	.0321	.2049
Maha~012	40	1:3	30	.030	0	420	64.7	94.3	-	.0290	.2001
Maha~013	80	1:3	30	.033	0	428	60.0	97.2	-	.0312	.2108
Maha~014	80	1:4	30	.039	0	439	63.3	91.4	-	.0367	.2044
Female fertility 92%, mortality at 0-1 age class 90%, female AFR 10, Male AFR 13											
Maha~401	40	1:4	40	.040	0	374	100.9	89.8	-	.0362	.3153
Maha~402	40	1:3	40	.037	0	382	110.9	92.2	-	.0331	.3125
Maha~403	40	1:4	30	.025	0	333	136.9	90.2	69.0	.0200	.3000
Maha~404	40	1:3	30	.022	2.0	310	114.9	92.7	55.5	.0169	.2944
Female fertility 90%, mortality at 0-1 age class 90%, female AFR 10, Male AFR 13											
Maha~405	40	1:4	40	.039	0	371	107.9	89.8	-	.0333	.3251
Maha~406	40	1:3	40	.036	0	357	116.1	92.1	-	.0298	.3221
Maha~407	40	1:4	30	.024	0	339	130.3	91.0	-	.0200	.3064
Maha~408	40	1:3	30	.021	1.0	309	121.4	91.9	79.0	.0149	.3056
Female fertility 50%, mortality at 0-1 age class 90%, female AFR 10, Male AFR 13											
Maha~409	40	1:4	40	.009	4.0	249	143.3	88.7	69.5	.0043	.3354
Maha~410	40	1:3	40	.006	3.0	221	156.7	89.8	66.0	.0011	.3319
Maha~411	40	1:4	30	-.004	11.0	134	124.6	86.5	71.8	-.0100	.3153
Maha~412	40	1:3	30	-.007	8.0	117	95.2	87.5	71.8	-.0106	.3147

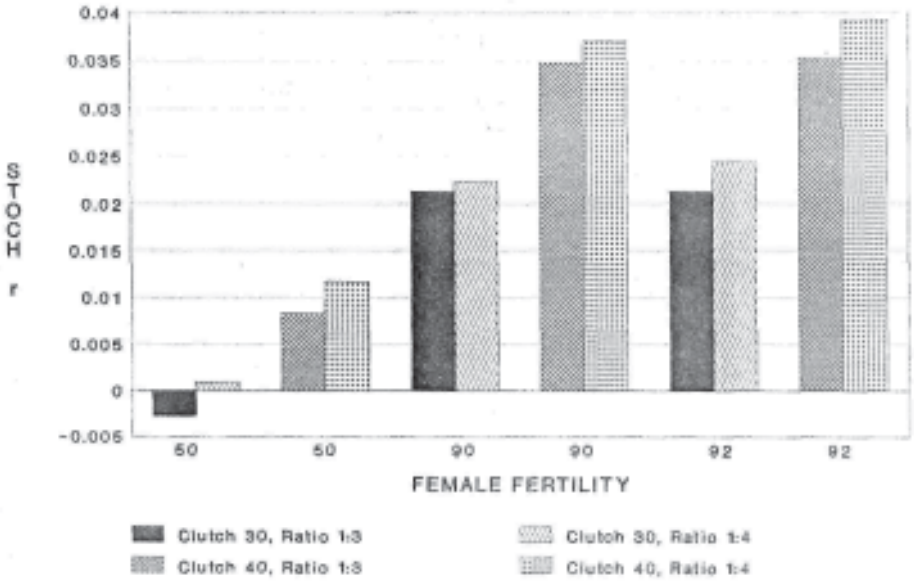
Table 10. Mahanadi populations

FILE NAME	DEATH	SEX RATI-O M:F	CLUT-CH	CATAS S.	r (D)	P.B. RESULT				TE	STOCH 'r'	
						PE %	N	SD	H		r	SD
Female fertility 92%, mortality at 0-1 age class 90%, female AFR 10, male AFR 13												
Maha~421	80	1:4	40	.75	.044	0	377	104.2	90.5	-	.0363	.3190
Maha~422	80	1:3	40	.75	.040	0	366	101.2	92.1		.0032	.3169
Maha~423	80	1:4	30	.75	.030	0	363	109.3	91.2	-	.0245	.3026
Maha~424	80	1:3	30	.75	.027	0	353	122.1	93.0	-	.0213	.2956
Female fertility 90%, mortality at 0-1 age class 90%, female AFR 10, male AFR 13												
Maha~425	80	1:4	40	.75	.042	0	372	98.2	89.9	-	.0371	.3246
Maha~426	80	1:4	40	.75	.039	0	361	113.9	92.4	-	.0348	.3204
Maha~427	80	1:4	30	.75	.029	1.0	340	122.2	91.0	-	.0223	.33061
Maha~428	80	1:3	30	.75	.026	0	337	117.2	92.8	-	.0214	.3043
Female fertility 50%, mortality at 0-1 age class 92%, female AFR 10, male AFR 13												
Maha~429	80	1:4	40	.75	.016	2.0	284	114.3	91.7	90.50	.0117	.3323
Maha~430	80	1:3	40	.75	.013	3.0	285	137.7	92.2	82.33	.0083	.3277
Maha~431	80	1:4	30	.75	.005	7.0	228	131.2	92.1	68.71	.0009	.3065
Maha~432	80	1:4	30	.75	.002	8.0	198	132.1	91.9	66.50	-.0028	.3124
Female fertility 92%, mortality at 0-1 age class 92%, female AFR 13, male AFR 17												
Maha~051	80	1:4	60	.90	.023	0	369	99.0	89.9	80.22	.0208	.3269
Maha~052	80	1:4	40	.90	.010	4	337	100.0	91.7	-	.0091	.3036
Maha~053	80	1:4	30	.90	.003	8	238	111.6	91.4	68.0	.0009	.2849
Maha~054	40	1:4	60	.90	.010	36.0	287	118.0	85.8	75.25	.0060	.3316
Maha~055	40	1:4	40	.90	-.006	21.4	119	91.7	81.4	70.17	-.0136	.3162
Maha~056	40	1:4	30	.90	-.017	53.4	48	42.0	76.7	72.27	-.0301	.3050

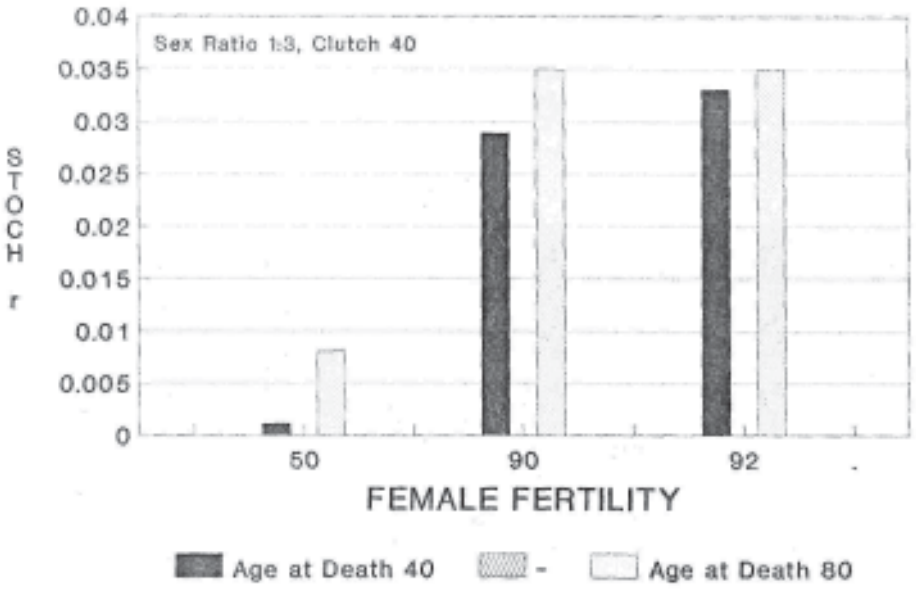
Graph 21. Mahanadi population. Stochastic growth rate for female fertility and different clutch sizes at 1:3 and 1:4 ratio and age 40. Age of first reproduction for females 10 and for males 13.



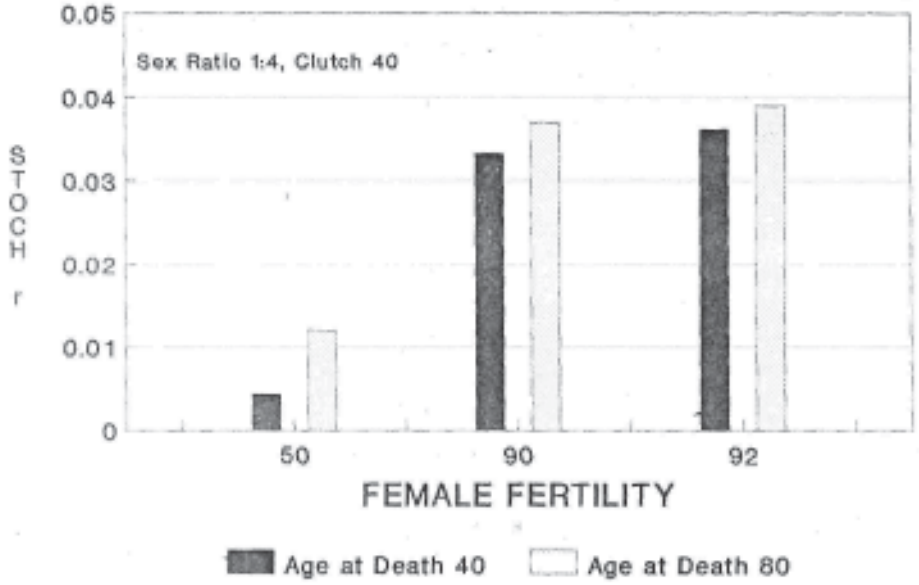
Graph 22. Mahanadi population. Stochastic growth rate for female fertility and different clutch sizes at 1:3 and 1:4 ratio and age 80. Age of first reproduction for females 10 and for males 13.



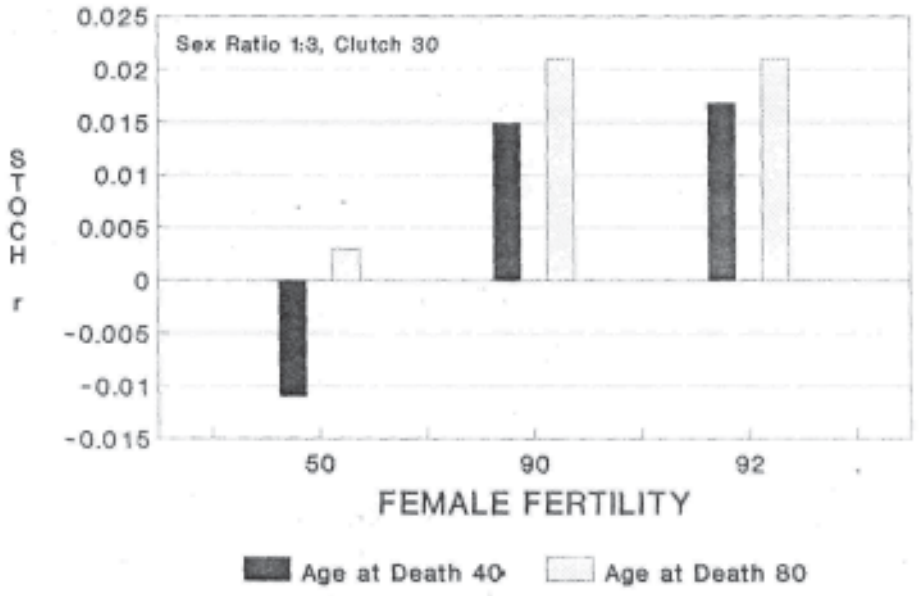
Graph 23. Mahanadi population. Stochastic growth rate for different fertility rates at ages 80 and 40, ratio 1:3 and clutch size 30. Age of first reproduction for females 10 and for males 13.



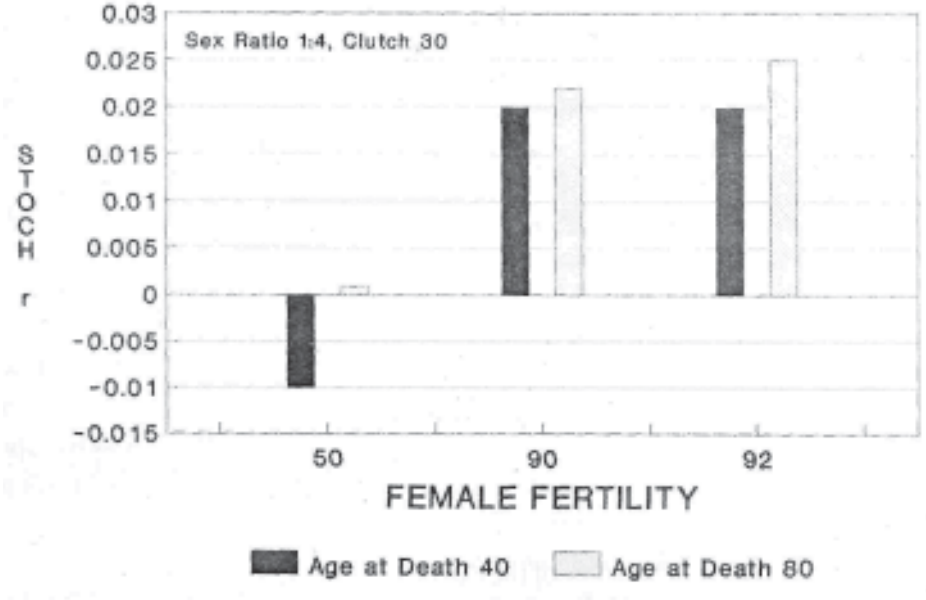
Graph 24. Mahanadi population. Stochastic growth rate for different fertility rates at ages 80 and 40, ratio 1:4 and clutch size 30. Age of first reproduction for females 10 and for males 13.



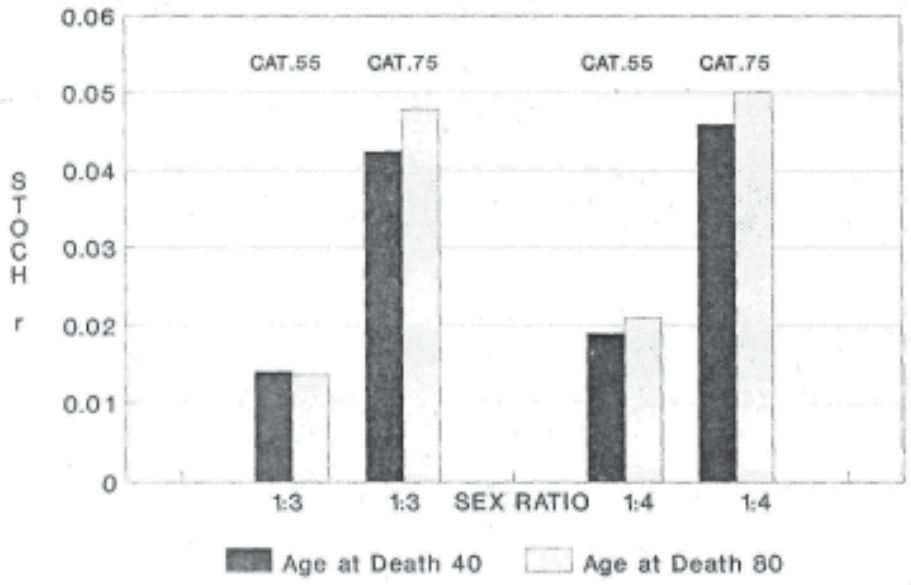
Graph 25. Mahanadi population. Stochastic growth rate for different fertility rates at ages 80 and 40, ratio 1:3 and clutch size 40. Age of first reproduction for females 10 and for males 13.



Graph 26. Mahanadi population. Stochastic growth rate for different fertility rates at ages 80 and 40, ratio 1:4 and clutch size 40. Age of first reproduction for females 10 and for males 13.



Graph 27. Mahanadi population. Stochastic growth rate at ages 80 and 40, with .55 and. 75 survival on catastrophe. Age of first reproduction for females 10 and for males 13.



Recommendations

1. Studies on the effects of threats must be made in detail. This will help understand the actual role such threats play on the dynamics of the population.

2. The Mahanadi population has been supplemented continuously over the last 19 years. This has infact helped the population avoid total extinction. Though continuous supplementations were carried out, the population has not stabilized. This shows that grave threats are affecting the populations still. Even though the simulation model showed no extinctions in the populations, high degrees of threats can push this population to extinction. Supplementation must therefore be carried out.

3. Genetic studies of this population should be carried out to see the difference between the Chambal and Mahanadi gharials. If the two populations are found not to differ as much as to be classified as distinct subspecies, supplementation of the Chambal gharials should be taken up in Mahanadhi. This would also increase heterozygosity in the Mahanadi population.

4. Monitoring and continuous studies of the existing and released gharials must be taken up to study population dynamics and the effects of pollution on the populations.

CENSUS AND DISTRIBUTION

INTRODUCTION

CENSUS

Conservation and management of gharial necessitates reliable periodic estimation of populations so that changes may be monitored and management methods modified appropriately. Census of gharial based on winter day time maximum counts may be done by motor boat to quickly cover metapopulations distributed over long river stretches. Census on foot is best suited for populations restricted to Small River stretches as these may be easily repeated for increased accuracy, afford better visibility of animals from elevated observation sites on river banks and eliminate difficulties confronted during boat census. Methods may be augmented by night counting with search lights for enhanced accuracy. Surveys to detect occurrence of gharial in new areas on the other hand may depend on indirect evidence such as spoors at basking sites but require interpretational skill with regard to spoors especially when such sites are used by large river turtles as well. So different methods of estimating gharial populations may be used depending on the specific requirements of accuracy of the estimate. Only a few populations of gharial in India have been censused with any regularity. These are (i) The Chambal river population censused between the years 1976 to 1978, and again from 1983 to 1985, then in 1988,1990 and 1994 (ii) the Girwa river population between 1975 to 1976 and again 1988 to 1994 with the exception of 1991 and the population in Ramganga river in Corbett National Park in 1974 and again in 1994. Other populations/river stretches that have been surveyed at least once are the Mahanadi river in Orissa; certain rivers of Nepal, Bangladesh and Pakistan, stretches of the Ganga (Rishikesh to Kanpur, Varanasi to Chhapra and Buxar to Farrakha), the Ghagra river (Kailashpuri to Chhapra) and Protected areas of the Son and Ken rivers in Madhy a Pradesh.

The results of preliminary surveys indicate a disappointing absence of significant populations, especially adult breeding groups that are stable and site specific residents, than what would be warranted by the numbers of captive reared animals that have been supplemented. This suggests that supplemented animals suffer in either any or all of the following fates

(i) Gharial fail to survive outside protected areas
(ii) They undergo a high degree of dispersal over very large distance
(iii) Survivors are wary and undetectable because of cryptic behaviour.

DISTRIBUTION

The sport value of gharial was never comparable to that of wild ungulates or other large land mammals and predators such as the rhino and tiger. Consequently, there are few references to the gharial in the better known works on Indian Shikar. Further, existing references rarely give a complete picture of the historical distribution of gharial especially with regard to

(i) relative abundance in different parts of its range.
(ii) it's occurrence in all of the many tributaries which comprise the river systems lying in the species range and
(iii) the distributional limits in different rivers with increase in altitude or in brackish water habitats in river estuaries and deltas.

Some very interesting questions exist about the former distribution of the gharial such as those concerning the species 'occurrence in the Irrawady river system in Myanmar or recent claims about its occurrence in the

Godavari Systems. Ecological changes of riverine habitat may possibly have irreversibly altered distributional limits as a consequence of habitat elimination. Research to unearth all available sources of information especially those not yet known, or accessible with difficulty may fill many gaps in our knowledge about the species' historical distribution. Results of recent surveys and census suggest that the present day distribution of gharial is a small fraction of that in historical times and relatively stable populations are known to be restricted to some well known protected areas.

The distribution of gharial within one protected area viz. The National Chambal Sanctuary has increased with the recolonization of at least 9 new nesting sites by 50 + recruits into the population of breeding females. If this has happened at all or not outside protected areas remains to be revealed by detailed surveys. This is especially relevant for rivers like the Yamuna downstream of its confluence with the Chambal and the Ghagra and Gandak in which considerable members of captive reared gharial have been supplemented at upstream locations creating the possibility of suitable habitat areas by dispersing animals.

REPORT OF THE CENSUS AND DISTRIBUTION GROUP

Group Members: Suresh Chugh, (Facilitator), R.K. Sinha, (Reporter), CM. Vyas, (Recorder), Sudhakar Kar, R.J. Rao, K.K. Tiwari, S.B. Mishra,, Sandeep Behera, Ishwar Das, A. K. Sinha, B. C. Verma

I. Census

The Working Group first addressed the question of availability of data on distribution of gharial in various rivers from 1975 to 1994 as well as what is the current status of gharial. The group also attempted to evaluate whether the efforts till date were sufficient.

It emerged that some of the areas have been covered fairly regularly such as Katerniaghat and Chambal river, but others have not been surveyed for some time. It emerged that there was a lack of consistency in timing of survey, survey strategy, etc. which was felt by some of the researchers to be a problem. Also, the researchers and field officers felt that a lack of coordination among the participating state agencies in census operation for multistate habitats was a matter of great concern.

It was noted during discussion that in Orissa more sightings of young and subadults of less than 6 ft. length were reported during night surveys/census and gharials of larger size were sighted more during the day time.

II. Distribution:

A detailed map of historical and present distribution map is needed to monitor and rehabilitate the gharial in future.

The working group felt that it would be useful to pinpoint more precisely whether and to what extent the distribution range had altered.

The Group also considered if releases had been made in suitable areas with regard to the distribution of the species and impact this has had on pre-project distribution.

It emerged that sufficient data on current distribution was not available. However, whatever data was available was listed to form baseline information. The Census and Distribution Chart # I lists this information including historical, pre-Project figures and present distribution. In view of the lack of monitoring for some areas, data was divided into categories and a “Data Quality Index” utilised. The Categories in the Data Quality Index are 1. Census - where figures reflect actual monitoring results; 2. Scientific Estimate, - where figures are not from actual monitoring but have been given on the basis of some available scientific information; 3. Anecdotal - where occasional, anecdotal information was contributed. As apparent from the Chart, there is a need for monitoring figures for many of the areas.

Recommendations

I. Census

As, a comprehensive census of gharial is manpower intensive, it is recommended that the local universities and college students as well as NGO’s, Panchayat, and other village based bodies/individuals should be motivated and involved to participate in Gharial census activity in addition to wildlife personnel and

researchers. A methodology to encourage them, such as that used by BNHS in their bird survey, may be considered.

A briefing session should be organised for all the participants, especially volunteers and persons not experienced in census work, before census every time. In view of the lack of agreement on methods of information gathering for Gharial, a brief brochure dealing with census techniques should be prepared and made available to all the agencies associated with the census.

It was felt by some of the members of the Working Group that motor boats should be avoided as far as possible while doing census as these may disturb the animals. Sailboats or oar boats could be used.

The Working Group felt that it is very important that annual census should be conducted. Field maps indicating preferred basking sites should be prepared during every census exercise.

Noting the lack of coordination between range states having Gharial, the Working Group felt that the participating state agencies should be coordinated. A Central Coordinating Unit for Gharial is proposed as a mechanism for providing coordination in an efficient and effective manner.

The Working Group strongly recommended that baseline data should always be collected before new animals are released and information should be shared among range states.

The Working Group recommends that census should be done for the whole stretch of river and not merely in the "identified habitats". *

The Working Group recommends that census should be done simultaneously in all range states, for which one month in winter should be fixed in which the maximum number of sightings are possible.**

As there are a number of agencies conducting surveys, it would be a valuable exercise to collect and collate the experiences of the agencies doing Gharial monitoring and census and a workshop held with the objective of standardising census methodology. It was pointed out by some members of the Workshop, however, that differences in individual areas exist which would require a somewhat different strategy. This could be included as Notes or Appendix in the document produced by this exercise.

II. Distribution

A detailed historical distribution map should be constructed from published information available in Boulenger, Smith, Hodgeson, BNHS Journals, District Gazetteers of the range states, and other historical references. Even ancient literature such as Ainee Akbari, Akbar-nama, etc. can be consulted for this map. Old royal family shikar records should be researched for this purpose, as well.

A distribution map giving status of species before 1975 when the Gharial Project started should be prepared and made available to concerned authorities.

A current distribution map should be constructed based on the information gathered from the different states on the present day status of the species. This should be updated year by year as census is completed and new figures and information becomes available.

The Wildlife Departments of the range states can take up a survey exercise to establish the current range of distribution of gharial in the instance that the comprehensive census proposed earlier does not take place. Information — anecdotal or about occasional sightings with the help of fishermen in particular, local schools, colleges, universities, and village bodies should be collected for a better understanding of the current distribution of the species.

Dissenting comments:

* Note: Mr. Basu felt that this was not a useful recommendation and that detailed census (as apart from surveys) should be done in identified habitats so as to save time and resources.

** Note: Mr. Basu (and a few others) felt that this may be impractical due to the different conditions in the various range areas.

CENSUS AND DISTRIBUTION GROUP: CHART 1

AREA	RIVER	STATUS / POPULATION/ HISTORY PRE-GHARIAL PROJECT		RELEASES	POST-RELEASE MONIT	PRESENT STATUS / POPULATION NUMBER		
						Data Quality Index		
						CENSUS	ESTIMATE ANECDOTAL	
NEPAL	KOSI(SAPTKOSI)	COMMON*	-	NEPAL-84	-	-	-	RELICT IF ANY
BIHAR	-DO-	"	<12*	-	NIL	-	-	-
NEPAL	NARAYANI -KALI GANDKI	"	(30-40)+	NEPAL 175	NARAYANI SURVEYED	N.A.	-	-
BIHAR	GANDAK	"	<15^{0}	-	-	-	3-4 BR.GROUPS RUMORED TO SURVIVE	TOTAL <100 -
BIHAR	SON	"	-	-	INFORMATION COLLECTED DURING DOLPHIN SURVEYS	-	-	POPULATION MAY SURVIVE UPSTREAM OF
BIHAR	GANGA	"	<10°	-	-	-	-	RELICT IF ANY
NEPAL	KARNALI	"	35(20)+	-	GIRWA CENSUSED	50-60 +	-.	
U.P.	GIRWA	"	14(06)	399	1975-79,88-94			
	GHAGRA	"	<10*	291	KARNALI SURVEYED	NA	PRELIM. SUR. OF GHAGRA	IN 1992 = <100
NEPAL U.P.	RAPTI	"	- -	5 10	NEPAL SURVEYED NIL	- -	<15 -	- -
U.P.	GANGA	"	<15°	225	PRELIM.SURV OF PORTION IN 1992	-	<15	-
	RAMGANGA	"	<5(4)+	257	CENSUS 1994 49(8)	-	-	-
U.P.	SARDA	"	-	260	SURVEYED ALONG WITH DOLPHIN	-	-	-
U.P.	YAMUNA	"	-	-	-	-	-	SURVIVES<50
M.P.	SON	"	<10	105	SURVEYED IN 1994	CA. 35	-	-
MP/UP	KEN	"	?	35((MP)	?	?	-	-
	TONS	"	-	-	-	-	-	-
UP	BETWA	"	-	55(UP)	-	-	-	-
	CHANDRAPRABHA	"	-	-	-	-	-	-
NEPAL	BABAI	"	<15^{0}	30	BABAI IN NEPAL SURVEYED IN 1989	(7)+	-	-
UP/MP	CHAMBAL	"	107(32)+	Ca. 1800	CENSUS	1976-78		

NOTE: 1. GOOD EVIDENCE EXISTS OF ABUNDANCE OF GHARIAL THROUGHOUT ITS HISTORICAL DISTRIBUTION WITH EXCEPTION OF MARGINAL HABITATS

2. FIGURES IN PARENTHESES REPRESENT ADULTS* BASED ON LITERATURE;

^{O} CONJECTUR/ESTIMATE/SC. GUESS J+SURVEY AND CENSUS ESTIMATES
NA. FIGURES NOT AVAILABLE.

HABITAT

Introduction

Essentially rivers are the habitat of gharial. Other than rare records of juveniles and sub-adults living in inland water bodies such as lakes and ponds, gharial have never been found outside major rivers. In literature its habitat often has been described as “deep and fast flowing rivers”, but in fact gharial select semi-stagnant aquatic habitats which exist in the pools of deeper waters within rivers. In these, gharial have to expend lesser energy against currents of flowing water to avoid dispersal beyond their preferred home range. Even young gharial less than 2 m in length which are found in swifter flowing river stretches occupy relatively semi-stagnant micro-habitats. Curiously gharial avoid the lake-like habitats of reservoirs above dams and barrages where there is no perceptible current.

Before descending to an elevation of 300 m. MSL rivers are too rapid and rocky to be normally suitable for habitation by gharial and gharial may also not have been common in brackish water environments of estuaries and deltas especially in those dominated by the estuarine crocodile.

With the exception of adult males in the breeding season gharials are social animals, They are also moderate feeders like all other poikilothermic crocodilians occurred in high densities in the past, in most parts of its range. The major limiting factors which restricted population densities were, apart from the territoriality of the males, overcrowding at the terrestrial components of habitat such as communal basking and nesting sites.

So far the carrying capacities of different gharial habitats have never been scientifically assessed. However, on the basis of existing literature, and their occurrence densities in certain areas even today ideal river habitat can easily support probably as many as 10 - 20 adults per kilometer.

Habitats and/or their carrying capacities have shrunk in recent times because of a number of man-induced ecological changes or the increase in human activity or habitation on river banks. Acute and irreversible changes have been caused by irrigation and hydroelectric works. Irrigation projects exist on nearly all range rivers with the exception of the rivers of the Bramhaputra system. Sometimes in rivers such as the Ganga and Sarda water is abstracted for irrigation systems by a series of barrages and lift irrigation schemes. Water abstraction reduce natural discharge of rivers and consequently stream width and depth. These may also create unnatural hydro-mechanical regimes disrupting natural activity cycles of both gharial and fish. Migration and breeding of fish, the exclusive prey base of gharial, are also obstructed by the presence of dams and barrages.

River fish themselves may be threatened not only because of the disruptive influence of dams and barrages but also from intense and indiscriminate artisanal fishing practices. Watershed degradation have resulted in serious floods and intensified erosion of river banks and have contributed to detrimental modifications of the hydrological characteristics of the rivers.

Because of intense persecution and killing of gharial in the past, wild gharial perceive threat in the human form and will desert otherwise suitable habitat in close proximity of human habitation and activity. However, captive reared gharial after release in rivers show much reduced threat responses and flight distances to human beings. So if left unpersecuted, especially if not injured or killed when accidentally netted, mere human presence by itself may not be a limiting factor in gharial habitat.

REPORT OF THE HABITAT WORKING GROUP

Members: Manoj Mishra, (Facilitator) D. Basu, (Recorder and Reporter); B.C. Choudhury, R.C. Gupta, S.M. Hasan, M.R. Yadav, J. N. Saxena, R. K. Pandit, IshwarDas$_f$ B. K. Sahu

1. OBJECTIVES

The group took as their primary objectives to

1.1 Define the "ideal" habitat characteristics

1.2 Make (preliminary) estimates of carrying capacity of existing habitats

2. METHODOLOGY

The Group adopted the following methodology for achieving objectives.

2.1. The Working Group first examined the attributes of habitats where gharial occur naturally at present (identify qualifiers).

2.2. Secondly, in determination of gharial habitats, an approach has been adopted whereby the essential requirements for the gharial with regard to its biology were analysed. Since the gharial is an inhabitant of rivers, the first step was to identify those rivers which have been historically inhabited by gharial. It was also attempted along with, to list such rivers which though possessing seemingly suitable gharial habitat were not known to have contained gharial. (See Habitat Chart I)

2.3. Thirdly, on a higher level of classification of qualifiers, habitat was considered to be composed of both i) aquatic and if) terrestrial components. The characteristics of each different size classes of animals were catalogued.

2.3.1 Aquatic habitat components

A catalogue of characteristics of aquatic components is listed as follows:

(a) Perenniality of the stream

(b) i. Adults: Free flowing but deep semi-stagnant pools;
ii. Juveniles: Existence of comparatively semi-stagnant eddies in river stretches which are shallower and swifter flowing in comparison to habitat inhabited by adults.

(c) Existance of perennial or seasonal side channels within annual home range for flood evasion behaviour.

(iv) Special characteristics of river bed for courtship/mating.
Shallow water beds contiguous with deep pools within the flowing river streams.

v) Minimum stream width : ca 100 m

vi) Other attributes: unpolluted and preferably devoid of any human habitation

2. 3.2 Prey availability is, of course, a determining characteristic for suitability of habitat. The following characteristics of prey, e.g. fish, were listed.

i) Prey item: Scaly and non scaly fish
ii) Prey size: ca. snout length of gharial
iii) Prey density: As predators gharial are efficient enough to capture prey in areas where fish populations may be depleted, but the existence of a critical lower threshold of fish population density has to be assessed,

2.4 Terrestrial component This can be further classified on the basis of the two territorial activities of gharial;

i) basking and

ii) nesting

Gharial show strong preference for river stretches with sandy banks although they have been found to adapt to clay/mud banks in obligatory situations.

2.4.1 Basking sites

Adults - Mid-river sand bars or reasonably flat and smooth rock promontories (that are exposed but not higher than 30 cms above water surface or just submerged). Basking sites must adjoin adult aquatic habitat described earlier.

Sub-adults and juveniles: similar as for adults and preferably adjoining the earlier described aquatic habitat of these size classes

2.4.2 Nesting sites

i) Steep sandbanks: 2-3 ms high above water level in snow fed tributaries and at least 1 m high in southern tributaries.

ii) Depth of sandy layer should be greater for larger females and in excess of minimum depth (45-60 cm) for smaller females

3. Availability of Habitat ~ Recommendations for Assessment

3.1. Availability/Status of Habitat should be assessed on basis of fulfillment of above described prerequisites by surveys of listed rivers.

3.2. An adequate numbers of surveyors selected for this work should be trained in survey competence-through special workshops.

3.3. Food preference needs to be investigated using state of art techniques before work on actual prey availability can be assessed in the field.

THREATS

Introduction

By the end of 1960's the gharial had dwindled to a trace of its former abundance due to combined effect of shooting, hunting for skin and meat, and loss of habitat from river alteration and human settlements. Under the Wildlife (Protection) Act, 1972, the species was protected by declaring it as an endangered species. The international laws have equally protected the species by including the gharial in Appendix I of CITES and in the IUCN Red-data Book. Although the animal is well protected legally, the increasing human pressure on gharial habitats as well as other threats bode ill for the long term survival of the species.

The various factors which have threatened the survival of gharial as a species have changed with the passage of time. These changes have been quantitative as well as qualitative. The degree of threat represented by some of these factors, such as killing for skins, has altered over time. While none of the factors responsible for rapid decimation of population in the past have disappeared entirely, even new sources of threat have originated. These are mostly from man induced ecological changes which affect either the species itself or its prey base.

Although this has not been extensively documented the indiscriminate killing of gharial either directly for skins or accidentally in modern fishing gear such as nylon set gill nets, has been largely responsible for the extermination of the species from extensive river stretches that were formerly described as 'abounding' with these animals. The regulation of international trade in crocodilian skins by enforcement of the CITES agreement, as well as then organised production from several international source areas, has reduced the profitability of poaching crocodiles or gharials to the extent that their skins no more constitute a significant proportion of clandestine consignments of wild animal products that are detected in India from time to time. Although deliberate killing of gharial for hides may have ceased to a large extent, accidental killing resulting from intensified artisanal fishing with modern nylon fishing gear continues to exist and may constitute one of the main hurdles in the success of supplementation/reintroduction programs.

In the near and distant future the main threat to the survival of self-sustaining populations of gharial arises from the intense competition they will face from man for the three resources which occur in their habitat, viz. fish, water and riparian lands. A major proportion of the species range lies within the Indo-gangetic Plains which are reputedly some of the most populous regions in the entire world. This competition may intensify with unchecked growth of human populations. Threats to the species should not be assessed in isolation — they are very similar to those threatening a collapse of the great river eco-systems of this region, and a concomitant loss of their biodiversity. Successful biological conservation implies that man will have to ascribe an appreciable value to the health and biodiversity of these ecosystems irrespective of whether this value is an economic, ecological, scientific, cultural or aesthetic one. The Report of the Threats Group is as follows:

REPORT OF THE THREATS WORKING GROUP :

Group Members: Brij Bhushan Sharma, Facilitator; B.C. Choudhury, Reporter; Dr. Dalwani; Dr. B.A, Daniel, Recorder; Ms. Fahmida Hanfee

In India the Gharial population exists in the four major River systems, e.g.
a) Mahanadi; b) Southern tributaries; c) Main Ganga; d) Northern tributaries

All these river systems have a varied degree of threats (direct and indirect) affecting the survival of gharial populations. The working Group listed the direct threats as:

1 Removal of eggs
2. Poaching of animal for medicinal use
3. Incidental catching in fishing nets
4. Accidental killing
5. Bamboo rafting.
6. Dynamite fishing
7. Inbreeding
8. Subsidised predation
9. Trade
10. Small Population size itself

and indirect threats as

1. Construction of dams
2. Pollution
3. Riparian cultivation
4. Man induced floods
5. Intra-specific conflict
6. Public attitude/practices
7. Sub-optimal captive management practices

See Chart 1.

The Threats Working Group addressed the following objectives:

1) Riverwise categorisation of the threats. The rivers were listed under Southern Tributaries as Chambal, Ken, Son; Mahanadi, Main Ganges, and Northern Tributaries Girwa, Ramganga, Brahmaputra and Ghagra and Sarda. See. Chart 1.

2) Degree of threats
3) Frequency of threats

These were listed on a scale of 1_{Least} 2 3 4 5 6 $7_{Highest}$ and rated in Chart # 2.
On the basis of this listing and rating scale, the Threats Group has formulated the following Recommendations:

1) Systematic monitoring of the river systems to assess the present status of gharial after supplementation is an urgent requirement.

2) A systematic, coordinated and concentrated research programme is needed to determine the degree of impact of several threats and of the conservation measures taken in the last twenty years.

3) Education and awareness at community level is required to provide a defense against various man-made threats,

4) Rivers (like Mahanadi) with high frequency of threats should be taken up for special study and monitoring on priority basis.

5) Genetic studies should be done so that it can be determined whether or not inbreeding constitutes a genuine threat to the various populations of gharial.

(The computer modelling exercise indicated that a lack of heterozygosity resulting from inbreeding may be a problem in some populations. Also very little is known, about the age structure of the populations. As no genetic management has been considered in release programmes to date, it is strongly recommended that managers take cognizance of genetic and demographic factors when planning further release.)

6) Coordination with the Irrigation Deptt of the respective states to determine the likelihood of flooding and avoidable man-induced floods.

7) Control measures for unprotected areas having gharial populations. Identify community nesting areas and provide protection to the nests to reduce the risk of predation.

As there are many Gharial in unprotected areas, threats such as fishing, sand mining, river bed cultivation and industrial pollution can be controlled best by education/awareness activities.

Gharial PHVA -- Threat Matrix

= no population

	River System	Mahanadi River	Southern Tributaries			Main Ganges	Northern Tributaries				
			Chambal	Ken	Son		Gandak	Girwa Ghagra Sarda		Ramganga	Brahmaputra
	DIRECT THREATS										
1	Removing eggs	yes	no	no	no	no	no	yes		no	no
2.	Medicinal use	no	no	no	no	no	no	no		no	yes
3.	Incidental catching in fishing nets	yes	yes	no	yes	yes	yes	no		no	yes
4.	Accidental killing	no	no	no	no	no	yes	no		no	yes
5.	Bamboo rafting	no	no	no	no	no	no	no		no	no
6.	Dynamite fishing	no	no	no	yes	no	no	no		no	no
7.	Inbreeding	no	?	yes	no	yes	no	no		no	no
8.	Subsidised predation	?	yes	no	no	-	no	no		no	no
9.	Trade	no	no	no	no	yes	yes	no		no	no
10.	Small Population size itself	yes	no	yes	yes	yes	yes	no		yes	no
1.	INDIRECT THREATS Construction of dams	no	yes	no	yes	yes	yes	no		no	no
2.	Pollution	no	no	no	no	yes	no	yes		no	no
3.	Riparian cultivation	no	yes	no	yes	yes	no	yes			no
4.	Man induced floods	no	yes	no	no	no	no	yes		no	no
5.	Intra-specific conflict	yes	yes	no	no	no	no	no		no	no
6.	Public attitude/practices	yes	no	yes	no	no	yes	yes		no	yes
7.	Captive management practices	no	no	no	no	no	no	yes		no	no

Gharial PHVA - Threat Ratings

	DIRECT										INDIRECT							
	RE	MU	IC	AK	BR	DF	IB	SP	TRE	SPS	CD	PN	RC	MF	IC	PA	HA	WCM
SOUTHERN TRIBUTARIES																		
CHAMBAL	1	1	6	3	4	2	YES	5	2	1	5	2	6	5	5	1	5	2
KEN	1	1	1	1	1	1	YES	1	1	5	1	2	2	1	1	4	2	1
SON	1	1	6	2	1	5	NO	2	2	6	5	2	6	2	2	2	4	1
MAHANADI	6	1	6	2	1	1	NO	2	2	6	2	2	2	2	5	5	2	2
MAIN GANGES	2	1	6	2	2	2	YES	5	5	6	6	5	5	2	2	3	6	1
NORTHERN TRIBUTARIES																		
GIRWA	6	2	1	1	1	2	NO	2	2	2	1	5	2	5	2	5	2	1
RAMGANGA	1	1	1	1	1	1	NO	1	1	6	2	1	1	1	1	1	2	1
BRAHMAPUTRA	1	5	5	5	1	1	NO	1	2	1	1	1	1	2	2	5	2	1 ---
GHAGRA & SARDA	NO POPULATIONS																	

TRADE

Introduction

The Crocodilian species have attractive and durable hides which make them desirable for the leather trade. In some countries, the wildlife establishment has attempted to amalgamate conservation and consumption of wildlife products in a sustainable manner with varying degrees of success. There is a general feeling among global conservation seers and policy makers that sustainable development of natural resources is the key to the salvation of species and their habitats. A policy statement on sustainable use has been drafted and is in the process of revision. A special task force has been set up for this purpose.

Two decades ago, when the crocodile project first started, there was an idea that farming of mugger crocodiles might be a viable proposition. Afterwards, the Government of India took a decision not to allow farming of wild animals for commercial purpose.

There were specific requests to address the subject of Trade by the I.G., Wildlife, and Ministry of Environment as a personal remark to the facilitators and in a letter to the organisers by the Chairman of the Crocodile Specialist Group, SSC, and IUCN. Because there have been repeated requests to open trade for crocodilians in India, the Trade Working Group was created at the P.H.V.A. to examine the feasible from a biological, economic, and ecological as well as cultural point of view and give an opinion by the P.H. V. A. Workshop,

REPORT OF THE TRADE GROUP

Members: Ms. FahmidaHanfee, Faciliator; BrijBushan Sharma, Recorder, Reporter; Bipul Chakraborty; Ravikant Pandit; Suresh Chugh; B. Dutta Gupta; D, Basu

Introduction

It is believed that due to commercial value of the skin, for preparing various leather goods, the populations of gharial were largely hunted. In addition to the trade in skins, crocodile eggs, meat, fat, gall bladder and other parts makes it worthwhile to kill crocodiles. The 1964-65 statistics show the export of Rs. 24,000 worth of crocodile skins to U.K. and France. However, with the ban on crocodile killing during 1975, the skin market went underground. There are very few official records of gharial trade. With the belief of growth of gharial population, especially in captive conditions, a question has been raised both by national and international organisations concerned with crocodiles to allow sustainable utilisation of gharial for commerical purpose through crocodile farming.

The conclusions drawn from the discussions and opinions of the Trade Working Group indicate that there are no official reports of gharial trade in India. As far as illegal trade is concerned, scanty reports are available, one of live Gharials being sold at Patna market and other of Amsterdam where the gharials are being sold at a price of $300 per gharial. It is also known that gharial is sometimes locally used for its eggs, meat and medicinal properties, which constitutes a sort of small scale commerce.

Recognising that the international conservation community strongly supports, and even encourages, the concept of trade in animal products when it can be done sustainably and also that there is interest in establishing commercial farms for crocodilians in India from different agencies, the Trade Working Group has discussed the merits and demerits of commercial farming and opening of trade in the Indian context. We have concluded that it is not in the best interests of the conservation of wildlife in India to opt for trade of this species.

1. Cultural values: The basic ethics of the country towards wildlife conservation and animal life cannot be ignored. Indians do not look at animals merely as a source of meat, hide and horns. From ancient times, animals — including both wild and domestic species — have been protected by imperial edict and religious principle. While it may not possible or even desirable to convert everybody into a vegetarian, the basic approach of the country is not to deny to right to live, to all living beings. It is even part of the national Constitution, e.g. Article 51 A.

Killing of animals for monetary benefits is discouraged by a large number of people in India. People have religious sentiments attached with their lifestyles. This must be respected.

2. Protection and legal aspects

Gharial is included under Schedule I of the Wildlife (Protection) Act, 1972. It is classified under Appendix I of CITES, as Endangered in the Red Data Book of IUCN and also the Red Data book of Indian animals by Zoological Survey of India.

Accordingly, any commercial dealing in such species is strictly prohibited. It would require that the Wildlife Act of the country be modified in order to bring trade into operation. Having altered the law for one order of animals, it is a short step to changing the law for others. It would open a floodgate of requests for alterations to the Act.

3. Wrong signals about conservation. If the Government of India should take up commercial farming, the general impression will be created in the villages as well as urban areas that the Government has relaxed the legal provisions regarding ban on killing, so poaching of animals is likely to increase.

4. Increasing illegal trade. With the poverty that exists in the country, particularly amongst the fishing community, it would be very difficult to exercise any effective control over capture of animals from the wild. These wild caught animals could be laundered very easily for the purposes of exploitation in the garb of captive bred animals. Commercial farming and trade is likely to lead to an increase of lust of the urban elite and rich people in the foreign countries to use wild animal's skins for consumer items which will encourage their demand in open markets.

5. Illiteracy of the poor people. Many of the people of India are illiterate and unsophisticated and unable to distinguish between sustainability and exploitation and the consequences of the latter.

6. Some of the Working Group of the PH VA have concluded that while the Gharial population can be sustained in the wild by supplementation, it cannot be easily increased to large numbers. Therefore the animal is likely to stay on the endangered list in perpetuity.

Recommendations:

1. The Trade Group recommends a survey to assess the dependency of people on fisheries in and around the protected areas. (Partial or total dependence)

2. Categorisation of the people.

3. The requests which have come from within India for opening up of trade in crocodilian products in recent years stems in part from the surplus animals which exist with different agencies which bred them in anticipation of need. Zoos and rearing centres should therefore be mindful to rear only such numbers of Gharial as are required by the authorities responsible for supplementation. In the case of accidental surplus accumulated "in good faith" and not required for conservation due to unavoidable circumstances, the Government of India will undertake to support the animals for the rest of their natural lives.

5. The Working Group recommends that Education Programmes focusing on Gharial should include as a target group the local people in and around gharial habitats who might be using Gharial for non-tannery products.

6. It is recommended that enforcement officers (customs, local police and the forest department) be trained in identification of seized animals and their products.

REINTRODUCTION

Introduction

Under the Crocodile Project, which was initiated by the technical expertise of Dr. H. R. Bustard, several State Governments have established crocodile breeding and management programmes. To reduce natural losses through management, the 'grow and release' technique was adopted, which involves incubation of wild-laid eggs in artificial hatcheries, rearing of young in controlled environment and releasing of grownup (over a meter length) animals in protected areas. So far around 3,865 captive, raised gharials have been released in 12 rivers in the country. The post-release monitoring indicated that the habitats have accepted the released animals and there are increasing trends in the populations. It is felt that in the near future, as the recruitment into the adult group steadily increases, new areas may have to be developed to attract sub-adults to settle to form breeding groups. In addition, new releasing sites have to be identified for reintroduction of gharial.

The recent instructions of Govt, of India to different State Governments regarding closure of egg collection by the rehabilitation centres became a great concern to many scientists and managers. In the Gharial PHVA workshop a working group for Re-introductions has been formed to discuss the future strategies for gharial re-introduction. The group consulted the draft-guidelines for reintroduction proposed by the IUCN/SSC/ Reintroduction Specialist Group.

Captive reared gharial have been both reintroduced in areas where they had been extirpated locally and also used for supplementation of relict populations. The major proportion of captive reared stock was produced through the collection and incubation of eggs laid by wild gharials, but eggs produced in captive breeding facilities have also contributed to this in recent years. Production of captive reared gharial for supplementation began with the inception of the Government of India gharial project in 1975-76 and since then continued without respite till 1992. During this period approximately five to six hundred eggs were collected from the nests of wild gharial every year. The overall production of animals for supplementation amounted to 40% of eggs collected. This represented an 8 to 10 fold increase in the survival of young gharial from eggs laid in the wild and, therefore, justified the supplementation programme of relict populations. Supplemented gharial were "head started" before their release in the wild by rearing in captivity for varying lengths of time. To date no studies have conclusively established any advantage accruing from a "correct" supplementation methodology with respect to age/size of animals at release, selection of release sites or season. Generally accepted thumb rules are; a minimum size of 1.2 metres length; the upper most stream point with a protected area preferably those inhabitated by animals of similar size; release should be completed earliest following the final recession of monsoon river spate and animals should not be released directly into flowing water but on land.

In practice there have been many deviations from the above rules as well as from IUCN guidelines for reintroduction. From a total of ca. 4000 captive reared animals which have been released in rivers, 60 to 65% have been used for supplementation of relict population within protected areas, which 35% were reintroduced in unprotected areas within the species' former distribution but where they did not occur anymore.

The supplementation exercise has been most successful in the Chambal river where approximately 33 per cent of the animals upto age 5 were recorded to have survived within the protected National Chambal Sanctuary, For animals of age 5 to 9 the recruitment rate rose to 79%. It is note worthy that after age 9; gharials show a marked tendency to become residents of a preferred home range. Plausible reasons which have contributed to comparatively rapid population recoveries of the gharial in this river are;

(i) Ideal habitat conditions (See Section habitat),
(ii) Abundant prey base,
(iii) Minimal disturbance because of remote and' inaccessible locations,
(iv) Management inputs such as total fishing ban and surveillance by sanctuary staff.
Similiar conditions also prevail in the Girwariver within the Katerniaghat Sanctuary, but recruitment into this population has been now here comparable with that of the Chambal river.

The most conspicuous differences between conditions prevailing in Chambal and Girwa are:

(l) the miniscule extent of habitat in the Girwa (8to 10km) in comparison to the 400 kms of protected habitat of the Chambal river.

(ii) The disruptive presence of an irrigation barrage located within 10 km of the downstream boundary of the Katerniaghat Sanctuary. As a result, an unknown percentage of gharial are lost from the sanctuary population where (a) they enter irrigation canals and are unable to return to the main river, (b) they disperse along the river, downstream of the barrage, but cannot migrate into the sanctuary area because of the surmountable barrier presented by the barrage, (c) animals die in accidents at the barrage gates.

The most significant reason for the higher success rate of the supplementation programme for the Chambal river population would, however appear to be the extensive protected river length available to the released gharials.

REINTRODUCTION WORKING GROUP

Members: R. J. Rao, Facilitator; D. Basu, Recorder/Reporter; Manoj Mishra; S. M. Hasan; Dr. D. N. Saxena; Dr. L. N. Acharjyo

POLICY RECOMMENDATIONS

The Workshop recognized that the supplementation activities under "Grow and Release" programme taken up in the last two decades have been successful in increasing the population. The modelling exercise clearly showed that without these supplementation activities the probability that these populations would have survived was very, very low. This conclusion is borne out by the fact that supplementation of the Chambal population with nearly 1788 animals, plus an estimated natural nativity of 1165 animals (a total of 2953 animals) has resulted in the recruitment of only 300 adults and subadults. This represents an actual population increase of 17% in 16 years, or only 1% annual growth rate.

The Working Group has listed the rivers belonging to Ganges and Mahanadi river system in which successful gharial grow and release (supplementation) efforts have been made, e.g. Chambal, Son, Ken, Girwa, Ramganga, Mahanadi. It is felt that supplementation in all the above rivers should be continued.

As already recommended by the habitat sub-group, extensive surveys by trained personnel should be carried out in the states of U. P., M. P., Orissa, Bihar, West Bengal and Assam to determine suitable habitat for possible further re-introductions. The Reintroduction Working Group noted the insufficiency of information about the areas where the species occurring earlier and became extinct. A committee of experts may then decide on the basis of survey results regarding the most appropriate site for actual reintroduction sites. Reintroduction of animals in Brahmaputra River should be taken up on priority because no previous conservation measures have been taken for the species there.

A strong and continuous monitoring component should be built into further supplementation / reintroduction programmes.

Requests for reintroduction of gharial in the historical range of Pakistan, Bangaladesh, Nepal, Bhutan, and Burma should be encouraged and surplus Gharial may be donated to those wildlife establishments for conservation purpose.

The Working Group recommends that re-introduction/supplementation programme should be as per the guidelines of the IUCN/SSC re-introduction specialist group with necessary modifications locally.

Technical recommendations

1. Releases for supplementation are made at a standard optimum size. It is now known through experience that smaller sized animals are highly dispersible so it may be beneficial to release a smaller number of larger animals with a cost equivalent to a larger numbers of smaller animals.

2. Rearing procedures such as hand feeding should be discouraged to eliminate the possibility of human familiarity which will increase vulnerability of animals when released in the wild.

3. Release procedures require to incorporate orientation of animals to be released in flowing water habitat by a minimum period of rearing in such enclosures where flowing water habitat is simulated.

4. Releases must strictly adhere to accepted norms of relate season post- monsoon - to pre-winter and release in habitat (in vicinity of wildly occurring similar sized animals until the norms have been scientifically demonstrated to be suboptimal in effectiveness

5. Release procedures have to be standardised for optimal efficiency, e.g., state-of-the-art techniques such as radio telemetry to monitor fate of individual batches of releases as against general monitoring that have been recommended elsewhere.

PROSPECT OF FURTHER GHARIAL REINTRODUCTION IN RANGE STATES IN INDIA *

	INP.A.'S	OUTSIDE P.A.'S	COMMENTS
U. P.	Yes	Yes	
M. P.	Yes	No	
Bihar	Yes	No	
Orissa	Yes	Yes	
West Bengal	Yes	?	
North. East Assam	?	.	Need to survey

PROSPECT OF FURTHER GHARIAL REINTRODUCTION IN RANGE COUNTRIES IN INDIAN SUBCONTINENT

		Stocks to come from:
INDIA	Y	INDIA
NEPAL	Y	INDIA/NEPAL
BANGALADESH	Y	INDIA
PAKISTAN	?	INDIA
BURMA	?	NEPAL
BHUTAN	?	?

* CHARTS GENERATED BY B.C. CHOUDHURY ON BASIS ON INPUT FROM STATES REPORTING SESSION

REINTRODUCTION GROUP -- CHART I

1 State	2 Rive r	3 Length of river protected (km.)	4 Number s released	5 Proportion successfully recruited into population	6 Estimation of carrying capacity of Protected habitat	7 Necessity of sustained release	8 Number of years	9 Annual Release rate
U.P.	Girwa	13	399	-20 A.D.	100	2000	20	100
	Ramganga	50?	257	6 adults and sub adults	<25	500-1000	20	50
	Betwa	-	55	*				
	Ganga	07	245	*				
	Rapti	-	10	*				
	Ghagra	-	291	*				
	Swarda	-	260	*				
M.P.	Son	209	17 35 - 45 young	adults < 5	adults 80-100	3500	35	100
	Ken	45	50	10-15				
Orissa	Mahanadi	30	609	25-30				
National	Chambal	600	1788	adults and sub adults 250-300 young 850-900	250 adults 500 sub adults	3500	100	100

CAPTIVE POPULATION

Introduction

Reviews of captive breeding of crocodilians point to its feasibility in the case of most species. Significantly however, so far only three establishments in the world, viz. Kukrail Rearing Centre, Madras Crocodile Bank and Nandankanan Biological Park have achieved regular success in breeding the gharial in captivity, although at least 15 known establishments hold adult males and females. Five of these are within India, and the others elsewhere in the world.

Likely reasons for the failure to breed gharial on the part of so many institutions may most easily be discovered by examining the comparable attributes of the establishments where it has been successful. These may be catalogued as under:

1. Location within the natural distribution of the species
2. Spacious enclosures especially planned for their breeding
3. Adequate seclusion and privacy in the breeding enclosure
4. Planned acquisition of adequate compatible breeding stock.
5. Availability of species expertise

The last two attributes are perhaps the most difficult to acquire, at least at short notice. This is because of the late attainment of sexual maturity in the species (12-15 years in ideal conditions) and requisite species expertise comes only from protracted and first hand, both *in situ* and *ex situ* experience. So at establishments intending to specialize in captive breeding of gharial, both breeding stock and expertise need to be maintained as a tradition and that too with continuity. This emphasizes the need for planned and coordinated long-term approach to *ex situ* meta-population management, if zoos and other *ex situ* breeding facilities are to actively contribute to supplementation programmes for *in situ* conservation. Well-managed *ex situ* facilities are also useful in a number of exclusive ways that complement *in situ* conservation efforts. These are

1. maintenance of endangered species stock reserves that are safe-guarded against *in situ* catastrophes

2. genetic manipulations for small species populations threatened with inbreeding

3. studies of taxonomy, behaviour, physiology and genetics

4. aiding public familiarization with the species as a defence against apathy towards extinction for a species shrouded in obscurity,

CAPTIVE POPULATION/DISEASE WORKING GROUP

Members: S. C. Sharma, L. N. Acharjyo, M. V. Subba Rao, T, P. Vyas, B. Dutta Gupta, Bipul Chakraborty, Rajeev Pawar

The Captive Population / Disease Working Group discussed captive management and disease on the first day with Mr. S. C. Sharma facilitating, and disease on the second day with Dr. L. N. Acharjyo facilitating. Using a list of zoos in India holding gharial provided by the Central Zoo Authority the working group discussed management in these facilities. It was not possible to tell from the information available how many zoos had been successful in breeding gharial. However, the Group felt that sufficient expertise exists about the rearing of gharials in the captive rearing centres started under "Grow and Release" programme of the Indian Crocodile Project. Captive breeding of gharials has been successful in one Indian zoo and one captive rearing centre. The expertise available in these centres can be utilised for other centres also.

Zoos as well as the captive rearing centres could provide stock for reintroduction in wild if it is required. Wildlife managers should intimate their exact demand well in advance so that an appropriate programme can be organised. Zoos can fulfill the demand of other zoos if self-sustaining captive population is built up.

However, in order to build up a self-sustaining meta-population — both for filling the modest needs of zoos for exhibition as well as the larger demand for supplementation, a coordinated approach for captive breeding of this species has to be undertaken. A species coordinator may be appointed for the purpose by the Central Zoo Authority.

On the basis of the assessment of the working group, the existing facilities now holding gharial have a potential capacity of 4000 to 5000 gharial hatchlings for supplementation purposes, <u>if renovation work to improve the facilities is taken up.</u> This includes changing of wire mesh, repairs of water pools, improvement of water supply system, in some cases, expansion of facility, etc.

As some of the captive rearing facilities are not maintaining gharial in proper way it is recommended that

1. Minimum facilities for welfare of the animals should be provided at all zoos.

2. Zoos which are designated as captive breeding centres for gharial should construct their enclosure for gharial as per the requirement of the species in the wild, such as deep pool, free flowing water (at least for some hours of the day) and high sand banks for nesting and basking.

3. The zoos which can afford both spatial and financial improvements should construct nature-simulating spacious enclosures for exhibition so that the public can be educated about the behaviour and biology of the species and also form a positive image of the animal. In order to start a coordinated breeding programme, an individual identification mark of gharial has to be done. This will make planned captive breeding possible. A Studbook should be started with available gharials in zoos/gharial rearing centres. All the zoos/captive rearing centres should maintain records indicating the origin of the individual/groups in order to facilitate maintenance of genetic diversity of the captive population as well as those which are to be used for supplementation in wild.

Moreover, as it has emerged from modelling exercises that introduction of more males may be required, contemporary research has opened up possibilities of controlling the sex ratios of crocodilians produced

through temperature controlled incubation. This technique should also be investigated through scientific research in the case of gharial to make available a tool for gharial management in the wild through supplementation if so required.

As it is not possible to determine the sex of the animal by the age at which they are normally reintroduced, biotechnology laboratories may be consulted for a means of doing this.

There is no provision in Zoo Rules 1992 about the maintenance of reptiles in captivity. Therefore, the group strongly recommends making provision in the Zoo Rules for providing minimum standards for the upkeep of reptiles in general with special reference to gharial.

In some of the centres captive breeding of the gharial is already going on. It may not be necessary for such centres to collect eggs from the wild for hatching. But those centres where successful breeding has not occurred must depend on collection of eggs from wild to fulfil the requirements of the supplementation programme.

Health and Husbandry

To ensure better survival and good health for animals the following husbandry recommendations are made:

a. Uninterrupted supply of clean fresh potable water must be ensured

b. Each pool should have good drainage system for effective cleaning.

c. As high mortality is observed during winter months, special care to provide warmth to the hatchlings has to be taken up.

d. It has been generally seen that good quality fish is not supplied by the contractors for the gharials and this affects the health and survival percentage in captivity. To overcome this, a captive fish breeding/rearing centre, managed by fishery specialists should be set up near every captive gharial breeding centre.

e. Each centre should have a small laboratory supported with qualified lab technician and attendant for routine health checkup. There should be provision of visit of a veterinary doctor for health monitoring of these animals regularly.

f. No dead animal of these centers should be disposed off without detailed post-mortem examination. In case the diagnosis is not possible on post-mortem examination only pathological studies of the materials collected during post-mortem examination should be carried out with the help of nearest animal disease diagnostic laboratory.

g. One of the views expressed was that the gharial populations found in northern and southern tributaries of river Ganges appears to be different from each other. It is suggested to find out whether these two populations belong to two sub-species or strains or not with the aid of DNA fingerprinting.

h. To avoid undue stress during transport and reduce the cost of transportation, the new proposed facility/ centres should be as near as possible to the release sites.

i. The number of hatchlings to be reared should be decided strictly according to the requirement of the stock intimated by the concerned authorities responsible for reintroduction programmes.

j. Entry of visitors inside the breeding/rearing enclosures should be prevented. Entry of others connected with the management works should pass through foot bath containing disinfection lotion.

k. So far, the diseases recorded in gharial hatchlings are: Gastroenteritis, Hepatitis, prolapse of the cloaca, E. coli infection, mouth canker, pneumonia, unabsorbed yolk, hunchback condition [calcium deficiency], hypoglycemia syndrome, eye infection, bent neck condition, debility, and skin infection. It is recommended to have detailed investigation with the help of disease diagnostic laboratories to come to definite conclusion about the disease responsible for mortality.

l.. The data available on diseases and mortality pattern should be collected from all captive rearing/breeding centres and compiled for distribution to the managers of these centres. This is likely to help in reducing the incidence of disease/mortality.

m. The Group recommends having a training programme for zoo/captive rearing centre personnel in management and health care of gharial in suitable institutions.

The captive breeding facility can also play a major role in educating the public about the importance of this species/programme. A small interpretation centre near every breeding/ rearing centre is likely to fulfil this objective. All the enclosures should have proper sign boards/plates depicting the date of hatching and other important features highlighting the success of gharial conservation programme.

Rearing procedures for hatchlings should be standardised and these standards strictly maintained to insure maximum production of gharial from eggs produced in captivity.

INDIAN ZOO & OTHER CAPTIVE FACILITIES HOLDING GHARIAL

State/Zoological Park	M	F	U	Total
1. Nehru Zoological Park, Hyderabad, A. P.	0	0	2	2
2. Zoological Park, Itanagar, Arunachal Pradesh	0	0	2	2
3. Assam State Zoo, Guwahati, Assam	0	0	1	1
4. Jawaharlal Nehru Biological Park, Bokaro, Bihar	0	0	6	6
5. Sanjay Gandhi Biological Park, Patna, Bihar	0	0	12	12
6. National Zoological Park, Mathura Road, New Delhi	1	2	0	3
7. Kamla Nehru Zoological Garden, Ahmedabad, Gujarat	0	0	4	4
8. Sakkarbaug Zoo, Junagadh, Gujarat	1	2	0	3
9. Sayyaji Baug Zoo, Kareli Bagh, Baroda	0	3	0	3
10. Bannerghatta (National Park), Bangalore, Karnataka	1	2	0	3
11. Sri Chamarajendra Zoological Garden, Mysore, -do-	2	4	3	9
12. Thiruvananthapuram Zoo, Thiruvananthapuram, Kerala	1	1	0	2
13. Van Vihar National Park, Bhopal, M. P.	0	0	10	10
14. Kamla Nehru Prani Sangrahalaya, Indore, M. P.	0	0	5	5
15. Maitri Baag Zoo, Bhilai Steel Plant, Bhilai, M. P.	0	0	4	4
16. Gandhi Zoological Park, Gwalior, M. P.	0	0	4	4
17. Deori Gharial Rearing Centre, Morena, M. P.	0	0	156	156
18. Veermata Jijabai Bhosle Udyan Zoo, Bombay	0	0	6	6
19. Nandankanan Biological Park, Bhubaneshwar, Orissa	1	6	239	246
20. Mahendra Chaudhury Zoological Park, Chhat Bir	0	1	0	1
21. Jaipur Zoo, Jaipur, Rajasthan	1	3	0	4
22. Jodhpur Zoo, Jodhpur, Rajasthan	3	2	0	5
23. Udaipur Zoo, Udaipur, Rajasthan	0	0	2	2
24. Arignar Anna Zoological Park, Madras, T. N.	2	2	0	4
25. Madras Crocodile Bank Trust, Mamallapuram, T. N.	0	0	49	49
26. Mini Zoo, Kurukshetra, (Haryana), U. P.	1	2	0	3
27, Madras Snake Park Trust, Guindy, Madras, T. N.	0	0	6	6
28. Katerniaghat Sanctuary, Gharial Rehab Centre, U. P.	figures not available ----------			
29. Kanpur Zoological Park, Kanpur, U.P.	0	0	5	5
30. Kukrail Crocodile Rehabilitation Centre, Lucknow	figures not available ----------			
31. Zoological Garden, Alipore, Calcutta, W. Bengal	0	0	4	4
TOTAL : 31	14	30	520	564

** From Central Zoo Authority records, supplemented by R. J. Rao's list of rearing centres*

FOREIGN ZOOS HOLDING GHARIAL

1) Zoo Atlanta, Atlanta, Georgia, USA	1	1	0	2
2) Honolulu Zoo, Honolulu, Hawaii., USA	2	2	0	4
3) St. Augustine Alligator Farm, Florida, USA	1	3	0	4
4) Silver Springs Park, Florida, U. S. A.	0	1	0	1
5) National Zoological Park, Washington D.C., USA	0	1	0	1
6) Singapore Zoological Garden, Singapore	1	1	0	2
7) San Antonio Zool. Gardens, San Antonio TX, USA	0	0	2	2
8) Sedge wick County Zoo, Wichita, Kansas, USA	0	2	0	2
9) Wildlife Conservation Park, Bronx, N.Y, USA	2	3	0	5
TOTAL:9	7	14	2	23

EDUCATION AND AWARENESS

Introduction

It is generally accepted that the greatest failure of any conservation programme carried out — both in India and in the world —in the recent past has been in the subject area of education and awareness. The inability of agencies implementing conservation management strategies to take into confidence the local people and involve them in activities being carried out, or — in many cases — even to compensate them for the losses both potential and actual incurred by them as a result.

It is not only local people who have to be educated but different groups, from managers and financial institutions, to policy makers and politicians. The budget given in any conservation project for promoting education and awareness, if it exists at all, is never sufficient for carrying out the work in a proper manner. Generally one brochure or handout will be made, often in a language that is not understood by the local people and in insufficient quantities.

Sustained and systematic activities to educate people of all levels have to be undertaken if even a dent is to be made in the problem.

In the case of gharial, its membership in the crocodilian order has given in an undeserved reputation for ferocity and aggressiveness which needs to be countered. Also the number of accidental deaths of gharial is sufficiently significant to justify an education campaign simply to communicate to people how to recognize gharial and to avoid inadvertently killing them.

The mandate given to the Education and Awareness Group, therefore, was to create a comprehensive Masterplan for Education and Awareness for Gharial, keeping in mind different target groups, variability in problem areas as well as social, cultural and educational levels, and the paucity of funds for this work. They were asked to create some material in the local language which can be made up and used in future for gharial education programmes.

REPORT OF THE EDUCATION AND AWARENESS

Members: Dr. K. K. Tiwari, Facilitator, Dr. Tej Prakash Vyas, Recorder and Reporter, Dr. D. N. Saksena, Dr. M. V. Subba Rao, Dr. Sudhakar Kar, Dr. B. K. Sahu, Dr. A. K. Sinha, Dr. R. K. Sinha, Dr. R. Gupta, S. B. Mishra, C. M. Vyas, Rajeev Pawar, Sandeep Behera.

Education and awareness working group after thorough and careful deliberations recommends the following major action programme

1. Identification of target groups

2. Actions to be taken to make them educated and aware for protection of Gharial with the help of action oriented methodology

IDENTIFICATION OF TARGET GROUPS

Due consideration was given in identification of target groups to their degree of dependency on the riverside resources and following target groups were identified.

1. Fishermen (anglers)
2. Riparian cultivators
3. Villages/panchayats/NGO’s/local bodies/towns along the river
4. Students and Teachers of local school/colleges and universities

5. Law enforcing agencies
6. Industrialists

2. ACTION PLAN

2.1 FISHERMEN

ACTION PLAN FOR 2.1

I). Establish close contact and take them into confidence to collect basic information about their problems and how Gharial affects them, then

II). Preparation and display of hoardings, handbills and other exhibits in local languages to educate the people in fishermen's villages.

2.1 METHODOLOGY FOR 2.1

i. Local students, volunteers of NGO's and researchers will establish close contact and collect the current status of Gharial killing, fishing practices, availability of fishes in the respective areas.

ii. Wildlife authority should put big hoardings in fisherman villages especially near identified habitats of Gharial. The hoarding will display a good illustration or photo of Gharial with clear instructions for the fishermen, "Do's and Don'ts in local parlance.

iii. The local NGO's / researchers/ and wildlife people will prepare booklets handbills with photographs of Gharial in local parlance. Such handbills should be distributed at some regular intervals among the fishermen and their cooperative societies, schools and panchayats. Handbills should contain some information about promoting/protecting economic conditions of fishermen like promotion of ecotourism and related activities.

2.2 RIPARIAN CULTIVATORS

ACTION PLAN FOR 2.2

i. Ban on agricultural/cultivation practices in the riparian zone specially where nesting/ basking grounds are located.

ii. Stop mining activities in riparian zone.

METHODOLOGY FOR 2.2

i. Demarcation of core zone and buffer zone in identified habitats of Gharial will be done by local wildlife authorities and revenue people.

ii. The state mining departments should be approached by the concerned wildlife department to stop any kind of sand/boulders/stone mining in the habitat area.

iii. Clear guidelines for the local cultivators should be given by the local NGO's / researchers/ and wildlife authorities about any agricultural practices in the netting zone and they should be told about proper legislative action for the same.

iv. Hoarding should be displayed in local language with clear cut instructions for the farmers by the local wildlife authorities.

2.3 VILLAGE/PANCHAYAT/NGO/LOCAL BODIES/TOWNS

ACTION PLAN FOR 2.3

i. To educate the people through awareness campaign

METHODOLOGY FOR 2.3

In every village/ panchayat in and around identified habitats a periodical/regular awareness campaign with the help of various exhibits should be organized by local wildlife authorities, researchers and volunteers. The exhibits would be audiovisuals, posters, charts, stickers, handbills, etc.

For Urban Areas along river bank: At least once a year a large exhibition cum awareness campaign should be organised in towns for few days to a week on Gharial with the following exhibits.

- models of riverine ecosystem showing Gharial at the apex of food chain, biodiversity, museum specimen of Gharial, if possible- charts, posters, stickers, handbills, Painting and essay writing competition on conservation also should be organised at the same time. Prizes should also be distributed

- Items like attractive calendars and gharial t-shirts to be made available on nominal cost

- On such occasions local cultural activists must be involved and arrange some drama, dance programme, mono act play etc. and some well-known person could be invited to deliver popular talk on relevant topic

2.4 STUDENTS AND TEACHERS OF PRIMARY AND HIGHER SECONDARY SCHOOLS LOCAL SCHOOLS / COLLEGES AND UNIVERSITIES

ACTION PLAN FOR 2.4

- To start a nature club in every organisation
- To create awareness among the students and teachers for conservation of Gharial
- To involve NSS and NCC specially naval wing in conservation efforts of Gharial.

METHODOLOGY FOR 2.4

-Local wildlife authorities and researchers should visit each and every primary and high school, college and university along the river and with the consultation of head of the institution nature clubs should be formed to motivate the students.

-NSS coordinators/programme officers and associated naval officers of NCC should be requested to motivate their volunteer/cadets for the protection of Gharial in their area.

- A regular awareness campaign with all possible exhibits should be organised for fishing community and to such educational institutions at regular interval by the authorities of such institutions, volunteers of the nature clubs and for this local wildlife authorities should take initiative.

2.5 LAW ENFORCING AGENCIES

ACTION PLAN FOR 2.5

- Constitution of a board at block/district level
- To assess efficacy of implementation of Wildlife Protection Act in the area.

-To create awareness among the authorities

METHODOLOGY FOR 2.5

-There should be provision under Act to constitute a monitoring board including host officials/NGO's/local researchers to enforce the implementation of the law.

- The NGO's and researchers should collect information about the efficacy of implemen-tation of wildlife protection act in the area and should bring it to the notice of local authorities through mass media of communication.

2.6 INDUSTRIALISTS

Industrialists should be educated to desist from polluting and any other practices such as would affect water quality and habitat of gharial. Promotional campaigns to encourage them to install operational pollution control units could be taken up in the name of Ghar-ial conservation.

Industries can be educated by making them apart of the effort. Industries usually have an advertising budget and can be convinced to sponsor educational materials such as brochures, handbills, stickers, etc. which promote conservation of Gharial and carry the logo of the company.

3.0 TWENTIETH ANNIVERSARY OF CROCODILE PROJECT

The Government of India, the range states of Gharial, and the zoos and captive rearing centres holding gharial should utilise the occasion of the 20th anniversary of the Croco-dile Project and Gharial Project to highlight the success of the Project, the need to con-tinue protection of Gharial and the importance of Gharial to the ecosystem.

Government of India should mark this anniversary in an elaborate manner, bringing out posters and brochures reviewing the Project and suggesting future directions.

4.0 MODEL EDUCATIONAL MATERIAL

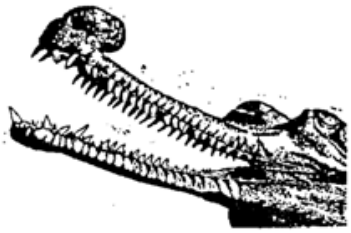
A sub-committee of the Education Group has designed a sticker/brochure which can be printed in a variety of ways for different groups. A text in English and in Hindi was contributed and a slogan *(Gharial is a mirror of the health of our rivers)* designed for a particular photograph. The English text of the sticker/brochure follows:

> Gharial is a reptile which inhabits four major river systems, namely Indus, Ganges, Brahmaputra and the Mahanadi river system in peninsular India. This reptile is an endangered species due to commercial exploitation and habitat destruction. The Government of India has launched a "Grow and Release" programme under the Indian Gharial Project, which celebrates its 20th anniversary this year, 1995. This animal has been saved from total extinction by intervention of wildlife managers to save the animal and its habitat which can only be done by larger participation, e.g. by the local people, NGO's and wildlife managers.
>
> Let us save this animal, our pride.

5.0 EDUCATION SHOULD BE A MAJOR CONSERVATION ACTIVITY

The PHVA participants agreed that lack of public education had been a major lacunae in the Crocodile Conservation Programme. It was felt by the Workshop that a major initiative should be directed towards specific target groups

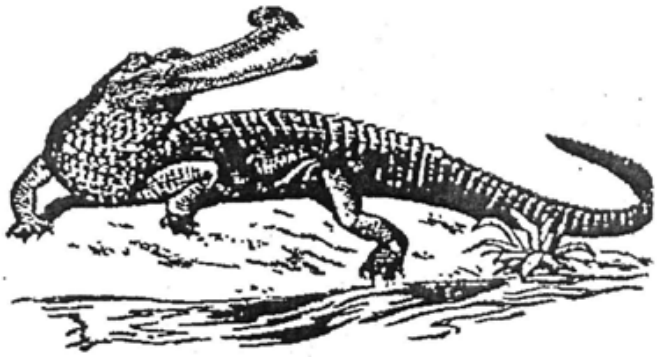
important to gharial conservation, such as fishermen and others who might have been affected by the Gharial programme. Emphasis should be given on utility of gharial for sustaining the health of the river system and the perilous consequences of its disappearance.



Vikrant Tyres

for Gharial conservation

Gharial is a reptile which inhabits four major river systems namely Indus, Ganges, Brahamputra and Mahanadi river systems in penninsular India. This reptile is an endangered species due to commerical exploitation and habitat destruction. Government of India has launched a "Grow and Release" programme under the Indian Gharial Project twenty years ago. This animal has been saved from total extinction by intervention of wildlife managers to save the animal and its habitat which can only be done by larger participation, i.e., by the local people, NGO's and wildlife managers. Let us save this animal, our pride.



घड़ियाल सरिसृप समुदाय का जन्तु है जो भारतीय उप महाद्वीप की चार प्रमुख नदियों: गंगा, सिन्धु ब्रह्मपुत्र तथा महानदी

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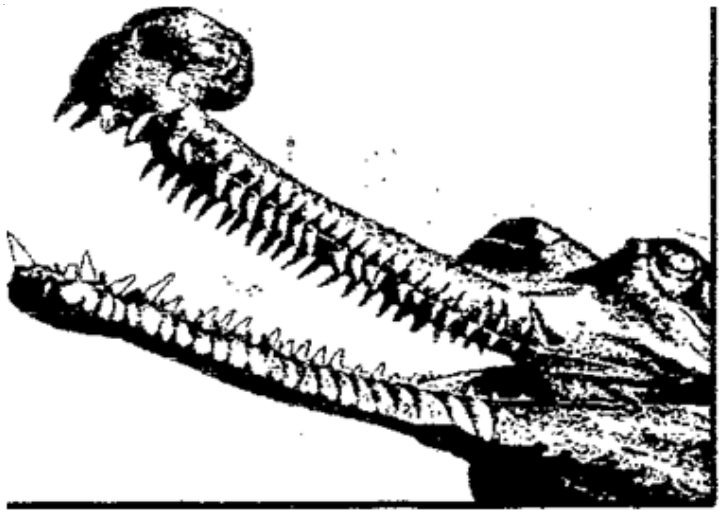
P.H.V.A. FOR GHARIAL - REPORT

II. Supplementary material



PROGRAMME

Inaugural Function

School of Studies in Zoology, Jiwaji University
& Organising Committee of
Population and Habitat Viability Assessment Workshop of Indian Gharial

16 January 1995 - 0915 -1030

Welcome Address	Professor R. Mathur Head, School of Studies in Zoology, Jiwaji University
Introductory Remarks	Dr. R. J. Rao Principal Coordinator
Technical Remarks	Mr. S. C. Sharma Secty., Central Zoo Authority
Ministry Representative	Mr. Suresh Chugh Dy. Director, Ministry of Environment & Forests
CBSG Facilitator's Remarks	Ms. Sally Walker Secty, Z.O.O., Convenor, CBSG, India
Patron's Comments	Prof. P. S. Bisen Vice Chancellor, Jiwaji University
Inaugural address	Dr. Ram Prasad Director General, MPCST
Presidential address	Dr. R. C. Sharma CCF, Wildlife, Forest Dept. of Madhya Pradesh
Vote of Thanks	Dr. D. N. Saksena Professor of Zoology
Tea followed by technical sessions	

III. Reference Material

Captive Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union
U. S. Seal, CBSG Chairman

POPULATION and HABITAT VIABILITY ANALYSIS WORKSHOPS

Objectives and Process

The PHVA workshop provides population viability assessments for each population of a species or subspecies as decided in arranging the workshop. The assessment for each species will undertake an in depth analysis of information on the life history, population dynamics, ecology, and population history of the individual populations. Information on the demography, genetics, and environmental factors pertinent to assessing the status of each population and its risk of extinction under current management scenarios and perceived threats will be assembled in preparation for the PHVA and for the individual populations before and during the workshop.

An important feature of the workshops is the elicitation of information from the experts that is not readily available in published form yet which may of decisive importance in understanding the behavior of the species in the wild. This information will provide the basis for constructing simulation models of each population which will in a single model evaluate the deterministic and stochastic effects and interactions of genetic, demographic, environmental, and catastrophic factors on the population dynamics and extinction risks. The process of formulating information to put into the models requires that assumptions and the data available to support the assumptions be made explicit. This process tends lead to consensus building on the biology of the species, as currently known, and usually leads to a basic simulation model for the species that can serve as for continuing discussion of management alternatives and adaptive management of the species or population as new information is obtained. It in effect provides a means for conducting management programs as scientific exercises with continuing evaluation of new information in a sufficiently timely manner to be of benefit to adjusting management practices.

These workshop exercises are able to assist the formulation of management scenarios for the respective species and evaluate their possible effects on reducing the risks of extinction. It is also possible through sensitivity analyses to search for factors whose manipulation may have the greatest effect on the survival and growth of the population(s). One can in effect rapidly explore a wide range of values for the parameters in the model(s) to gain a picture of how the species might respond to changes in management. This approach may also be used to assist in evaluating the information contribution of proposed and ongoing research studies to the conservation management of the species.

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124, USA tel. 612-431-9325 fax 612-432-2757 (home) 9801 Pillsbury Ave. S., Bloomington, MN 55420, USA tel. 612-888-7267 fax 612-888-5550

Information and Expertise

Short reviews and summaries of new information on topics of importance for conservation management and recovery of the individual populations are also prepared during the workshop. Of particular interest are topics addressing:

(1) factors likely to have operated in the decline of the species or its failure to recover with management and whether they are still important,

(2) the need for molecular taxonomic, genetic heterozygosity, site specific adaptations, and the effects of seed banks on the rate of loss of heterozygosity,

(3) the role of disease, predation, and competition in the dynamics of the wild population, in potential reintroductions or translocations, and in the location and management of captive populations,

(4) the possible role of inbreeding in the dynamics and management of the captive and wild population(s),

(5) the potential uses of reproductive technology for the conservation of the species whether through genome banking or transfer of genetic material between subpopulations,

(6) techniques for monitoring the status of the population during the management manipulations to allow their evaluation and modification as new information is developed,

(7) the possible need for meta population management for long term survival of the species,

(8) formulation of quantitative genetic and demographic population goals for recovery of the species and what level of management will be needed to achieve and maintain those goals,

(9) cost estimates for each of the activities suggested for furthering conservation management of the species.

Preparation and Documentation Needs

Information to be included in briefing book:

1. Bibliography - preferably complete as possible and either on disk or in clean copy that we can scan into a computer file.

2. Taxonornic description and most recent article(s) with information on systematic status including status as a species, possible subspecies, and any geographically isolated populations.

3. Molecular genetic articles and manuscripts including systematic, heterozygosity evaluation, parentage studies, and population structure.

4. Description of distribution with numbers (even crude estimates) with dates of information, maps (1:250,000 or better if needed) with latitude and longitude coordinates.

5. Protection status and protected areas with their population estimates. Location on maps. Description of present and projected threats and rates of change. For example, growth rate (demographic analysis) of local human populations and numerical estimates their use of resources (development plans) from the habitat.

6. Field studies - both published and unpublished agency and organization reports (with dates of the field work). Habitat requirements, habitat status, projected changes in habitat. Information on reproduction, mortality (from all causes), census and distribution particularly valuable. Is the species subject to controlled or uncontrolled exploitation? Collecting?

7. Life history information - particularly that useful for the modelling. Includes: size - stage information, stage transitions, age of first reproduction, mean seed production and germination rates, occurrence and survival of seed banks, life expectancy, stage mortalities, adult mortality, dispersal, and seasonality of reproduction.

8. Published or draft Recovery Plans (National or regional) for the wild population(s). Special studies on habitat, reasons for decline, environmental fluctuations that affect reproduction and mortality, and possible catastrophic events.

9. Management master plans for the captive population and any genome banks.

11. Color pictures (slides okay) of species in wild - suitable for use as cover of briefing book and final PVA document.

Plans for the Meeting:

1. Dates and location. Who will organize the meeting place and take care of local arrangements? Should provide living quarters and food for the 3 days in a location that minimizes outside distractions. Plan for meeting and working rooms to be available for the evening as well as the day. Three full days and evenings are needed for the workshop with arrival the day before and departure on the 4th day.

2. Average number of participants about 30 usually with a core group of about 15 responsible for making presentations. Observers (up to 20) welcome if facilities available but their arrangements should be their own responsibility. Essential that all with an interest in the species be informed of the meeting. Participants to include: (1) all of the biologists with information on the species in the wild should be invited and expected to present their data, (2) policy level managers in the agencies with management responsibility, (3) NGOs that have participated in conservation efforts, (4) education and PR people for local programs, (5) botanical garden or herbarium biologists with knowledge of the species, (6) experts in plant population biology and needed areas of biological expertise and (7) local scientists with an interest in the species.

3. Preparation of briefing document.

4. Funding (cost analysis available) - primarily for travel and per diem during the meeting, preparation of briefing document and the PVA report, and some personnel costs. CBSG costs are for preparation of the documents, completion of the modelling and report after the meeting, travel of 3-4 people, and their per diem. We estimate that each PHVA Workshop costs CBSG $10,000 to $15,000 depending upon the amount of work required in preparation and after the workshop to complete the report.

5. Preparation of agenda and securing of commitments to participate, supply information, and make presentations needs to have one person responsible and to keep in close contact with CBSG office on preparations.

6. Meeting facilities need to include meeting room for group, break away areas, blackboard, slide projector, overhead projector, electrical outlets for 3+ computers, printer (parallel port IBM compatible), and photocopying to produce about 200-500 copies per day. Have food brought in for lunches. Allow for working groups to meet at night.

SSC MISSION

To preserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats.

PHVA WORKSHOPS Guidelines

Every idea or plan or belief about the Species can be examined and discussed

Everyone participates & no one dominates

Set aside (temporarily) all special agendas except saving the Species

Assume good intent

Yes and ...

Stick to our schedule ... begin and end promptly

Primary work will be conducted in sub-groups

Facilitator can call ‘timeout’

Agreements on recommendations by consensus

Plan to complete and review draft report by end of meeting

Adjust our process and schedule as needed to achieve our goals

POPULATION AND HABITAT V1ABILITY ASSESSMENT

- CBSG/SSC/IUCN thanks the 'Host Agency' for the invitation to participate in this Workshop on the conservation of the 'SPECIES'.

- SSC MISSION: To preserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats.

- Captive Breeding Specialist Group (CBSG) works as a part of the IUCN Species Survival Commission (SSC) to assist rescue of species.

- CBSG has conducted **Population and Habitat Viability Assessment** (PHVA) workshops for >50 species in 22 countries at the request of host countries.

- Values of the Workshops are in:

* bringing together all groups responsible for the saving and management of the species to build a consensus on actions needed for the recovery of the species;

* bringing together experts whose knowledge may assist rescue of the species;

* assembling current information on status of the species and the threats to its survival;

* providing an objective assessment of the risk of extinction of the species based upon current information;

* using simulation models to test alternative management actions for rescue of the species and its recovery;

* producing an objective report which can be used as a basis for the policy and implementation actions that are needed to save the species.

- These Workshops have helped chart a course for saving of many species; we hope that this Workshop will be a help to our colleagues in their work to save the 'Species'.

PHVA DATA NEEDS

MAP OF POPULATION(S) DISTRIBUTION AND FRAGMENTATION CENSUS AND CHANGES DURING PAST 10-50 YEARS

AVERAGE AGE OF FIRST REPRODUCTION (FEMALE & MALE) OLDEST AGE (SENESCENCE)

MONOGAMOUS OR POLYGYNOUS

INBREEDING

CATASTROPHES & THREATS

ALL MALES IN BREEDING POOL?

MAXIMUM YOUNG PRODUCED PER YEAR

PROPORTION OF ADULT FEMALES REPRODUCING PER YEAR PROPORTION OF YOUNG (LITTER/CLUTCH SIZES)

MORTALITY: 0 - 1
JUVENILES ADULT

FREQUENCY & SEVERITY OF CATASTROPHES

STARTING POPULATION SIZE (AGE DISTRIBUTION IF KNOWN)

CARRYING CAPACITY AND PROJECTED CHANGES

HARVESTS

SUPPLEMENTATION

ANNUAL RATES AND STANDARD DEVIATIONS IF POSSIBLE

VORTEX
Simulation model of stochastic population change
Written by Robert Lacy
Chicago Zoological Park
Brookfield, IL 60513

Version 5.1, 13 April 1991

Stochastic simulation of population extinction

Life table analyses yield average long-term projections of population growth (or decline), but do not reveal the fluctuations in population size that would result from variability in demographic processes. When a population is small and isolated from other populations of nonspecific, these random fluctuations can lead to extinction even of populations that have, on average, positive population growth. The VORTEX program (earlier versions called SIMPOP and VORTICES) is a Monte Carlo simulation of demographic events in the history of a population. Some of the algorithms in VORTEX were taken from a simulation program, SPGPC, written in BASIC by James Grier of North Dakota State University (Grier 1980a, 1980b, Grier and Barclay 1988). Fluctuations in population size can result from any or all of several levels of stochastic (random) effects. Demographic variation results from the probabilistic nature of birth and death processes. Thus, even if the probability of an animal reproducing or dying is always constant, we expect that the actual proportion reproducing or dying within any time interval to vary according to a binomial distribution with mean equal to the probability of the event (p) and variance given by $Vp = p * (1 - p) / N$. Demographic variation is thus intrinsic to the population and occurs in the simulation because birth and death events are determined by a random process (with appropriate probabilities).

Environmental variation (EV) is the variation in the probabilities of reproduction and mortality that occur because of changes in the environment on an annual basis (or other timescales). Thus, EV impacts all individuals in the population simultaneously - changing the probabilities (means of the above binomial distributions) of birth and death. The sources of EV are thus extrinsic to the population itself, due to weather, predator and prey populations, parasite loads, etc.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes determined by a pseudo-random number generator. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, whether each adult female produces broods of size 0, or 1, or 2, or 3, or 4, or 5 during each year, and which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Mortality and reproduction probabilities are sex-specific. Fecundity is assumed to be independent of age (after an animal reaches reproductive age). Mortality rates are specified for each pre-reproductive age class and for reproductive-age animals. The mating system can be specified to be either monogamous or polygynous. In either case, the user can specify that only a subset of the adult male population is in the breeding pool (the remainder being excluded perhaps by social factors). Those males in the breeding pool all have equal probability of siring offspring.

Each simulation is started with a specified number of males and females of each pre-reproductive age class, and a specified number of male and females of breeding age. Each animal in the initial population is assigned two unique alleles at some hypothetical genetic locus, and the user specifies the severity of inbreeding depression (expressed in the model as a loss of viability in inbred animals). The computer program simulates and tracks the fate of each population, and outputs summary statistics on the probability of population extinction over specified time intervals, the mean time to extinction of those simulated populations that went

extinct, the mean size of populations not yet extinct, and the levels of genetic variation remaining in any extant populations.

Extinction of a population (or meta-population) is defined in VORTEX as the absence of either sex. (In some earlier versions of VORTEX, extinction was defined as the absence of both sexes.) Recolonization occurs when a formerly extinct population once again has both sexes. Thus, a population would go "extinct" if all females died, and would be recolonized if a female subsequently migrated into that population of males. Populations lacking both sexes are not considered to be recolonized until at least one male and at least one female have moved in.

A population carrying capacity is imposed by a probabilistic truncation of each age class if the population size after breeding exceeds the specified carrying capacity. The program allows the user to model trends in the carrying capacity, as linear increases or decreases across a specified numbers of years.

The user also has the option of modelling density dependence in reproductive rates. i.e., one can simulate a population that responds to low density with increased (or decreased) breeding, or that decreases breeding as the population approaches the carrying capacity of the habitat. To model density-dependent reproduction, the user must enter the parameters (A, B, C, D, and E) of the following polynomial equation describing the proportion of adult females breeding as a function of population size:

$$\text{Proportion breeding} = A + BN + CNN + DNNN + ENNNN,$$

in which N is total population size. Note that the parameter A is the proportion of adult females breeding at minimal population sizes. A positive value for B will cause increasing reproduction with increasing population sizes at the low end of the range. Parameters C, D, and E dominate the shape of the density dependence function at increasingly higher population sizes. Any of the values can be set to zero (e.g., to model density dependence as a quadratic equation, set D = E = 0). To determine the appropriate values for A through E, a user would estimate the parameters that provide the best fit of the polynomial function to an observed (or hypothetical) data set. Most good statistical packages have the capability of doing this. Although the polynomial equation above may not match a desired density dependence function (e.g., Logistic, Beverton-Holt, or Ricker functions), almost any density dependence function can be closely approximated by a 4th-order polynomial. After specifying the proportion of adult females breeding, in the form of the polynomial, the user is prompted to input the percent of successfully breeding females that produce litter sizes of 1, 2, etc. It is important to note that with density dependence, percents of females producing each size litter are expressed as percents of those females breeding, and the user does not explicitly enter a percent of females producing no offspring in an average year. (That value is given by the polynomial.)

In the absence of density dependence, the user must specify the percent of females failing to breed, and the percents producing each litter size are percents of all breeding age females (as in earlier versions of VORTEX). Read the prompts on the screen carefully as you enter data, and the distinction should become clear. VORTEX models environmental variation simplistically (that is both the advantage and disadvantage of simulation modelling), by selecting at the beginning of each year the population age-specific birth rates, age-specific death rates, and carrying capacity from distributions with means and standard deviations specified by the user. EV in birth and death rates is simulated by sampling binomial distributions, with the standard deviations specifying the annual fluctuations in probabilities of reproduction and mortality. EV in carrying capacity is modelled by sampling a normal distribution. EV in reproduction and EV in mortality can be specified to be acting independently or jointly (correlated in so far as is possible for discrete binomial distributions).

Unfortunately, rarely do we have sufficient field data to estimate the fluctuations in birth and death rates, and in carrying capacity, for a wild population. (The population would have to be monitored for long enough to separate, statistically, sampling error, demographic variation in the number of breeders and deaths, and annual variation in the probabilities of these events.) Lacking any data on annual variation, a user can try various values, or simply set EV = 0 to model the fate of the population in the absence of any environmental variation.

VORTEX can model catastrophes, the extreme of environmental variation, as events that occur with some specified probability and reduce survival and reproduction for one year. A catastrophe is determined to occur if a randomly generated number between 0 and 1 is less than the probability of occurrence (i.e., a binomial process is simulated). If a catastrophe occurs, the probability of breeding is multiplied by a severity factor specified by the user. Similarly, the probability of surviving each age class is multiplied by a severity factor specified by the user.

VORTEX also allows the user to supplement or harvest the population for any number of years in each simulation. The numbers of immigrants and removals are specified by age and sex. VORTEX outputs the observed rate of population growth (mean of N[t]/N[t-l]) separately for the years of supplementation/harvest and for the years without such management, and allows for reporting of extinction probabilities and population sizes at whatever time interval is desired (e.g., summary statistics can be output at 5-year intervals in a 100-year simulation).

VORTEX can track multiple sub-populations, with user-specified migration among the units. (This version of the program has previously been called VORTICES.) The migration rates are entered for each pair of sub-populations as the proportion of animals in a sub-population that migrate to another sub-population (equivalently, the probability that an animal in one migrates to the other) each year. VORTEX outputs summary statistics on each subpopulation, and also on the meta-population. Because of migration (and, possibly, supplementation), there is the potential for population recolonization after local extinction. VORTEX tracks the time to first extinction, the time to recolonization, and the time to re-extinction.

Overall, VORTEX simulates many of the complex levels of stochasticity that can affect a population. Because it is a detailed model of population dynamics, it is not practical to examine all possible factors and all interactions that may affect a population. It is therefore incumbent upon the user to specify those parameters that can be estimated reasonably, to leave out of the model those that are believed not to have a substantial impact on the population of interest, and to explore a range of possible values for parameters that are potentially important but very imprecisely known. VORTEX is, however, a simplified model of the dynamics of populations. One of its artificialities is the lack of density dependence of death rates except when the population exceeds the carrying capacity. Another is that inbreeding depression is modelled as an effect on juvenile mortality only; inbreeding is optimistically assumed not to effect adult survival or reproduction.

VORTEX accepts input either from the keyboard or from a data files. Whenever VORTEX is run with keyboard entry of data, it creates a file called VORTEX.BAT that contains the input data, ready for resubmission as a batch file. Thus, the simulation can be instantly rerun by using VORTEX. BAT as the input file. By editing VORTEX.BAT, a few changes could easily be made to the input parameters before rerunning VORTEX. Note that the file VORTEX.BAT is over-written each time that VORTEX is run. Therefore, you should rename the batch file if you wish to save it for later use. By using data file input, multiple simulations can be run while the computer is unattended. (Depending on the computer used, the

simulations can be relatively quick - a few minutes for 100 runs — or very slow.) Output can be directed to the screen or to a file for later printing. I would recommend that VORTEX only be used on a 80386 (or faster) computer with a math co-processor. It should run on slower machines, but it might be hopelessly slow.

The program can make use of any extended memory available on the computer (note: only extended, not expanded, memory above 1MB will be used), and the extra memory will be necessary to run analyses with the Heterosis inbreeding depression option on populations of greater than about 450 animals. To use VORTEX with expanded memory, first run the program TUNE, which will customize the program EX286 (a Dos Extender) for your computer. If TUNE hangs up DOS, simply re-boot and run it again (as often as is necessary). This behavior of TUNE is normal and will not affect your computer. After TUNEing the Dos Extender, ran EX286, and then finally ran VORTEX. TUNE needs to be run only once on your computer, EX286 needs to be run (if VORTEX is to be used with extended memory) after each re-booting of the computer. Note that EX286 might take extended memory away from other programs (in fact it is better to disable any resident programs that use extended memory before running EX286); and it will release that memory only after a re-boot. If you have another extended memory manager on your system (e.g., HIMEM.SYS), you will have to disable it before using EX286.

VORTEX uses lots of files and lots of buffers. Therefore, you may need to modify the CONFIG.SYS file to include the lines

```
FILES=25
BUFFERS=25
```

in order to get the program to run.

VORTEX is not copy protected. Use it, distribute it, revise it, and expand upon it. I would appreciate hearing of uses to which it is put, and of course I don't mind acknowledgement for my efforts, James Grier should also be acknowledged (for developing the program that was the base for VORTEX) any time that VORTEX is cited.

A final caution: VORTEX is continually under revision. I cannot guarantee that it has no bugs that could lead to erroneous results. It certainly does not model all aspects of population stochasticity, and some of its components are simply and crudely represented. It can be a very useful tool for exploring the effects of random variability on population persistence, but it should be used with due caution and an understanding of its limitations.

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ISSUE 1. MODELING

What is A Model?

One method for understanding the factors affecting the population extinction process is to use population models. A model is a basic tool used to represent or describe, in a simplified and abstract form, a particular process of interest. In the case of the PHVA, modelling is a tool that mimics the processes by which populations propagate themselves from one year to the next.

Models can be very simple or extremely complex. Models may seem abstract, only academic, or even threatening. However, we make use of and encounter models in our normal day-to-day activities. Simple models that many of us encounter every day are symbols used in common signs. For example, the male/female diagrams on toilet doors are in fact simple models used to summarize and simplify important information. A more complicated day-to-day model is family financial planning. When we plan for financial savings or budgets, we: 1) define a financial objective; 2) collect data on our financial situation; 3) analyze the data under different scenarios using simplifying assumptions of real process; 4) evaluate different scenarios; and 5) make a decision. We may do all this in our minds, without the aid of a computer or calculator, but we nevertheless have preformed a modelling exercise to come to some conclusions. Population models are just an extension of this process of compilation and analysis of data using a simplified version of real processes. It is important to note that the purpose of the model is not intended to represent realistically and accurately all the processes involved, but to simplify the process sufficiently to gain a better understanding.

A very simple population model may look like this;

```
        ________
        Population
        Size 1994
          = 100
        ________
           |
           |
           \/
        +10 Births
        +3 Immigrants
        -7 Deaths
        -2 Emigrants
           |
           |
           \/
        ________
        Population
        Size 1995
          = 104
        ________
```

This simple process can be repeated year after year to give a basic idea of long-term changes in population size. At a very basic level, all we need for a model of population projections are data on birth rates, mortality, immigration, and emigration. This very simple model may be sufficient for some purposes. However, more complex models that consider additional factors that affect population dynamics are more appropriate and useful for the PHVA process.

What is A Simulation Model?

A stochastic population simulation model is a kind of model that attempts to incorporate the uncertainty, randomness or unpredictability of life-history and environmental events into the modeling process. Events whose occurrence is uncertain, unpredictable, and random are called stochastic. Most events in an animal's life have some level of uncertainty. For example, there usually is a 50/50 chance an individual is a male or female and a certain probability that individual will live through one year to the next, mate, reproduce, and produce an uncertain number of offspring. Although we cannot predict exactly what events an individual will experience during its life, we may have a general idea of the range of possibilities for these various events (e.g., on the average an individual may have a 90% chance of surviving from one year to the next, or that litter sizes vary from 1 to 4), but individuals vary within that range. Similarly, environmental factors, and their effect on the population process, are stochastic - they are not completely random, but their effects are predictable within certain limits.

Simulation solutions are usually needed for complex models including several stochastic parameters. A simulation model of an animal population mimics actual demographic and genetic events, such as deaths and births, in an explicit time dimension. Both time steps and individuals are usually simulated as discrete and finite. When stochasticity is included in a simulation model, each run may be a unique sequence of events, with different end results in all runs. So, to be able to present both a reliable expected average result, as well as an estimate of expected variations in the result, we need to run the simulation many times, often several thousand times.

Events that are stochastic need to be described in terms of both their average value (mean) and their variance, or standard deviation (a measure of the distribution which values can take around their mean). For example, if litter size ranges from 1 to 5, average litter size may be about 3 and the variance around 1. When modelling the effect of stochastic properties, both the average and variance need to be known.

The Vortex model incorporates factors with uncertain outcomes (stochastic factors) by randomly making a decision about what will happen within the limits as specified by the variance associated with that factor. For example, sex determination of a newborn is determined by the simple process of the computer "flipping a coin." Heads assigns one sex, tails the other. More complicated stochastic events, like the variation in survival rates associated with fluctuations in the environment (both the survival rates and the effect of environment have stochastic properties), are incorporated by the computer flipping multiple "biased" coins (those with probabilities for heads and tails are not 50/50). The coin flipping process is achieved by the computer using random number generators.

Because many of the processes in the population are stochastic, one run (simulation) of the model will result in a different outcome than a second run. One run is no more accurate than another - they simply reflect differences that might result from normal, expected variation in those stochastic factors that affect the population's dynamics. There are two levels of stochasticity incorporated throughout much of Vortex: reproduction and mortality are inherently stochastic (like a coin toss) and also the probabilities of reproduction and mortality vary over time (like a random selection of the coin to be tossed from a bag of variably biased

coins). Thus the stochastic processes modelled by VORTEX includes both individual survival and annual fluctuations in population survival rates (as distinct levels of stochasticity) and individual reproduction and variable reproductive rates. Also (in contrast to the above) dispersal but not dispersal rates (or probability) is stochastic in the VORTEX model. With respect to inbreeding, it is the individual mortality due to inbreeding that is stochastic (i.e., some inbred individuals live, others die, but all have a higher probability of mortality than do non-inbred individuals).

The same is true in real populations: two identical populations exposed to the same conditions will likely have different projections. That is the nature of stochastic effects. One of the purposes of running the stochastic model is to determine how much variation there might be around the average population projections. Therefore, multiple model simulations (perhaps as many as several hundred) are needed to show the range, or distribution, of possible outcomes that reflect the range of possible values affecting the population.

The processes in VORTEX that have stochastic or random components are:

Sex determination
Individual survival
Survival rates or probability
Reproduction
Reproductive rates or probability
Number of offspring
Dispersal
Gene transmission
Inbreeding induced mortality
Mate selection
Occurrence of catastrophes
Mortality and loss of reproduction due to catastrophes

Why Model?

There are a host of reasons for why simulation modeling is valuable for the PHVA process. The primary advantages, of course, are to simulate scenarios and the impact of numerous variables on the potential of population extinction. Interestingly, not all advantages are related to generating useful management recommendations. The side-benefits are substantial.

- Population modeling supports consensus and instills ownership and pride during the PHVA process. As groups begin to appreciate the complexity of the problems, they have a tendency to take more ownership of the process and the ultimate recommendations to achieve solutions.

- Population modeling forces discussion on biological aspects and specification of assumptions, data, and goals. The lack of sufficient data of useable quality rapidly becomes apparent and identifies critical factors for further study (driving research), management, and monitoring. This not only influences assumptions, but also the group's goals.

- Population modeling generates credibility by using technology that non-biologically oriented groups can use to relate to population biology and the "real" problems. The acceptance of the computer as a tool for performing repetitive tasks has led to a common ground for persons of diverse backgrounds.

- Population modeling explicitly incorporates what we know about dynamics by allowing the simultaneous examination of multiple factors and interactions - more than can be considered in analytical models. The ability to alter these parameters in a systematic fashion allows testing a multitude of scenarios that can guide adaptive management strategies.

- Population modeling can be a neutral computer "game" that focuses attention while providing persons of diverse agendas the opportunity to reach consensus on difficult issues.

- Population modeling outcome can be of political value for people in governmental agencies by providing support for perceived population trends and the need for action. It helps managers to justify resource allocation for a program to their superiors and budgetary agencies as well as identify areas for intensifying program efforts.

- The VORTEX model analyzes a population in a stochastic and probabilistic fashion. It also makes predictions that are testable in a scientific manner, lending more credibility to the process of using population modeling tools.