Inbreeding and captive-breeding: helping the sungazer survive

On-going threats

Sungazers in the wild face an uncertain future, because not only is their habitat being destroyed for agriculture and development purposes but the animals themselves are still being collected, illegally, for the pet and traditional medicine trades. This is despite them being listed under Annex II of CITES and being classified as Vulnerable on the IUCN Red List in 1996.

Some species are very rare in collections, and if they are not bred, they could die out completely. On the other hand, the risk of in-breeding - using closely-related animals in pairings - can have harmful and long-lasting effects on a population too. Geneticist Andy Tedder and European sungazer studbook keeper Fraser Gilchrist explain the pitfalls and how to avoid them, when faced with this type of situation.

Over the last two decades, the number of rare and endangered reptile and amphibian species being kept in captivity has risen sharply. Along with this rise has been a similar increase in the level of understanding of the basic husbandry needs and environmental factors affecting the survival of these species. Testament to such achievements by hobbyist breeders is the switch in the organisation of captive-breeding programmes from being exclusively the realm of zoos and research institutes to encompassing a more diverse group of participants.

There is now a welcomed move towards co-ordinated captive-breeding programmes between non-professional organisations, as private keepers unite to further the understanding of, and the survival of rare species in captivity. This development is not without its potential pitfalls however, which is a lesson countless captive-breeding programmes have learnt the hard way in the past. With private keepers now working together with a common goal however, it is more important than ever to create breeding programmes which will be not only scientifically sound, but that will also stand the test of time.

Perhaps one of the most poignant examples of the change in zeitgeist by reptile keepers over the last 20 years is shown by the case of the sungazer (*Cordylus giganteus*). Once commonly seen in the reptile trade as wild-caught stock, this lizard was popular, mainly due to its intriguing behavioural characteristics. Sadly for these captive animals however, their husbandry requirements were poorly understood back then, and there were few (if any) reported cases of captive-breedings. The vast majority of these lizards simply died without reproducing and today, the number of individuals being kept in collections throughout Europe is very low.

A new initiative

Last year saw the start of a new initiative for captive-breeding of sungazers in Europe. With advances in husbandry practices, and the development of bespoke captive-breeding strategies, it is hoped that a new generation of private keepers and enthusiasts, with the co-operation of the small number of European zoos currently maintaining this

Captive breeding of the Komodo dragon is already proving successful.

species, can make positive steps forward in terms of ensuring the long-term survival of the sungazer.

Captive-breeding strategies rarely benefit from a 'one size fits all' standardised approach, and for this reason, it is very important to understand a little about the causes and consequences of breeding certain individuals. Looming over every discussion about captive-breeding programmes with just a small number of founder individuals is, of course, the subject of inbreeding depression.

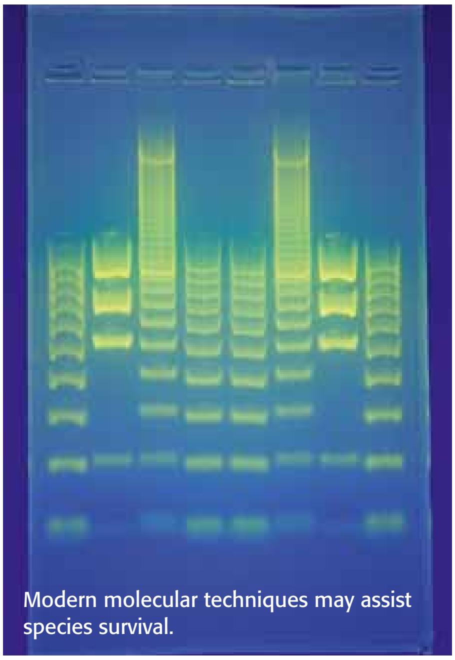
Inbreeding theory

The long-term detrimental effects of prolonged inbreeding have been well-documented in both captive and wild populations for many years. Early work on Mendelian genetics developed our understanding further, with inbreeding being shown to lead to increased homozygosity and the resultant decrease in fitness was termed "inbreeding depression".

The effects of inbreeding and selection have been studied intensively for many decades and yet the consequences of the joint application of these two evolutionary processes are still quite poorly understood. Undoubtedly the reason for this is the array of complex interactions, which are apparent when combining the two processes in different situations.

In addition, the impact of inbreeding and selection is not well-studied when populations become extinct as a result of these processes. But it is exactly this complex situation that small captive populations of endangered species face, with inbreeding being a 'necessary evil', the ultimate aim of which is avoiding extinction.

The genetic goals of any captive-breeding programme are to avoid inbreeding depression, and also to maintain genetic diversity. In 1980, scientists attempted to provide a base-level population size estimate



Modern molecular techniques may assist species survival.

that would avoid the detrimental effects of inbreeding as far as captive populations were concerned. Their research suggested that breeders would need to accept inbreeding coefficients (the proportion of loci at which an individual is homozygous) with around a one per cent increase per generation. They calculated the effective population size (Ne) would need to be 50.

As many of you will know, acquiring a founder population of 50 individual sungazers for captive-breeding purposes would be incredibly difficult. Yet by this logic, the theory also suggested that a relatively slow rate of inbreeding would then allow selection to remove any deleterious alleles without affecting the overall fitness of the population. This would obviously be an ideal situation.

On the other hand however, the resulting findings of a large scale captive-breeding programme (not involving the sungazer) carried out in 1984 suggested that a rapid and effective reduction in inbreeding depression could be achieved, depending on the pairings used.

There have been various interpretations of this theory, with some suggesting that deliberate inbreeding can itself serve to purge a population of the deleterious alleles responsible for inbreeding depression. This is due to the creation of selective conditions, which can favour individuals with certain genes or gene combinations that do well under conditions of inbreeding.

For this to work however, sufficient inbreeding must firstly occur to create the proper selective conditions (but not so intense as to kill off most individuals), and then sufficient genetic variation is carried over into the founder population, so that the animals can genetically respond to the selective conditions induced by inbreeding.

It has also been suggested that natural populations can become effectively adapted ▶

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to inbreeding because of the selective elimination of harmful alleles. The prediction is that after a period of either very small population size or substantial inbreeding, there will be a reduction in these detrimental alleles remaining within the population, and any further inbreeding will not result in a decrease in population fitness.

If these theories are true, then purging captive populations of animals with reduced fitness becomes extremely important to the success of any breeding programme, be it wild or captive.

The communal group structure of species in the genus *Cordylus* may add a further level of complexity in terms of understanding the effects of inbreeding in both captive and wild sungazers. Although group structure is poorly understood, it is believed that they live in large family groups with only a small number of these individuals breeding each year. This can then reduce the effective gene pool size greatly within any given area, which has both positive and negative repercussions as far as captive-breeding is concerned.

Concerns for captive-breeding programmes

Avoiding inbreeding depression in captive populations of sungazers (or indeed other species) by either method would not be without its pitfalls. There are several potentially negative consequences of purging within captive populations that will undoubtedly be of major concern for those who work with both sungazers and other endangered species. With the wild population being very limited, so the main concern is obviously preventing the species from becoming extinct. This makes the rate of purging, which increases rather than decreases the risk of extinction in the short term, of the utmost importance.

During the process of purging in the captive environment, increased homozygosity may reduce the fitness of the population, adding to the potential risk of extinction. Furthermore, detrimental alleles may become fixed in the population, permanently altering the overall fitness of the population, thereby increasing the long-term prospects of extinction. There is circumstantial evidence of this happening in some captive-bred bloodlines already.

Purging of individuals with reduced fitness may also effectively reduce variation at other loci, which again will have the effect of reducing the effective population size, in a genetic sense, and could also restrict the ability of the species to adapt to changes in the future. This means that there are clear advantages in eliminating a large part of the genetic load (a measure of the cost of alleles lost due to selection) of a species in a short period. This benefit may, however, be outweighed by a long-term risk of extinction or reduction in the adaptation potential of the species.

Sungazers have a well-developed social structure, with significant implications for their captive care and breeding.

Getting the right information

Inbreeding depression presents a real concern for captive-breeding programmes, and the creation of a viable breeding programme that will not lead to the long-term reduction in fitness of the species which it is hoped to protect is clearly of the utmost importance. For this reason, basing your breeding programme on the correct type of data becomes essential.

Many captive-breeding programmes sponsored by zoos rely heavily on pedigree analysis; however, estimating relatedness of individuals with no prior knowledge of their genealogy can be difficult. This is the problem faced in the case of many species without a long history of captivity in a controlled environment. In these instances, molecular markers (using polymorphic loci which allow determination of relatedness) can make a very valuable contribution to the creation of a breeding plan.

Basically, genetic data can help to resolve issues such as unknown parentage. This can be very useful if an incomplete pedigree is available. In situations where no pedigree is available for a species, molecular markers can be used to estimate the pair-wise relatedness between an individual, and the rest of the population.

Whilst most captive-breeding programmes

Sungazers are live-bearing lizards and so put considerable resources into hatchling survival.

assume that the founder individuals are unrelated, being wrong about this could have profound effects on the programme's ability to maintain genetic diversity over a long time period. A marked increase in inbreeding in early generations, above what is factored into the programme, due to full sibling (brother-sister) matings can effectively reduce genetic diversity and fitness in just a very few generations.

For this reason, molecular marking from the outset can overcome this potential pitfall, by helping to prevent any breeding of closely-related animals. This then controls the degree of inbreeding that would otherwise occur, based on the false assumption that the founder individuals were unrelated. Plans to collect molecular information from captive sungazers for this purpose are already underway.

For captive-breeding programmes where there is no pedigree information available, the use of microsatellite markers (focusing on what are rapidly-evolving polymorphic loci within the genome) could lead to an improvement in captive management. They can resolve issues surrounding unknown parentage among the breeding stock involved; allow molecular estimates of kinship to inform future breeding recommendations; give a clear understanding of the effective population size, in genetic terms; and finally, allow the creation of an accurate stud book.

Merging molecular markers and an effective breeding schedule

The use of modern molecular techniques for captive-breeding programmes is seen by many as essential for the further development and success of a host of projects involving reptile and amphibian species, not least those contained within the genus *Cordylus*. Clear guidance on the relatedness of individuals will allow for the foundations of a proper breeding schedule to be established, although this technique should never be considered a stand-alone.

Careful management of breeding individuals is as important as ever, especially when the effective population size is small. Determining this figure becomes very important under these circumstances. This will directly affect decisions about pairings, and alongside this, the criteria for purging which will be needed for small populations, removing such individuals out of the breeding programme.

The increasing accuracy and application of modeling techniques should allow a mathematical approach to be devised for a breeding model based on genetic data. This will provide an insight into multiple generations of offspring and the theoretical deleterious genetic load, even before two individuals have been paired together.

These technological advances really do take much of the uncertainty out of captive-breeding programmes both in the immediate and longer term. They allow meaningful statistical decision-making to be undertaken, regarding pairings, effective population size, deleterious alleles within the population, and purging.

Captive husbandry practices must mimic the sungazer's natural environment and biology to be successful.

Discussion

There is continued debate over the most effective method to eliminate inbreeding depression, or how to reduce the inbreeding burden to a manageable level. It has been suggested that inbreeding depression could be rapidly reduced by the use of a well-constructed breeding programme, and that inbreeding depression does not have to be a barrier in species even where inbreeding itself cannot be avoided.

Conversely however, it has been subsequently concluded that a programme devised with the aim of purging inbreeding depression could effectively decrease population fitness, with little recovery under inbreeding. The apparent discrepancy here could be due to the rate and extent of inbreeding in the populations themselves. This again highlights the necessity for an accurate understanding of the effective population size for each species at the outset.

One thing that becomes very clear is that no single breeding programme should be applied to every species in captivity. There are a great number of species currently involved in breeding programmes around the world that potentially face serious negative consequences if we, as herpetologists, fail to use the most appropriate methods to ensure not just the survival of the species, but also the on-going production of healthy captive individuals.

Another vital aspect that is clear at this early stage in the planning of the captive-breeding programme for sungazers is that as much research as possible must be carried out in advance to ensure that the end result is positive. The damage that has already been cannot be undone. We can, however, draw a line in the sand and move forward collectively to help prevent these magnificent creatures from becoming extinct, especially when there are people with the necessary skills and enthusiasm to help reverse the present downward trend. ■

Help wanted!

We would like to take this opportunity to ask once again if there is anyone with current or prior experience with this species to get in touch with the European Studbook Keeper - Fraser Gilchrist, via email: inf@cordylusgiganteus.com. The more information we can gather, the better able we shall be able to protect these animals for the future.