ROAD CONSTRUCTION IN WETLANDS, AN OPPORTUNITY TO HELP INCREASE ENDANGERED AMPHIBIAN POPULATIONS IN MEXICO: A CASE STUDY ON LERMA, STATE OF MEXICO.

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ABSTRACT

Road construction affects animal populations due to habitat fragmentation and organism loss. Nevertheless, when compensation measures in the Environmental Impact Statement (EIS) include habitat restoration and reproduction programs, species can strongly benefit from a road.

Sometimes there are not enough economic resources to develop conservation programs for endangered species, and the opportunity to acquire such resources on behalf of a construction budget could be a useful way to get a win-win situation; such is the case of the Lerma – Tres Marias toll highway.

Controversy was the main issue when this road was planned as it crossed near a protected wetland area the "Cienegas de Lerma". These wetlands formerly were composed by three large lagoons with great biodiversity, but for the past 40 years they have been strongly reduced and severely affected by human activities and pollution, with fauna population reduction as a consequence.

A general idea was that the new road could cause severe damage to the ecosystem and there was a strong social opposition to the project in its beginnings. The EIS proved this general concept to be wrong as the project had been design to protect the wetland environment by developing the highway as a physical barrier between the growing urban area and the wetlands. Habitat restoration and endangered species recovery programs were included as compensation measures, among other different mitigation measures intended to protect the wetland environment. These measures led to the approval of the Lerma – Tres Marias project by the environmental authorities.

Coordinated actions between the road contractor and the Mexican Ministry of Ecology (SEMARNAT) through the CONANP (Protected Areas National Commission) and our company had to be taken. The EIS for the highway was the tool to enforce the development of such actions, one of which considered habitat restoration and population increase of the Lerma salamander, *Ambystoma lermaense* (Taylor, 1940); an endangered species endemic to this ecosystem, whose population has been severely reduced for the past 30 years.

On December 2011, 51 salamanders were handed to us by a field laboratory of the University of the State of Mexico to care and reproduce. An Environmental Management Unit (UMA) had to be created to comply with Mexican regulations and enable us to carry out the care and reproduction program required by the environmental resolution.

Being an endemic to the system, little information on the biology of the species was known and conservation in captivity conditions had to be trial-error based. By April 2011, 34 organisms had survived and the mortality rate was significantly reduced, specimens started to grow and some of them matured to reproductive stages. On March 2012 nuptial tanks were established and as a result, since November 2012 more than 660 individuals are now in the UMA, waiting to be reintroduced into the wetlands and monitored as part of the second phase of this program for full compliance of the compensation measure; actions that will also need to be paid by the contractor from the highway construction budget.

INTRODUCTION

When we think about road construction, we automatically get the idea of flora and fauna destruction, and other environmental damages caused by the machinery. In general, roads are the "bad guys" in the "development movie". Nevertheless, that assumption is not always correct. Road construction can be an important subject for the rescue, conservation and propagation of rare, endemic, threatened or endangered species, as well as for the protection and conservation of those species habitats.

Road projects represent social and economic growth, a fundamental issue in developing countries like Mexico. As in other human activities, their construction causes environmental impacts that can affect ecosystems structure and processes.

Nowadays, thanks to the improvement and advances of environmental impact studies for roads, and the growth of a related science, Road Ecology (Forman *et al*. 2003), effective preventive, mitigation, restoration and compensation measures have been developed, and the adverse ecological effects from a road can be reduced through well planned and executed mitigation measures. One of such measures or responsibilities that are usually assigned by the environmental authorities in Mexico (SEMARNAT), as stated in the project environmental resolution, is the development and execution of a rescue, conservation and habitat amelioration program; all within a reintroduction plan for certain protected species in the surrounding ecosystem. These measures are to be paid by the road promoter and executed by approved environmental specialists, who have to report directly to the environmental authority, therefore, a specific item budget needs to be set aside for this purposes from the total project budget.

An example of this type of environmental resolution is the case of the Lerma – Tres Marias highway; section Lerma - Tenango del Valle in the State of Mexico. This road, built between 2010 and 2011 has been nominated as the first "green highway" in Mexico, due to the numerous actions that have been proposed to protect, mitigate and restore the surrounding environment, all of which had to be considered within the project costs.

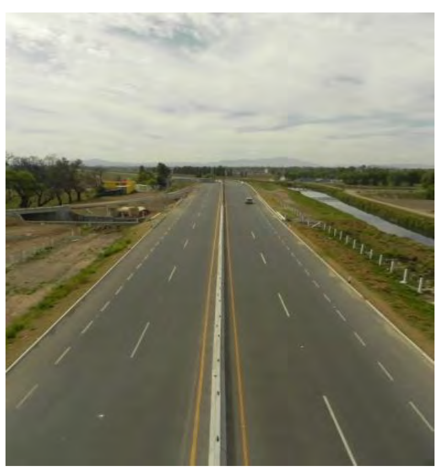

Figure 1. Actual view of Lerma – Tres Marias toll highway; section Lerma - Tenango del Valle.

Like other highways, authorization resolution by the SEMARNAT (environmental secretariat in Mexico), included several mitigation measures that the construction and the operation companies must comply with; in particular due to the closeness of the highway to the natural protected area of Cienegas de Lerma; considered to be one of the most important wetland ecosystems in the state of Mexico and habitat to more than 300 plant and animal species, including several migrating birds and endemics.

One of such conditions was the conservation and reproduction (for species propagation purposes) of the native endemic Lerma salamander *(Ambystoma lermaense).*

Figure 2. Juvenile stages of *Ambystoma lermaense*.

The salamander group in Mexico encloses around 30 species, of which almost half of them are endemics to the country. The species distribution pattern is restricted to the Lerma Lagoons, within the protected area and the channel system in its surroundings, usually used for irrigation.

Study Site

The Cienegas de Lerma is a wetland ecosystem composed by three large lagoons (19°09'05"N, 99°30'13"O, 2570 msnm), habitat to great biodiversity of plants, invertebrates and vertebrates; protected by law as a Natural Protected Area (SEMARNAT, 2002) and it is also listed as a RAMSAR site (2006) and an AICA (Area of Importance for Bird Conservation) due to its importance as a habitat for resident and migratory birds (Arizmendi and Marquez, 2000).

Almost 30% of the cienegas is an open water reservoir with an average depth of 70 cm (40-150 cm). The remaining 70% has an average depth of 50 cm (30-120 cm) and its covered with softstem bulrush (*Schoenoplectus tabernaemontani; Cyperaceae*), common cattail (*Typha latifolia; Typhaceae*) and chairmaker's bulrush (*Schoenoplectus americanus, Cyperaceae)* (Colon-Quezada, 2009). Other hydrophytic species are *Eleocharis macrostachya* y *Cyperus sp*., Polygonum punctatum, P. lapathifolium y P. mexicanum; (*Polygonaceae*), *Leersia hexandra (Poaceae), Echinochloa sp*., *Sagittaria latifolia; (Alismataceae*), *S. macrophylla; (Alismataceae*), and *Berula erecta (Apiaceae*) and *Hydrocotyle ranunculoides* (*Apiaceae*) in the surrounding channels and ditches (Arriaga Cabrera et al., 2000), as well as other vegetation species like *Myriophyllum aquaticum (Haloragaceae*), *Ceratophyllum sp.(Ceratophyllaceae*), *Chiara sp*., *Lilaea scilloides (Juncaginaceae*), *Potamogeton pectinatus (Potamogetonaceae)*,(*Potamogeton ilinoensis (Potamogetonaceae*) and floating vegetation composed by *Hydromystria laevigata (Hydrocharitaceae*), water fern (*Azolla filiculoides; Salviniaceae*), *Utricularia sp.(Lentibulariaceae*), and *Lemna gibba, Lemna trisulca, Wolfiella lingulata, Wolffiella oblonga, Wolffia columbiana* (*Lemnaceae*) (Colon-Quezada, 2009).

For the past four decades, the cienegas open reservoirs have been strongly reduced and severely affected by human activities and pollution, with fauna population reduction as a consequence; this has targeted their amelioration as a priority for the State of Mexico and the SEMARNAT.

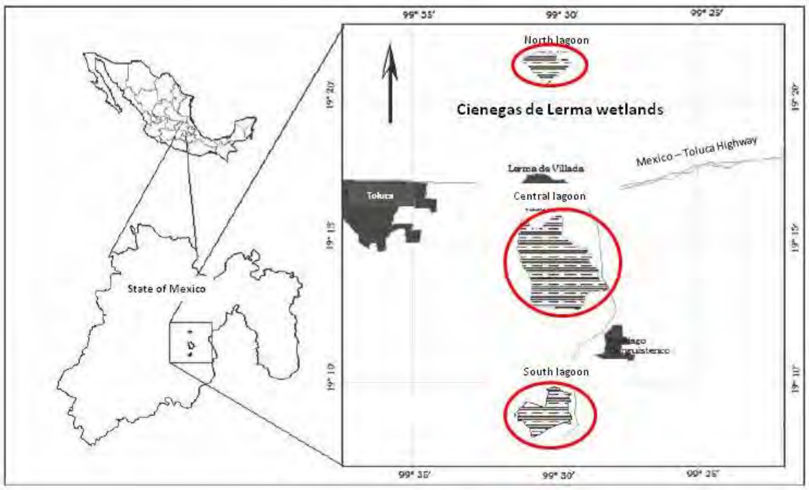

Figure 3. Location of "Cienegas de Lerma" wetlands in the State of Mexico. RAMSAR site 1335. (Source: modified from Colón–Quezada, 2009).

Biology of the Species and Problem

The Lerma salamander population has declined in the last decades due to lagoon desiccation, poor water quality, human population growth in the lagoon perimeter, as well as commercialization of these organisms as a traditional food and cuff medicine elaboration. As a result, nowadays *A. lermaense* is considered as an endangered species and is protected by law (NOM-059-SEMARNAT-2010), as well as its natural habitat.

Figure 3. View of Cienegas de Lerma, State of Mexico.

Salamanders are typically characterized by a superficially lizard-like appearance, with slender bodies, short noses, and long tails. They inhabit continental water systems like ponds and streams on temperate areas within the Holartic and Neotropical regions. Some species show a limited population distribution that could be restricted to a particular river, lake or stream, which makes their conservation complex and must be focused on habitat amelioration as well as population *ex situ* increase.

Lerma salamanders have a humid permeable skin with a large head with external gills on both sides of it during juvenile stages. Their moist skin usually makes them reliant on habitats in or near water, or under some protection (e.g., moist ground), often in a wetland. The skin secretes mucus, which helps keep the animal moist when on dry land, and maintains their salt balance while in water, as well as providing a lubricant during swimming.

The life history of salamanders is similar to that of other amphibians, such as frogs and toads. Most species fertilize the eggs internally, with the male depositing a sac of sperm in the female's cloaca. The eggs are laid in a moist environment, often a pond, but sometimes moist soil, or inside bromeliads. In *A. lermaensis*, a larval stage follows the hatching of the eggs, in which the organism is fully aquatic or water-dwelling, and possesses gills.

Respiration differs among the different species of salamanders. Juvenile stages of *A. lermaensis* breathe through gills, visible as tufts on either side of the head. Some individuals metamorphose to terrestrial forms using lungs for respiration. Neoteny (*Paedomorfis* in this case*)* has been observed in all salamander families, in which an individual may retain gills into sexual maturity. This may be universally possible in all salamander species. More commonly, however, metamorphosis continues with the loss of gills, the growth (or increase in size) of legs, and the capability of the animal to function out of the water. In the Lerma salamanders, gills are lost as the organism matures, changing from a water respiration organ to a primitive lung that allows the salamanders to inhabit wetland terrestrial ecosystem. This is one of nature's most extraordinary adaptation capacities that enable them to remain in the juvenile/adult –gill aquatic state for many years, or rapidly change to a pulmonary-air based stage. This adaptation allows salamanders to adjust to different conditions in their ecosystem environment and be able to survive to drought conditions and control population growth when resources are scarce.

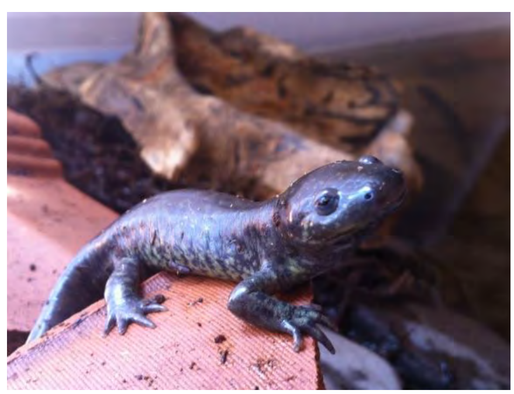

Figure 4. Left: Juvenile of *Ambystoma lermaense* with external gills for a water based life. Right: Mature air breathing organism (paedomorphed) with lungs for a land based life.

Mexico's more than 290 amphibians have not been fully studied and little is known about the biology of some of their endemics, in particular, themes related to feeding, reproduction and diseases. In the particular case of Ambystoma, there is information for other species within this genera, like *A. maculatum, A. mexicanum* and *A. jeffersonianum;* nevertheless, little is known about *A. lermaensis,* therefore, to care and reproduce this species, in this work we had to make decisions on trial-error basis, as we present in the following document.

OBJECTIVE

To care and increase (reproduce) *ex situ* population of *Ambystoma lermaense* for future habitat reintroduction, as part of the environmental compensation measures (offsets) for the construction of the Lerma-Tres Marías toll highway, section Lerma - Tenango del Valle.

METHODS AND RESULTS

Initial conditions

Grupo Selome's participation in this project started when the Laboratory of Conservation and Ecology in the Center for Biotic Research Ecology of the University of the State of Mexico claimed to be unable to continue with the conservation and reproduction program for the Lerma salamander, with an initial number of 83 organisms that were dying in an accelerated pace. On December 9th, 2011, 57 organisms of the original 83 were transferred to us to care, reproduce and continue with program objectives, as we already were working in the area as the environmental supervisors for the highway construction, and had the expertise and installations to continue with the program.

Being a delicate species due to its biological rarity and properties, it was crucial to keep the organisms under ideal conditions to be able to reproduce and reintroduce them in their natural habitat in a near future. Nevertheless, some of the organisms handed to us showed signs of illness and physical wounds from confinement, therefore each organism had to be placed in individual containers with optimal water quality and room temperature. Initial health status, metamorphic stage and a general condition evaluation had to be done.

On the first three weeks, mortality rate was high due to parasites and fungal skin infection, so our first challenge was to control diseases and disease spread. Necropsies were done to identify the causes of illness and be able to control it. Little is known on this species diet, and several food items had to be tried until a balanced food combination was identified.

Figure 5. Mortality rate of Lerma salamanders. Figure shows declining number of organisms until high mortality was controlled after the fourth week of caring for the organisms.

A diet of crickets, flour worms, zophobas (Darkling Beetle/Mealworm) and small amounts of liver as protein, fat, iron and vitamin C source, proved to be a balanced diet that will give the organisms enough reserves required for their reproduction and disease resistance, as one of the main reasons for such a high mortality rate was pneumonia.

Once the diseases were controlled and a balanced diet was defined, the population's death rate diminished significantly and growth and weight increased was observed in the surviving 34 individuals, what made us start with reproduction essays.

Ex-situ conservation and reproduction

Mexican law allows *ex situ* conservation and reproduction of protected species only within an authorized Environmental Management Unit (UMA). Therefore, the moment we received the first 57 individuals, we had to design a UMA and its administration program in order to ask for the authorization and to be able to keep, reproduce and investigate the species. This way the "*Kimpaleuy Axolotl*" UMA was created and once all of the requirements had been complied, we could start to reproduce some individuals.

By the end of 2011 we started several reproduction attempts with some healthy grown adults. Five nuptial tanks were conditioned by simulating underwater natural vegetation using different types of materials as shown in figure 6 and rocks to create hiding places and reduce stress caused by captivity.

A. *A. Lermaensis* nuptial 80 litters tank decoration

B. Nuptial tank with simulated underwater vegetation

Figure 6. Reproduction tanks and mating couples with decorations to simulate natural conditions.

As a result, through the last two weeks of March 2011 we observed courtship conducts and spermatophores were deposited in the tanks. Several couples reproduced continuously from 2011 to 2012 laying their eggs on the simulated vegetation as shown in figure 7. The embryos and juveniles developed satisfactorily, increasing the number of Lerma salamanders in our facilities up to more than 600 individuals, which are now being cared for at different development stages in our UMA facilities.

Eggs on simulated vegetation

Healthy embryios developed after the eggs

New born stage

Juvenile stages of Lerma salamander

Figure 7. Eggs and embryos layed on simulated vegetation. *A. Lermaensis* juveniles born *ex situ*.

Nowadays, healthy metamorphosed lerma salamanders are growing in our UMA (figure 8) and reproductive couples are increasing, so are salamander numbers. We will soon start adaptation trials to identify critical parameters for their reintroduction in the Cienegas wetlands.

Figure 8. Healthy metamorphosed Lerma salamanders born in our UMA in 2012.

DISCUSSION AND NEXT STEPS

All the accumulated knowledge through these two years of experience with the Lerma salamander has established an important scientific precedent, as little was known on the biology and captivity conditions of the species. Information on management techniques, optimal water quality conditions and temperature, reproduction conditions, nutrition and diseases will be published henceforth as a contribution to science; information that would have not been obtained without the road project compensation measures solicited by environmental authorities.

The information generated by this work will help identify the conditions needed to reproduce the Lerma salamander in captivity and better understand their requirements in their natural surroundings. This is relevant information if we want to increase population density in the cienegas in a near future. Diseases and water quality play a central role in population survival, as this species is very sensitive to both variables as it was observed in our work. These can be controlled under captivity but strong measures need to be taken by the State of Mexico's government and the CONANP to reduce pollution conditions in the cienegas throughout site amelioration actions and regulations, especially if the salamander population is intended to return into these wetlands.

Natural population recovery can be assisted by *ex situ* reproduction, only if there is a series of acclimatization phases before the UMA salamanders can be released to their natural habitat, as they now are cared for under very specific conditions; that are different and more stable than those the organisms will encounter in their natural habitat.

We think that the combination of habitat amelioration, *ex situ* reproduction of the species, jointly with making people in the surrounding areas of the cienegas more aware of the importance of this resource, will be necessary for population's recovery. Therefore, our next steps will be to develop experiments with different acclimatization practices and time periods, in which we will gradually simulate the existing conditions within the natural habitat in order to maximize the survival opportunities of released individuals. Also we will need to identify areas on the Lerma wetlands where water quality is still good and there are enough food resources in order to define the best places to reintroduce some of our individuals under monitored conditions. This will throw more information on the species survival capabilities and allow us to make adjustments to our adaptation program before a generalized reintroduction can be implemented.

CONCLUSIONS

These results and the increase in population numbers through ex-situ reproduction, to be returned to their natural habitat later on, would have not been possible without the construction of the Lerma – Tres Marias toll Higway, and the joined efforts of the environmental authorities. Road construction is not always detrimental to the environment, especially when mitigation and compensation measures are executed on behalf of the construction budget.

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