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The Axolotl (*Ambystoma mexicanum*): Factors That Limit its Production and Alternatives for its Conservation

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Abstract: *Ambystoma mexicanum* is an amphibian endemic to Xochimilco Lake in Mexico City. It has been declared in danger of extinction and is under special protection. Some chemical contaminants in the water are extremely high and could be the cause of its high mortality rate in certain areas of Xochimilco. In order to preserve this species it will not only be necessary and fundamental to prohibit fishing axolotls in their natural state, a market study and nutritional chemical analysis will also be necessary in order to establish the organoleptic properties and level of acceptance before a taste panel; that is to say, get to know more about the specie in order to give the product added value offering its meat as an unconventional delicacy. This way the creation of farms that will help its conservation will be justified. On the other hand it is important to mention that the axolotls are very important in scientific research. Since it serves as an amphibious model for many physiological and morphological processes that explain the regenerative process that this species possess. The objective of this study is to emphasize the advantages that the *Ambystoma mexicanum* has with the intention to rationally exploit these attributes in order to achieve its conservation.

Key words: *Ambystoma mexicanum*, axolotl, amphibious endemic

Introduction

All together, little more than half the Mexican amphibious species and reptiles are endemic (Graue, 1998). *Ambystoma mexicanum* lives exclusively in bodies of water close to Mexico City, particularly in the Xochimilco and Chalco water systems (Griffiths *et al.*, 2003). The Xochimilco water system is located in the central southern part of Mexico City which has been populated by humans even before the Spanish colonization. Today Xochimilco Lake is confined to a central belt within the county of the same name. The lake has a system of Channels fed by water treatment plants located on “Cerro de la Estrella and San Luis Tlaxialtemalco” (González *et al.*, 1995). The axolotls are an amphibious which is neotenic, that is that it attains sexual maturity during the larval stage. Since pre-Hispanic days, the axolotls (water monster), has been considered good nutritive food, it is also used therapeutically for respiratory illnesses such as asthma or bronchitis, because of this, the inhabitants

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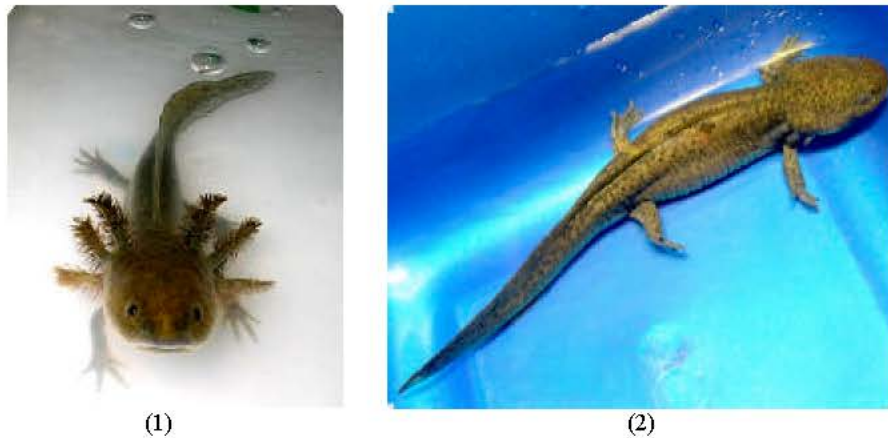


Fig. 1 and 2: *Ambystoma mexicanum* is an amphibious endemic to Xochimilco Lake in Mexico City

in this area traditionally capture this animal. Today it has a high demand in aquariums and is sold as a rare species. The axolotl is a very important animal in research, since it serves as an amphibious model in many physiological and morphological processes; it also has many hormonal processes that have been widely studied in order to explain its particularly interesting regenerative process. Maybe this is one of the reasons its reproduction is so well studied in controlled fish farms and fisheries where conditions are totally artificial (Ensastigue and Salas, 1995). On the list of existing axolotls colonies (Malacinski and Able, 1989) 12 of them are in diverse parts of the world, but surprisingly none in Mexico, even with the fact that it is endemic to the area. The present study observed that production in its natural habitat has not been promoted on a permanent basis allowing for conservation and exploitation of this species. The objective of the present study is to point out the advantages of *Ambystoma mexicanum* with the purpose of raising it with rationale to achieve its conservation.

The Axolotl Biology

Ambystoma mexicanum is a *Caudata* amphibious from the Ambystomatidae family, endemic to Xochimilco Lake in Mexico City (Flores-Villela and Canseco-Márquez, 2004) (Fig. 1 and 2). It can be distinguished from other species by its phenotypic characteristics: prominent external gills, wide trunk, undulated tail and its degrading grey to black color (Rivas *et al.*, 1992).

Breeding

Maintaining breeding animals in groups is possible, but preparing the males under such circumstances will require a bit of coordination to ensure that they are ready to breed in a timely manner. When housed in groups, males often court each other and release their sperm as they would when a female is present. Individually housing males for 2 weeks before presentation with a female helps prevent such spontaneity and also helps ensure potency when he is paired with a female. Males housed individually will also react more vigorously when presented with a female, because they are more sensitive to the presence of a tank-mate than are males that are regularly reared in groups. One can determine from a female's body shape if she is ready to be mated. As she becomes heavily egg-laden, her midsection becomes round. Mature males lack this round body shape and appear slimmer. Around his cloaca (the shared opening for the digestive and reproductive tracts), a sexually mature male axolotl has a swelling that is due to the presence of an enlarged gland that produces jelly to package and protect his sperm. Females possess this gland but lack the swelling. These animals require very few special conditions for successful breeding. After being presented with a female, the male will deposit his sperm, which is packaged into cone-shaped packets called spermatophores (Gresens, 2004).



Fig. 3: Axolotl eggs in laboratory conditions

The most favorable age for reproduction is one year; however, it is commonplace that they reach optimum sexual maturity at one and a half years of age. The female can lay around 660 eggs at a time (Fig. 3). At optimum conditions the captive female is capable of laying eggs once every 2 months, without a reduction in quantity. However, these quantities are only maintained for 5 or 6 years and later the number of eggs decrease and have a high mortality rate, for which they have little use in reproduction (Armstrong *et al.*, 1989). The hatching rate is very high in captivity. In two independent studies the hatching rate was 90% (Hernández, 1996; Prado *et al.*, 1996). However, it is possible that the hatching rate in their natural environment is much lower than the same in captivity.

Facts Attributed to the Axolotls

Axolotls are edible and it is said that the meat is as delicious as that of eel. The axolotls have been called a cure all for many illnesses, but there is no evidence of these benefits. In the days of the Spanish conquest they could be found throughout the expansive lake divided in 7 regions, Zumpango, Xaltocan, San Cristóbal Texcoco, Chalco, Xochimilco and Mixquic (Duhon, 1997).

Water Quality and Contaminants

The poor water quality could be a factor that is generating illness in the axolotls species (Duhon, 1989). The Xochimilco channels have been polluted with biotic and abiotic contaminants. Some quantities of chemical contaminants in the water are extremely high and could be contributed to the high mortality rate of this species in certain areas of Xochimilco. Contaminants, both organic and non-organic have been found at high levels in Xochimilco. Particularly high concentrations of ammonia nitrogen (Sandoval, 2003) are one of the causes of mortality of the axolotls (Fox, 1982). Also the inorganic variables are much higher than the standard NOM-127-SSAI-1994 that stipulates acceptable water quality: residual free chlorine, nitrates and total trihalomethane. These contaminates, together with heavy metals can also be putting pressure on the population level of the axolotls. An area with high bacterial density corresponds to the water plant discharge of treated waters (Sandoval, 2003).

Fish Species that Coexist With the Axolotls

The fish species present in Xochimilco are just a sample of how out of balance the system is. Many of the fish present are introduced to the system. For example, four of the native species from the Cyprinidae family are extinct while three others were introduced, leaving only one native species of this family in the lake. Among the species introduced to the lake we have the Carp (*Cyprinus carpio*). This species made important changes in the food chain when it was introduced in Mexico City (Zambrano *et al.*, 2001). Indirectly the carp also could be reducing hatching by the axolotls by causing diminution of underwater plants (Zambrano *et al.*, 1999) that are fundamental for the reproduction and conservation of the axolotl population.

Exploitation

Reproductive Farms and Clients

Interest in the *Ambystoma mexicanum* has created many different farms on an international level. Up to 1989, 24 farms were counted in the following countries: Canada, The Netherlands, Japan, South Korea, France, Soviet Union, Switzerland, the United States, Sweden and England (Malacinski and Able, 1989). Today the most important is "The Axolotl colony" at the University of Indiana (Shaffer, 1993). The colony breeds *Ambystoma mexicanum* and is a source for genetic supply of embryos, larva and adults for laboratories in the United States and other countries.

In Mexico City, there are at least two reproductive farms for this species in the FES-Iztacala at Universidad Nacional Autónoma de México and at Universidad Autónoma Metropolitana, Xochimilco Campus. These and other farms are the suppliers for part of the national and international market.

Among the investigative centers that need these organisms are:

- Center for Regenerative Biology and Medicine, Indiana University
- School of Clinical Laboratory Sciences at the University of Nottingham
- Axolotl Genome Project, Department of Biology, University of Kentucky, Institute of Cellular and Molecular Biology, University of Texas.
- Section of Evolution and Ecology, University of California at Davis.
- NCBI (National Center for Biotechnology Information)
- XenBase, University of Calgary, Canada.
- Laboratory of Regeneration Studies, University of California at Irvine.
- Zoology Department, Neuroscience Program and Ecology, Evolutionary Biology and Behavior Program, Michigan State University.

In Mexico: Hospital Infantil "Dr. Federico Gómez", Instituto Nacional de Cardiología and Instituto Nacional de Psiquiatría. These three carried out investigations, thesis and masters degrees based on the axolotl.

In addition to investigation purposes, these organisms are used as pets on a national level. On an international level, there is a web site that sells them as pets on the internet at prices as high as 20 Euros.

Conservation Management

The conservation of the Ambystomatidae family and especially the *Ambystoma mexicanum* is very important, it is an important part of the long history of the Mexico City area lakes. The presence of this species is estimated to reach as far back as the Pliocene-Pleistocene age, around 3 to 12 million years ago (Harris, 1993).

An important step for the conservation of the species is its reproduction and exploitation by means of the Mexican UMA (Unit for management and conservation of wildlife), according to the regulation established and that was published in the Official Newspaper "Diario Oficial" on the 16th of April 1994 (NOM-059-ECOL-2001).

Black Market

Collectors

Black market fishing is carried out by experienced fishermen who collect these amphibians by catching the axolotls with "atarraya" nets. The fishermen take orders for this species and supply them on demand to the Sonora and New Market of San Lázaro in Mexico City. These markets supply the species from black market sources or specialized reproductive farms. It is important to establish the origin since it would be difficult to adapt the axolotls to an artificial environment where they would feed on flakes. Another important issue to consider would be the amount of infestation by parasites in the axolotls living in the contaminated Channels of Xochimilco.

Customary Use

The fishing or marketing of this species is not authorized in Mexico, since it is an endangered species and is under special protection with the NOM-059-ECOL-2001 regulation. It is also protected for its unusual capability to regenerate, a vertebrate object of interest for biological investigative development in genetics and neurology (Smith, 1989).

The demand for axolotls is diverse since it has multiple uses for a number of markets. They can be used for pets, as a research model or a source of a cure all: it is used for everything from the common cold to rheumatism. In the following you will find the most common uses in the black market and clandestine collection of the species.

Sonora market consumers. Basically they are used for a natural cure all for throat illnesses or ointments for arthritis. Apparently, the demand is decreasing since only older people maintain use of the species as a medical source.

New Market at San Lázaro consumers. On a national level this market is more popular because today you can find a variety of different genetic lines that make them more attractive.

On an international level this market is competing with established farms that have the necessary permission to reproduce and sell the species, for which we may be able to attribute low demand. The organizations that collect the species charge a market value between 200. 20 and 30 USD.

Scientific consumers. Axolotls are very useful for scientific research. Some investigative centers mentioned could still be ordering axolotls from the local fishermen. For example some of the axolotls for the investigation have been brought by people who live or work in Xochimilco. However, the number of axolotls that are collected are low.

Farm consumers in Xochimilco. The tendency to conserve the species has been augmented by local people who belong to the ONGs creating reproductive farms for axolotls inside the same area in order to obtain recourses for this activity. Other well meaning organizations have managed to reproduce axolotls inside there own installations.

Foreign consumers. Even though it seems that farms are supplying the demand on an international level, the black market reaches beyond the boarder.

Anesthesia and Euthanasia Methods

The most satisfactory anesthesia is the narcotic MS 222 that has a mild effect on heart rhythm. For euthanizing an axolotl it should be placed in a tank with cotton soaked with chloroform. Sometimes it is preferable to sacrifice an axolotl by decapitation (Boterenbrood and Verhoeff-De, 1976) and/or lethargy that consists of emerging the axolotl in a tank with ice for 12 hours, this will diminish its metabolism and cause lethargy.

Conclusions and Recommendations

It would be fundamental to create a program that would eradicate certain exotic species, particularly ones with high density inside Xochimilco such as carp and tilapia, which impede the reproduction and development of the axolotls. This is why a dynamic population study by region and species would be necessary to provide a viable program with successful results.

It is also fundamental to prohibit fishing axolotls in their natural habitat.

The water treatment plants should be repaired and maintained so that residual waters spilling into the Channels at Xochimilco and Chalco do not effect the survival of the native species and so that they are not endangered by the high levels of contaminated water.

In order to conserve this species it would not only be necessary and fundamental to prohibit fishing in its natural habitat, it would be indispensable to do a market study, a chemical nutritional

analysis, a morphometric analysis of the species in the adult stage, carry out an analysis of its physical and chemical properties of its meat, establish the organoleptical qualities (aroma, taste, tenderness, juiciness) and level of acceptance through a taste panel; that is to say, get to know the species better in order to give added value to the product and offer its meat as a non conventional delicacy, generating resources while conserving the axolotls by way of its rational exploitation in controlled reproductive farms.

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Figure 1 and 2 are courtesy of the Academic Staff "Aquarium", Facultad de Ciencias from UNAM, Mexico. Figure 3 is courtesy from Biol. Christian Silva.

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