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Original article

Quantification of the trade in *Xenopus laevis* from South Africa, with implications for biodiversity conservation

CHÉ WELDON[1,2], ATHERTON L. DE VILLIERS[3] AND LOUIS H. DU PREEZ[1,4]

[1]*School of Environmental Sciences and Development, North-West University, Private Bag X6001, Potchefstroom 2520, South Africa*

[2]*che.weldon@nwu.ac.za*

[3]*Western Cape Nature Conservation Board, Private Bag X5014, Stellenbosch 7599, South Africa; atherton@cncjnk.wcape.gov.za*

[4]*louis.dupreez@nwu.ac.za*

Abstract.—Harvesting wild amphibians for animal trade and consequent introductions of exotic species are considered threats to biodiversity. For this study, we evaluated the literature and unpublished data on *Xenopus laevis* exports from the Western Cape, South Africa, since the onset of the trade in the early 1930s. Exports for medical science have changed from the use of both captive-bred and wild-caught animals to the export of wild-caught animals only. More than 10 000 frogs were exported annually during 1998-2004 to 132 facilities situated in 30 countries. Uncontrolled harvesting, feral populations, and the spread of parasites and disease associated with *X. laevis* trade, highlight the relevance of this trade to the conservation of amphibian biodiversity.

Key words.—Common platanna, African clawed frog, suppliers, utilisation, feral.

The frog trade in South Africa has been centred largely on a single taxon: the African clawed frog, *Xenopus laevis laevis* (Daudin, 1802). This animal is very common in sub-Saharan Africa (Measey 2004), however molecular data indicate two genetically distinct groups that coincide with winter and summer rainfall regions (Grohovaz et al. 1996; Measey & Channing 2003). In this paper we deal with only the Western Cape group and use the designation suggested by Measey and Channing (2003) of *X. laevis*. Large-scale exploitation of *X. laevis* started after Shapiro and Zwarenstein (1934) developed a pregnancy assay that used the clawed frog as a test animal.

At first, animal dealers exploited this demand by uncontrolled collection of large numbers of *X. laevis*. By the late 1930s the Cape Provincial Administration (CPA) established protective legislation regarding the collection of wild *X. laevis* out of concern for local populations in the Cape Peninsula and Cape Flats (Harrison 1941; Hey 1945).

The use of *X. laevis* as a model system in scientific research grew increasingly popular in the 1970s and during the 1990s it surpassed *Rana* as a laboratory animal, thereby becoming the most widely used amphibian in research (Hamilton 1976; Major & Wassersug 1998). A survey by Weldon (1999) indicated that the biggest demand for *X. laevis* is the various research facilities in genetics, molecular biology, embryology, biochemistry and ecotoxicology (see also Dawson *et al.* 1972). The relative ease with which this species can be maintained in captivity makes it a popular choice among aquarists (e.g. Bury 1953; Bustard 1964; Jennings 1968). In South Africa *X. laevis* is also used as live bait for freshwater angling.

The African clawed frog is not cultivated for the food market and few are eaten by South Africans (Steyn 1984; Hey 1986).

Despite the long existence of the *X. laevis* trade and the extent of the trade in terms of numbers exported and global distribution, little attempt has been made to monitor and quantify trends. Data pertaining to the trade were formerly summarised in annual reports of the CPA, and more recently assimilated in electronic format by the provincial nature conservation authority "Cape Nature", officially known as the Western Cape Nature Conservation Board (WCNCB). We conducted an assessment involving suppliers and WCNCB to assess the demand for *X. laevis* in South Africa and internationally. Conservation issues pertaining to the trade are also addressed.

MATERIALS AND METHODS

This study is based largely on the evaluation of literature and historical data pertaining to *X. laevis* exports from the Western Cape. Information on the activities at the Jonkershoek Fish Hatchery regarding the cultivation and selling of *X. laevis* was retrieved from archived reports of the Inland Fisheries Department of the CPA (1941-1951, six reports), which later became the Department of Nature Conservation in 1952 (1952-1976, 21 reports). Data on the numbers and destinations of *X. laevis* for the period 1998-2004 were extracted from the permit files of the WCNCB head office in Cape Town, and verified through interviews and correspondence with four suppliers (see Appendix 1 for questionnaire). Detailed information on collection sites, captive breeding, and supply to South African institutions were also obtained from the interviews and correspondence. An inquiry was made to South African universities on whether or not *X. laevis* was used at their facilities and for what purpose.

The use of *X. laevis* in freshwater angling in South Africa was also investigated. The owners of seven angling shops in the Free State Province were interviewed in person with a standardised questionnaire on their involvement in the selling of *X. laevis* (Appendix 2).

RESULTS AND DISCUSSION

Suppliers.—In 1941 the propagation of *X. laevis* was initiated at the Jonkershoek Fish Hatchery to meet the growing demand and to protect local populations from over exploitation (Harrison 1941; Hey 1945). The collection, cultivation and selling of *X. laevis* from Jonkershoek continued until 1974 when the trade was left to private enterprises (Hey 1976). We were unable to obtain any information on suppliers during the next two decades. Since the late 1990s, the WCNCB has issued annual permits for the collection and export of *X. laevis* to four major suppliers. Each supplier was allocated one or more magisterial districts within which they are allowed to collect from the wild. The suppliers did not compete for the collection of *X. laevis* as the allocated districts did not overlap. Each supplier was limited to 10 000 frogs per annum. The localities from which suppliers were allowed to collect *X. laevis* were restricted to man-made water bodies (such as dams and sewage treatment ponds), and these may be visited only once per annum. The number of localities differed between suppliers, and from year to year (e.g. between 23 and 43 localities during 1998-2001 for one supplier). Suppliers most frequently caught *X. laevis* using baited aquatic traps set for up to one week. Variations of the aquatic trap exist, but they all shared these basic components: a baited enclosure fitted with a funnel entrance, and a design that allows the animals to surface for breathing. All quotas were made up of wild-caught frogs, because none of the facilities breed *X. laevis*. All suppliers only traded with education and research related facilities and not with the pet industry. Frogs were usually col-

lected on request and housed at the collector's facility until the date of export. When asked about the role of *X. laevis* as a carrier of parasites, all of the suppliers acknowledged that *X. laevis* is host to many parasites, but only one had knowledge of the infectious fungal disease chytridiomycosis.

Numbers traded.—The Jonkershoek Fish Hatchery was the only official supplier of *X. laevis* in the Western Cape for 34 years, until 1974. Records of frog sales are available for 23 of these years. During this period, a total of 343 588 frogs were sold, the majority of which went to local South African institutions. It was calculated from 11 years of data that less than one fifth (19.6%) of the frogs were exported between 1949 and 1974. Mention of sex ratio is made for only six of the years, consistently indicating that more females were supplied (average male to female ratio 1:1.6). Collections were biased towards usable females and often wasteful, because unwanted frogs were not always released at the point of collection (Hey 1986). The preference for females may reflect the uses for the frogs. When the *Xenopus* pregnancy assay was in use, a disproportionate number of females were exported because the assay did not require males.

We were not able to retrieve any data on *X. laevis* sales for the decades after the Jonkershoek Fish Hatchery withdrew from the trade, until the current suppliers started operating in the late 1990s. Since 1998, more than 71 500 frogs have been exported from the Western Cape. This corresponds to an average of just over 10 200 frogs per year. Sales of *X. laevis* showed two peaks, namely 18 871 in 1998 and 14 269 in 2003, and reached a low of 5 331 during 2004 (Fig. 1). The peak of 2003 was the result of a large shipment of frogs by a single facility that accounted for 70.1% of the annual export. These frogs were translocated to a sister facility in France to replenish its stock population.

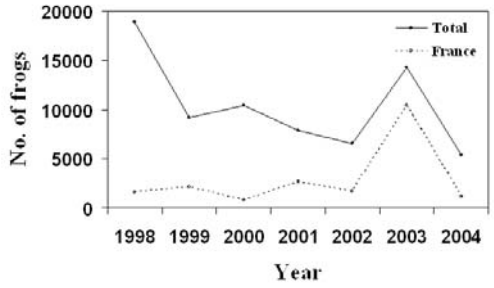

Figure 1. Export numbers of *Xenopus laevis* to foreign facilities for the period 1998-2004. The graph indicates how exports to France contributed to a peak in sales for 2003.

Because of the limited usable data it is difficult to assess whether the demand for *X. laevis* has increased or decreased in recent years. The peak of 1998 could have been the result of an exceptionally good year in sales as in 2003.

Export destinations.—During 1998-2004, *X. laevis* from the Western Cape have been exported to 132 facilities in 30 countries. The majority of destinations were research facilities associated with academic and government institutions; other institutions included companies that breed and supply *X. laevis* directly to the end-user. In terms of number of import facilities per country, Germany ranked the highest with 34, followed by Switzerland and England with 11 and nine facilities respectively. Countries with only a single import facility were the most common (12 countries respectively). There seems to be a high turnover of facilities that import *X. laevis* as 35.1% of facilities imported this species only once (Fig. 2). This does not exclude the possibility that the facilities establish in-house colonies and continue to use *X. laevis*. An increase in the number of orders per facility was concomitant with a decrease in the number of import facilities. The highest number of orders per facility (37) was from one facility. This implies that the minority of facilities have long-term research programmes that involve continuous restocking with *X. laevis*.

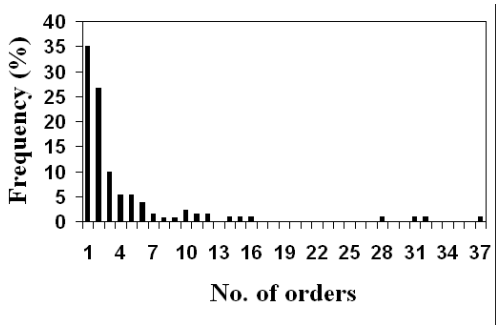

Figure 2. Relative frequency, as a percentage of total number of orders (n = 114), at which overseas facilities ordered *X. laevis*.

When the countries were grouped according to categories of imported frog numbers, it became apparent that the largest trade was with only a few countries (Table 1). More than half of the importing countries (16) imported fewer than 500 frogs, accounting for 3.2% of the total frog exports. Almost two thirds of the total number of exports (64.4%) were sold to only three countries, France (20 435), the USA (14 637) and Germany (10 988).

Utilisation in South Africa.—*Xenopus laevis* is used in teaching as a model system for physiology, anatomy and parasitology, and occasionally in research at tertiary academic institutions. The same South African companies that provided for the international demand, distributed frogs within South Africa. During 1998-2004 more than 8 000 frogs were sold within South Africa to one government, 11 academic and two private research institutes. Annual sales peaked at 3 500 in 1998 then dropped below 1 500 and varied only slightly between years.

Juvenile *X. laevis* were also used as live bait by freshwater anglers in South Africa. *Xenopus laevis* is a highly desired bait when fishing for the sharptooth catfish (*Clarias gariepinus*). Only young frogs between 35 mm and 50 mm (snout-vent length) are used for bait. Other fish that eat *X. laevis* are the endemic yellowfish species (*Labiobarbus* spp.) and introduced bass and trout species (see also Skelton 2001). Numbers utilised at a national level were not available because independent collectors and the anglers typically collect unofficially. The use of live bait is illegal in South Africa according to the Animals Protection Act No. 71 of 1962, however, whether this legislation actually reduces the number of frogs used as bait remains speculative. A large number of frogs are sold annually in angling shops, but apparently the shops do not record the numbers of frogs sold. Based on shop owner estimates in surveys, the annual sales range from 5 000 to 32 000 frogs. This amounts to a gross annual income between US$2 308 and US$14 769. Sales continue throughout the year, but large quantities are sold during the angling season (September until April).

Conservation implications.—Introductions of huge numbers of largemouth bass and trout into Cape rivers and dams by the Jonkershoek Fish Hatchery (e.g. Harrison 1939; Hey 1945) must have impacted *X. laevis* populations, especially because largemouth bass is a known biological control against *X. laevis* (Prinsloo *et al.* 1981). Experimental harvesting practices have indicated that irresponsible collection of *X. laevis* can lead to the rapid depletion of a population (Weldon 1999). Hey (1986) ascribes observations of *X. laevis* population declines on the Cape Flats during the 1940s to excessive collection. However, Van Wyk (1953) implicated urbanisation, agriculture and periodic cleaning of dams as causal factors. Successful control of *X. laevis* through trapping at a fish farm in the Eastern Cape illustrates the efficiency of this method (Schramm 1986). Control over licensed suppliers from the Western Cape and collection from man-made water bodies may prevent trade from threatening *X. laevis*.

Whenever captive animals are moved to other countries, there is a risk that some individuals escape to the wild. In the case of *X. laevis*, the high numbers that are exported, and the many

Table 1. Numbers of import countries and numbers of frogs (*X. laevis*) exported from the Western Cape, South Africa for the period 1998-2004. Countries have been grouped into broad categories according to the numbers of frogs exported.

No. frogs category	No. countries	No. frogs imported	% of total exports
20 001 - 25 000	1	20 435	28.6
15 001 - 20 000	0	0	0
10 001 - 15 000	2	25 625	35.8
5 001 - 10 000	1	5 485	7.7
1 001 - 5 000	6	14 717	20.6
501 - 1 000	4	2 960	4.1
< 501	16	2 294	3.2
	30	**71 516**	**100**

global destinations, increase the risk of escape. High fecundity and the ability to tolerate a wide range of environmental conditions are among the factors that provide escaped animals with a selective advantage to survive in a novel environment (Tinsley & McCoid 1996). Feral populations of *X. laevis* were first detected shortly after mass exportation from South Africa began, and persist in several countries including Ascension Island, Chile, France, the U.K. and U.S.A. (Tinsley & McCoid 1996; Fouquet 2001; Lobos & Measey 2002). Three of these countries, the U.K. (England and Wales), U.S.A. (Arizona and California) and France share a high risk for feral populations establishing due to the large import numbers. There is no evidence that feral populations are a result of legal imports, however, this possibility warrants further investigation.

Of particular relevance to the global trade in *X. laevis* is that whenever this animal is translocated, the parasites and pathogens that it might harbour are translocated as well. This risk is augmented by the fact that *Xenopus* hosts an exceptional array of metazoan and protozoan parasites, representing over 25 genera from seven invertebrate groups (Tinsley 1996). Evidence exists for the presence of parasites endemic to Africa in feral *X. laevis* populations in southern California (Laferty & Page 1997). The likelihood that parasites could switch hosts depends on the type of parasite. Host switching is unlikely in the instances of strictly host-specific parasites or where a specific intermediate or final host is required to complete the life cycle. The discovery of *Cephaloclamys namaquensis*, an intestinal tapeworm of *X. laevis* in *Amietophrynus angolensis*, in Zimbabwe has raised concerns of the tapeworm spreading to other ranid species in receiving countries (Mettric 1963; Laferty & Page 1997).

Interviews with suppliers of the *X. laevis* trade have shown that they are often well informed about the role that this species plays as a carrier and vector. Despite this awareness, suppliers seem oblivious to the effects of *X. laevis* as a carrier of infectious diseases as a direct consequence of negligent collection and confinement practices. The trade in *X. laevis* has been identified as a major source of the international dissemination of an emerging infectious disease of amphibians; the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (Weldon *et al*. 2004). It is imperative that suppliers and all frog handlers be made aware of practices that promote the spread of amphibian related diseases, and of mitigation measures that can decrease this risk.

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APPENDIX 1

Questionnaire for suppliers of the *Xenopus laevis* trade:

1. During which years did you export *X. laevis*?
2. How many frogs were exported annually?
3. To which countries and facilities were the frogs exported?
4. Did you ever breed wild-type *X. laevis* for export purposes?
5. How many sites did you collect frogs from?
6. Have you ever supplied *X. laevis* to the pet trade?
7. Have you ever supplied *X. laevis* to South African facilities?
8. What method do you use to collect *X. laevis*?
9. Are you aware of the role of *X. laevis* as a parasite carrier?

APPENDIX 2

Questionnaire for angling traders on the role of *Xenopus laevis*, Platannas, in the angling industry:

1. Which fishes are generally caught when using Platannas as bait?
2. How popular are Platannas among anglers?
3. Is there an angling season and does the demand for the frogs correlate with this season?
4. How many frogs are sold during the peak months of the season?
5. What size frog is ideal for angling purposes?
6. Do you supply to the entire angling community or do some anglers catch their own live bait?

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