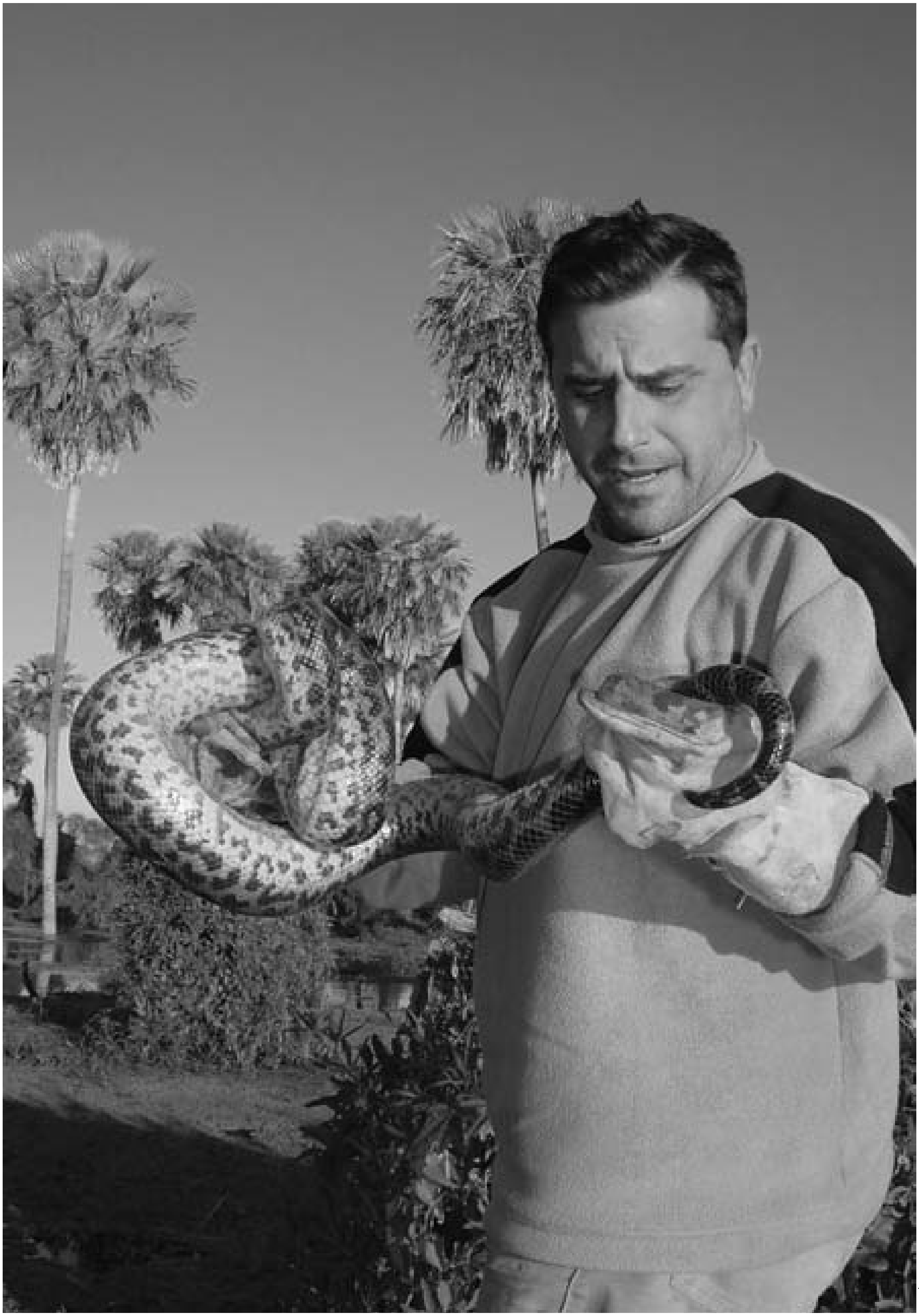


The senior author with a Yellow Anaconda (*Eunectes notaeus*) just captured in La Estrella marshes.

The Management of Yellow Anacondas (*Eunectes notaeus*) in Argentina: From Historical Misuse to Resource Appreciation

Patricio Alejandro Micucci and Tomás Waller

Fundación Biodiversidad, San Martín 945 piso 3 # 23, Buenos Aires, Argentina, C1003AAS

Abstract.—Herein we describe a program for the sustainable utilization of Yellow Anacondas (*Eunectes notaeus*) that was implemented in 2002 in the Province of Formosa, Argentina. The management plan was conceived to manage an activity that had been misusing a valuable wildlife resource with no regard for existing regulations. Delimited hunting areas were assigned to a restricted number of local skin buyers (LSB). A LSB is authorized to acquire hides from enrolled hunters living or working in his assigned territory; overlapping areas among buyers is discouraged and regulated. A minimum size limit of 230 cm was established for skins, while annual changes in skinning patterns ensure that hunters or LBs do not stockpile hides from one year to another. Sustainability is regulated by examining hunting effort in relation to catch-per-unit effort (CPUE) and monitoring traditional parameters like sex, origin, and size structure of the skins harvested. About 15% of the program's gross revenues return to cover program costs, whereas 13% goes to community members. Quantitative harvest data from the first five years are presented and discussed.

Introduction

Many developing nations are attempting to convert unmanaged and often illegal wildlife exploitation to sustainable utilization programs. Such projects seek to instill economic value in components of natural ecosystems threatened primarily by traditional land-use patterns. In many instance, a lack of scientific data has been used to defend the status quo and to boycott a sustainable use approach. However, recent history (Webb, 2002) suggests that management decisions rarely emerge from pure research; instead, long-term research can be a beneficiary of sustainable use plans.

Effective wildlife management results from a strong commitment by governmental agencies, users, pro-active NGOs, and other stakeholders. A well-planned management program should provide for an optimum allocation of resources, meaning that revenues have to be reasonably distributed among stakeholders, balancing the different economic levels, investments, risks taken, and responsibilities. Moreover, the main beneficiaries should return part of the income to the community. If funds are applied directly to the management plan, it will generate income and promote conservation.

Harvesting wildlife has received increasing attention and criticism in recent years. Biocentric views (Singer 1976, Callicot 1980) have been exacerbated in a media-dominated culture that promotes antipathy regarding the killing of charismatic animals. Although arguments against species exploitation are valid when based on solid scientific or even philosophical criteria, much of the criticism (e.g., Rivas, 2007) reflects emotional, political, or ideological perspectives.

The Yellow Anaconda (*Eunectes notaeus* Cope 1862) is the largest snake in Argentina. It is distributed in the River Paraguay drainage in Brazil, Bolivia, and Paraguay to northeastern Argentina, where its range covers 120,000 km^2 across six provinces (Henderson et al. 1995, Dirksen 2002, Micucci et al. 2006a). It is largely aquatic, a dietary generalist, and its range is restricted mainly to wetlands and floodplains.


TOMÁS WALLER

A Yellow Anaconda (*Eunectes notaeus*) from Formosa Province, Argentina.


TOMÁS WALLER

The dorsolateral position of nostrils and eyes reflects the aquatic habits of Yellow Anacondas (*Eunectes notaeus*).

Anaconda skins, like those of other boas and pythons, are considered a valuable resource and are highly prized for the manufacture of exotic leather goods (Jenkins and Broad 1994). In Argentina, trade in snake hides probably began earlier, but peaked during the 1940s. An estimated 60,000 Boa Constrictor (*Boa constrictor*) and Yellow Anaconda hides were exported from Argentina during each year of that decade (Gruss and Waller 1988, Micucci et al. 2006a). From 1980 through 1999, about 320,000 Yellow Anaconda skins were exported mainly from Argentina and Paraguay, primarily to the USA and Europe (Micucci et al. 2006a).

As with practically all squamates (Dodd 1993, Scott and Seigel 1992), the exploitation of Yellow Anacondas was carried out informally, without management guidelines or any regard to the species' biology (Waller et al. 2007). Our recent study shows that Yellow Anaconda populations from Argentina exhibit favorable ecological attributes, with high scores in six broad scale categories that "enhance" (Shine et al. 1998) the species' ability to withstand decades of intense harvesting (Waller et al. 2007).

Hunting of Yellow Anacondas diminished abruptly when trade was effectively banned in 1999; however, in several locations in Formosa, anacondas were opportunistically captured and their hides smuggled to Paraguay for export. In 2001, we carried out a study in the Province of Formosa, Argentina, for the purpose of analyzing the feasibility of harvesting Yellow Anaconda skins in a sustainable manner (Micucci et al. 2002). Research focused on social and ecological aspects, and involved experimentation with innovative management policies. In 2002, as a direct result of that research, the CITES National Authority (National Coordination for Biodiversity, Environment, and Sustainable Development Secretariat) asked us to design a management program for the species.

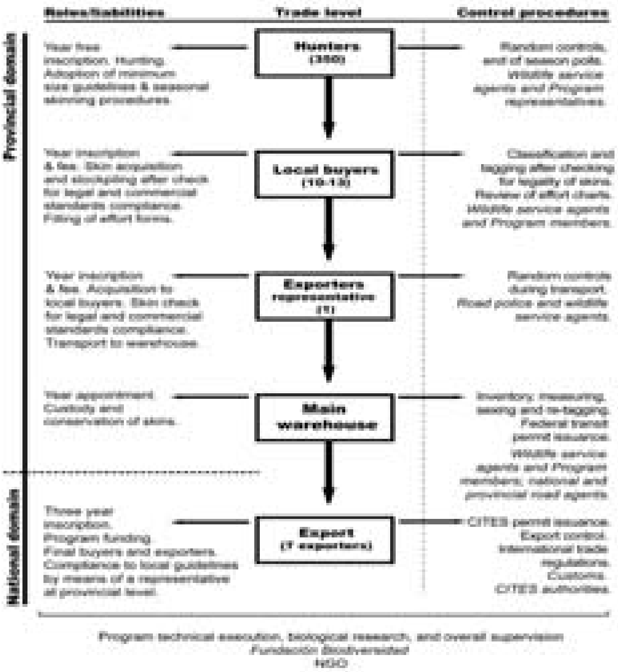
The Yellow Anaconda Management Program

We conceived the Yellow Anaconda Management Program (YAMP), seeking to reconcile the traditional utilization of a resource with its long-term conservation, and with the additional goals of promoting biological research on anacondas, avoiding resource misuse and waste, and maximizing local income favoring resource and habitat appreciation (Micucci et al. 2006a).

From a conceptual perspective, we followed the Adaptive Management Approach (AMA; Holling 1978), which was adopted due to the fact that we faced a system with high levels of uncertainty, and because it provides the ideal conceptual framework for exploited species for which research and population monitoring by standard methods becomes unfeasible in practical terms. The AMA works on a step-by-step basis, monitoring the effects of actions taken through specific control variables and promoting changes, when appropriate, in a feedback fashion to progressively reduce uncertainty.

Anaconda populations are actually managed on the basis of "sustained yield" harvest theory (Caughley and Sinclair 1994, Webb 2002). Specifically, we tested surplus-yield production models (i.e., Schaefer 1954, Fox 1970), which have been used mainly in fisheries, but also for terrestrial fauna.

From a methodological perspective, a harvest can be controlled either by placing a quota or by controlling hunting effort (setting a hunting season or limiting the number of people or the amount of time they are harvesting a population; Caughley and Sinclair 1994). The YAMP follows the latter approach, making no effort to control *directly* the number of animals harvested. Controlling effort usually is a safer mean of regulating a harvest than imposing a quota. Harvesting a constant number of animals each year is risky, particularly when the population is affected by environmentally induced swings in abundance (Caughley and Sinclair 1994) or when conducting a census of populations is a major constraint, both situations we knew or expected to occur in Yellow Anacondas inhabiting highly seasonal savannas.



Operative scheme of the Yellow Anaconda Management Program.

Fundación Biodiversidad (FB) was appointed by agreement with the federal government to lead and execute the program. Annual tasks and budgets are outlined in operative plans submitted annually for approval by the federal and provincial wildlife authorities. Seven major reptile skin exporters finance the program under a mechanism controlled by the central government. Federal regulations state that project benefactors will distribute benefits (i.e., snake hides) among themselves in proportion to the funds that each has contributed. Funds are received from donors by an administrative NGO (Fundación ArgenINTA), bonded by the federal authority, and then transferred to FB as needed. The Province of Formosa, in northeastern Argentina, was selected for implementing the experimental harvest program due to the abundance of anaconda habitat, a long-standing hunting tradition, and a favorable governmental predisposition. Formosa (Wildlife Agency, Ministry of Production) has the responsibility for establishing and controlling procedures and guidelines for executing the program at the local level.

TOMAS WALLER

The floodplain of the Pilcomayo River in northeastern Argentina, locally known as "Bañado La Estrella," covers approximately 3,000 km^2 and harbors a large population of Yellow Anacondas (*Eunectes notaeus*). This savanna exhibits drastic seasonal changes, from complete flooding in autumn (shown) to almost complete drought in early summer. Yellow Anacondas take advantage of rodents and concentrations of birds during both periods.

Map of Formosa Province, Argentina, showing the areas with suitable Yellow Anaconda (*Eunectes notaeus*) habitat.

The Setting

The 72,066-km^2 Province of Formosa lies entirely within the Chaco region. For the purpose of our work, we divided the area into two regions: (a) Eastern Formosa, a 35,000-km^2 plain with meandering rivers and creeks, palm savannas, mesic forest patches, and swamps; and (b) La Estrella marsh, a 250-km long seasonal floodplain covering nearly 3,000 km^2 in the otherwise dry west of the province. This very unstable wetland originates from the Pilcomayo Riverbed; the original river inundated vast dry woodlands during its progressive regression to the west. Large grasslands, palm savannas, and standing dead Chaco forest patches, with tree stumps covered with climbing plants (locally called "champales") during the flood season, combine to form a singular landscape matrix.

Formosan anaconda populations are comprised mainly of adults. Females are larger than males, occasionally reaching a maximum size of 335 cm SVL, whereas males rarely exceed 250 cm. Average animals are about 180 cm, and very large specimens are uncommon (< 5%). Males exhibit larger cloacal spurs than females, allowing the determination of sex even on skins. Growth and maturity are quite rapid, with males capable of breeding at 128 cm SVL and females at 147 cm, during the third year of life, depending on food availability, genetics, and individual life history traits. Courtship lasts from the beginning of September to early November (local spring), and pregnant females are found during the summer months. Parturition in Formosa occurs from late March to the end of April (local autumn). Anacondas reproduce on average every two years, depending on the female's fat reserves. Fecundity is positively correlated with female size, with an overall mean value of 24 offspring per clutch. Newborns are large (49 cm SVL), very aggressive, and fast growers (Waller et al. 2007).

Anacondas are abundant everywhere in Formosa, with the eastern provincial plains providing the most extensive habitat (>6,000 km^2 of scattered tropical wetlands) and harboring potentially the largest populations. However, YAMP has received particularly strong support from the local communities

DANIEL GOMEZ

Yellow Anacondas (*Eunectes notaeus*) do not breed every year; however, clutch mass can equal half the weight of a female. Here, an individual from San Juan Poriahu Ranch, Loreto, Corrientes, Argentina, is giving birth.

Burn scars on the head of a Yellow Anaconda from La Estrella marshes. The grasslands and dry wetlands are burned during the dry season to facilitate removal of domestic pigs. Snakes are sometimes injured or killed.

living around La Estrella marsh, where a subsistence economy of rural and indigenous people prevails. Eastern Formosa is more socially complex, with a different land tenure scheme, more jobs, and demanding a different approach. Because 90% of the harvest takes place at La Estrella marsh (Micucci et al. 2006a), most of the analysis and conclusions presented here pertain to that region unless indicated otherwise.

Harvest Control Procedures

The harvest of Yellow Anacondas is strictly confined to three elements: hunters, local skin buyers, and exporters. Middlemen (sub-local buyers and transporters) are not allowed. In the past, middlemen increased the value of the skins to the detriment of hunters. Anaconda collectors are rural and mostly indigenous (pilagá, toba). They rely on livestock breeding, hunting, and fishing. Some 250–450 families are involved in anaconda hunting, mostly (80%) from the area surrounding La Estrella marsh.

The local skin buyer (LSB) also serves as a food supplier or market-man, and can manage the logistics of transporting and stockpiling snake hides. Ten to 13 LSBs participate in a harvest, with a mean number of 35 hunters per buyer. According to YAMP guidelines, the exchange of goods for skins is forbidden, unless it is at the specific request of an indigenous community. To ensure compliance, at the end of each harvest season, we randomly survey hunters, collecting data on prices and payout modalities. Each LSB serves a designated area, defined in the local buyer's license. If the buyer reaches beyond his area, this could conflict with other LSBs, who will consequently report it to relevant authorities. The infringer could suffer confiscation of his goods, among other penalties. The rationale is to generate a local socio-economic impact, equitably including as many families as possible.

During April and May, a series of trips are organized to register and inform LSBs of any modifications to program guidelines. These activities are intended to regulate the hunting effort, although the program places no limit on the number of hunters (in practice they represent a finite number), actual numbers are closely tied to the number of skin buyers for economic and cultural reasons. During the last week of May, and immediately before the beginning of the harvest (June), we notify the LSBs of the skinning pattern to be used in the forthcoming season. In some cases, hides must bear both spurs on one side, in other cases, one on each side. This, in combination with leaving the entire head attached to the skin or not, for instance, allows us to select from a large array of different skinning specifications from one year to the next in order to minimize the incidence of illegal hunting and stockpiling.

Emergent logs and logs covered by climbing plants, locally known as "champas," are preferred basking sites of *Eunectes notaeus* in La Estrella marshes in northeastern Argentina. Snakes seek these microhabitats during the winter, when water temperatures drop to 15 °C or lower. Both males and females need warmer temperatures to complete gonadal cycles before the onset of the mating season in spring.

Patricio Micucci (left) and collaborators from the Paraguayan CITES office measuring Yellow Anaconda skins seized in Asunción, Paraguay in 1996.

Yellow Anacondas (*Eunectes notaeus*) are most vulnerable to collection during the winter when they are cold and leave the water to bask.

The minimum size of hides is 230 cm from the neck to the anal scale, corresponding to a live specimen measuring approximately 200 cm SVL (live SVL = 11.71 + 0.66 × skin length + 1.59 × skin width, $r^2 = 0.93$, $P < 0.01$; Micucci et al. 2003). Because females mature at an average of 165 cm SVL (Waller et al. 2007), this precautionary provision is intended to allow anacondas a reproductive opportunity before hunted.

The harvest takes place from June to August (local winter), a period when Yellow Anacondas do not exhibit any reproductive behavior. The cool weather and the wide range of winter temperatures promote thermoregulatory behavior, allowing hunters to find and capture snakes by hand. Snakes, depending on program research requirements, are killed in place or transported live to the hunter's home for data collection.

Most of the conditions imposed on the hunters are enforced when they bring their skins to the LSBs for sale. Skins that do not comply with program standards are worthless. Furthermore, LSBs are visited periodically by a representative of the exporters (purchasing agent), a provincial wildlife officer, and a program team member for the purpose of buying skins. Anaconda hides are checked for compliance to the year-specific skinning pattern and minimum size guidelines. At this time, skins that conform to program standards are individually tagged for control and future tracking; non-compliant hides are seized and, according to program provisions, destroyed. These visits occur at intervals of about three weeks. These procedures and a gradual decrease in flexibility criteria have reduced the number of undersized skins from 1,109 hides in 2002 to 142 hides in 2006.

During the sale, the LSB fills out an "effort form," a legal document that records the number of skins, the name of the hunter, and the date and place of harvest. This document is needed for the hides to be legally transported within Formosa. The contents of the document are crosschecked against the results from periodic hunter surveys. In case of irregularities, a buyer could be penalized by the cancellation of his license.

Tagged hides obtained through the prescribed process are transported periodically to a warehouse in the city of Formosa. The representative of the exporters is the only person authorized to transport anaconda hides. Once they arrive, skins are inventoried. At the end of the season, but before leaving the province, hides are sexed (by spurs and bone remnants), measured, and field tags are replaced by export tags that comply with federal regulations. The export tag is required before a CITES export permit is issued and the skins can be transported out of the province. Wildlife inspectors from Formosa, and eventually from the central government, as well as a representative of YAMP supervise this procedure.

Once skins are tagged and all valuable data gathered, the skins are released for distribution among the seven exporters. In order to transport the hides to tanneries or export ports, Formosan authorities must issue a Transport Guide to each exporter. This document is enclosed with the shipment and is required by CITES Management Authorities in order to issue the pertinent CITES Export Permit.

Harvest Sustainability Monitoring

We monitor the impact of the harvest on anaconda populations through traditional indicators (i.e., capture per unit effort vs. effort, size and sex structure of the harvest). Hunting effort is closely checked by means of the aforementioned effort forms, on which basic data are recorded. The model assumes that each batch of skins sold by a hunter to his local buyer (LSB) represents a short and measurable hunting period or event. In case of suspicious data, we compare hunting effort information from hunters among different years to detect possible changes in pattern due to involuntary or intentional errors. For instance, since the LSBs are the only middlemen approved to stockpile skins, an excessive number of skins (above average values) sold by a hunter is considered suspect and is investigated.

Most of our energy is invested in reducing data errors and uncertainty. For example, since the beginning of the Program in 2002, we have been able to reduce uncertainty progressively from about 15% to 5% with regard to the number of hunters that are effectively collecting snakes in a given year. Since current uncertainty values are stabilized and are acceptable, we can check and recalculate weak hunting effort estimates from the first year.

Hunting effort values depend not only on the number of hunters, but also on the time invested in that activity. Because we cannot closely monitor the time each of the 350 hunters invests in collecting snakes, we record the gross time (or total days) a LSB and its hunters are operative as a valid approximation of actual time invested. This is easily accomplished since each hunting season is precisely framed by start and end dates:

TOMÁS WALLER

An excavation used by hunters in La Estrella marshes to keep the snakes alive for biological studies.

Table 1. Yellow Anaconda (*Eunectes notaeus*) harvest monitoring indices for La Estrella marsh, Formosa.

Year	Hunters	Effort (dH^{-1})	Capture (u.)[1]	CPUE[2]	Mean Autumn T
2002	305	24,779	3,973	0.14	18.0 °C
2003	303	37,000	3,327	0.08	20.7 °C
2004	313	22,407	4,275	0.15	16.6 °C
2005	301	22,187	3,834	0.12	20.0 °C
2006	213	16,051	2,346	0.11	18.7 °C

[1] Skins >230 cm
[2] See text for CPUE estimation

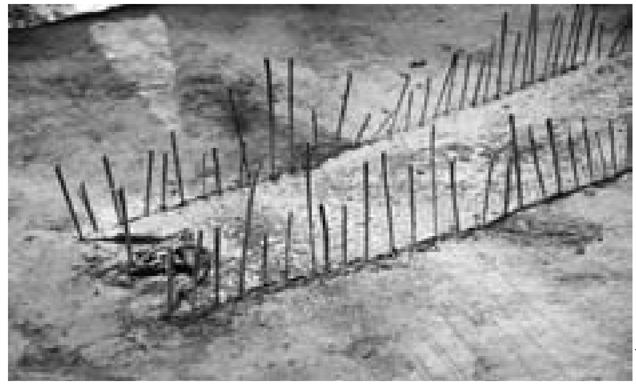
(1) The day the skinning pattern is distributed to hunters (harvest opening day), and (2) The day the last skins are retired from a local buyer's facility (harvest closing day).

Capture per unit effort (CPUE = capture/hunters * total days), the first of our indicators, is calculated at the end of the harvest season. CPUE is an affordable and inexpensive estimator of population trends and can be assessed at different spatial scales from local to provincial. From a theoretical perspective, rather than presenting estimates for a specific location or for the entire province, calculating CPUE values for an ecologically uniform and delimited area is desirable. From a management perspective, our resolution level should be the management unit (Mendez et al. 2007). La Estrella marsh, aside from being our main management unit for anacondas in Formosa, has a clear landscape homogeneity delimited by definite natural boundaries and exhibits no particular internal barriers to the dispersal of the snakes.

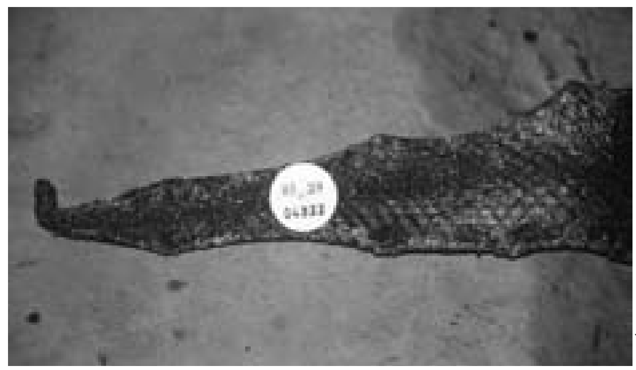
Annual CPUE values for La Estrella marsh were calculated from the slope of the "catch versus effort" regression line for each year, using the catch and effort data from the different buying centers (Micucci et al. 2007).

The effective hunting area (the cumulative territory of all the hunters) encompasses 20,000–30,000 ha of wetlands, depending on number of hunters. If we know the area for which the CPUE value has been calculated, we can estimate other demographic parameters, such as anaconda population density (Micucci et al. 2006b). To carry out this analysis, we made several assumptions that render the estimate very preliminary and without statistical significance, but nevertheless of great utility in providing an idea of abundance. For instance, we considered that a hunter always follows the same trail, which we know is not entirely true. However, we also assumed that collecting areas do not overlap among hunters, and again this is not realistic, although it compensates for errors caused by the previous assumption. We assumed that all anacondas are removed in a given year or season within a hunter's territory, which could not possibly be true, given the striking landscape complexity and current rudimentary methods of hunting. Consequently, density values are presumed to be greatly underestimated. A calculated density value for Yellow Anacondas of approximately 30–60/km^2 of wetland is consistent with our subjective perceptions of abundance based on years of field observations.

CPUE values for the first five years of harvest show an oscillating system tightly related to late autumn average temperatures



A Yellow Anaconda skin nailed to the soil with Palm spines, which are used for this purpose in eastern Formosa. In La Estrella marshes, spines from a local bush (*Prosopis ruscifolia*) are used for the same purpose.



The button marks used to identify skins prior to export (AR: Argentina, YA: Yellow Anaconda, and the number).

A hunter extracting *Prosopis ruscifolia* spines for use as "nails" to stretch skins.

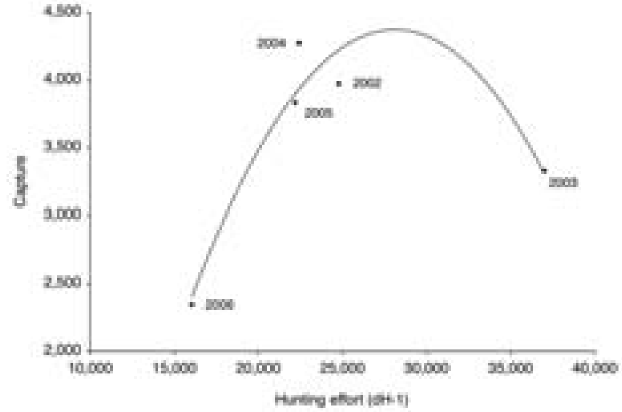
Table 2. Yellow Anaconda (*Eunectes notaeus*) density at La Estrella marsh compared to other large snakes for which data are available.

Snake Species	S/km^2	Locality and Source
Python regius	234	Southern Ghana, Africa (Gorzula et al. 1997)
Naja melanoleuca	212	Reserva Natural Abuko, Gambia, Africa (Starin and Burghardt 1992)
Dendroaspis viridis	120	Reserva Natural Abuko, Gambia, Africa (Starin and Burghardt 1992)
Python sebae	67	Reserva Natural Abuko, Gambia, Africa (Starin and Burghardt 1992)
Eunectes notaeus	30–60	This article
Bitis arietans	42	Reserva Natural Abuko, Gambia, Africa (Starin and Burghardt 1992)
Eunectes murinus	36	Hato El Catedral, Venezuela (Rivas 1999)

TOMÁS WALLER

TOMÁS WALLER

Drying Yellow Anaconda skins "nailed" to the dry Chaco soil using spines of a local bush (*Prosopis ruscifolia*).



The Yellow Anaconda Management Program observed yield curve.

(May–June). The harvest takes place mostly during the cool winter (June–August), when anacondas need to bask to raise their body temperatures. In this sense, the relationship between CPUE and temperature is an expression of vulnerability: When autumn temperatures are high, fewer anacondas will bask and CPUE values in the subsequent season are expected to diminish. A predictive model between CPUE and average autumn temperatures was inferred by calculating the following linear regression: CPUE $= -0.015 \times T\ ^{o}C_{meanM,J} + 0.40$ (R^2: 0.78; Micucci et al. 2007).

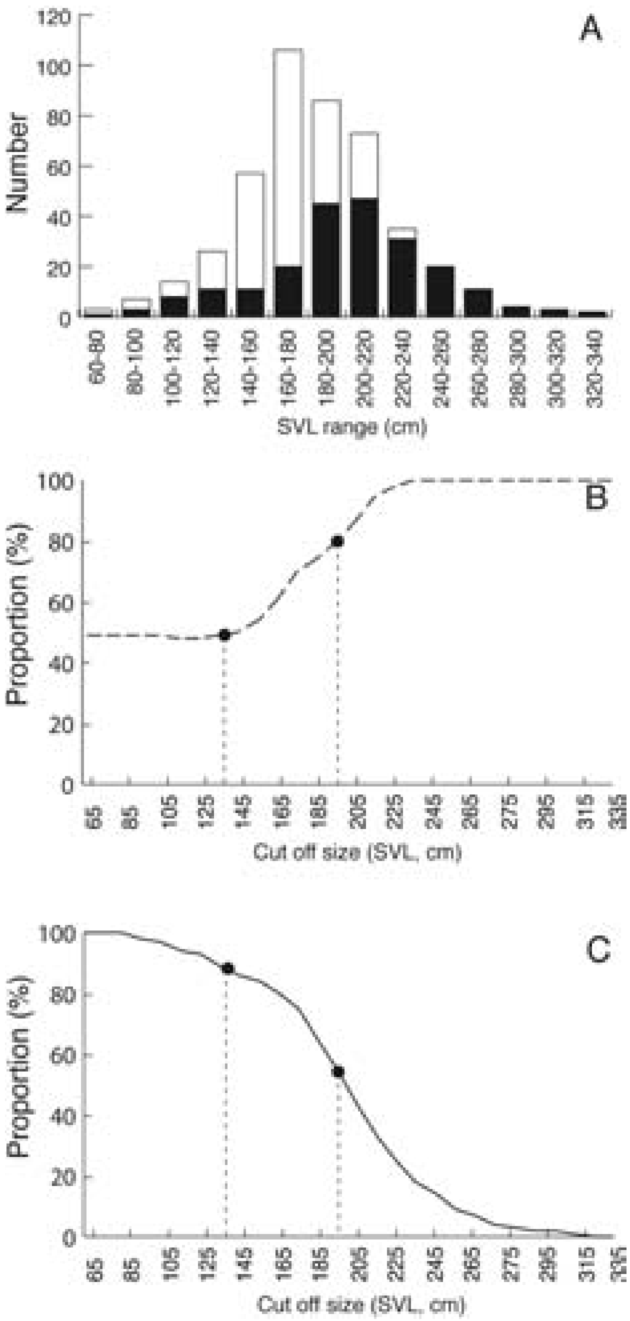
Appraisals of harvest intensity are derived from yield curves, analyzing capture volumes in relation to applied effort. These curves can be obtained from effort and CPUE data but, for this to be accurate and have some predictive value, large temporal series are needed in order to deduce the maximum sustainable yield. Our data do not represent a large temporal series (only five years); thus they do not yet exhibit the broad diversity of effort values needed to present conclusive results for a particular surplus-yield model.

Total capture values are certainly useless to predict population trends if they are not considered in relation to hunting effort. While reductions in capture volumes should catch our attention, data misinterpretation could lead to incorrect conclusions. Because the rationale of sustained yield models implies that a harvest represents a specific proportion of the total population, a reduction of the crop would be expected, for instance, in the case of a population decline caused by natural conditions (i.e., drought, fires), but this does not mean over-harvesting in that year (Caughley and Sinclair 1994). As temperatures play a significant role in anaconda vulnerability, captures will vary from year to year.

Actual harvest monitoring also takes into consideration the significant correlation between number of hunters and gross capture. More hunters usually implies more effort, more capture, and vice versa: Gross capture = 17 × hunters – 1.280 (R^2: 0.97) (Micucci et al. 2007). 2006, for example, was a "bad" year for captures because of the low number of hunters, which meant that the effort for that year diminished in relation to previous harvest seasons. In this sense, a gradual but permanent drop in the number of hunters has not influenced CPUE values in a significant manner (Table 1). This drop was in response to an increased demand for labor and an indiscriminate distribution of unemployment benefits to hunters and their families since 2003. In other words, if YAMP does not increase skin prices in order to compensate for currency depreciation (as we are constantly striving to do), the system tends to stabilize in such a way that exporters' actual profits are in consonance with actual structure. If exporters are reluctant to increase skin price as a means of avoiding hunter desertion, evidence strongly suggests that, in this effort-mediated system, a commercial collapse will precede the biological collapse of the resource.

Although a substantial reduction in active hunters inevitably leads to a drop in gross capture, the time variable is also a significant component for estimating hunting effort. The difference between hunters and effort is the sum of gross time invested by each local buyer. This is evident from the capture and CPUE values for 2003. The harvest season was extended for two weeks due to exceptionally warm conditions, and, with the same number of hunters compared to other seasons (2002 and 2005), both capture and CPUE diminished. In this way, we deduced a preliminary maximum sustained yield (MSY) value for La Estrella marsh of about 4,350 hides, with an ideal effort of approximately 28,000 dH^{-1}.

Monitoring sustainability must assess the evolution of the sex ratio of the harvested population. Both sexes, due to low temperatures, are equally vulnerable to capture (Waller et al. 2007). However, because females attain larger size than males, the established size limit (> 200 cm SVL) was expected to result in the harvest of more females than males, presumably in a fairly constant and predictable proportion. Consequently, the actual harvest sex ratio (ca. 75% females) reflects only the established minimum size limit. The harvest sex ratio was relatively similar season after season, with only a small increase in females in later years. We consider this increase a mathematical artifact. Eight percent of the skins in the first two years were classed as "unknown" sex. Subsequently, sex determination became much more accurate by also examining the attached limb bone remnants rather than just the spurs, and the undetermined proportion of skins diminished to 1.3%, although the proportion of females increased, whereas the proportion of males remained constant.



Effects of skin minimum size limits on female anaconda harvest: (a) Natural size distribution of anaconda populations in Formosa, females in black (Waller et al. 2007); (b) Expected proportion of females in the harvest at different size cut-off limits; (c) Proportion of potentially harvestable females in a natural population at different size cut-off limits.

Table 3. Main parameters for Yellow Anaconda (*Eunectes notaeus*) skins harvested at La Estrella Marsh, Formosa.

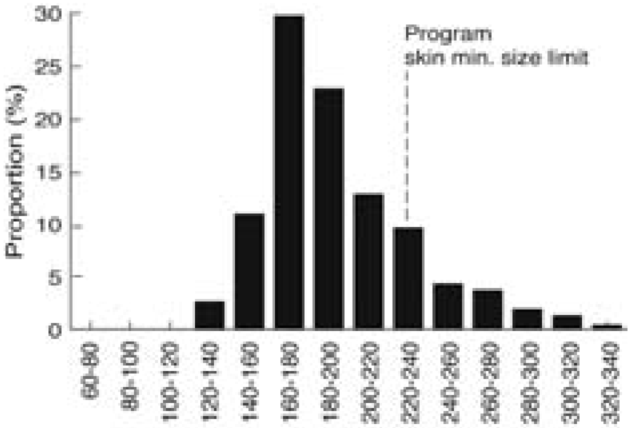
Year	2002	2003	2004	2005	2006
Average skin length (cm)[1]	271	268	264	263	263
Number of skins < 230 cm	1,109	1,075	420	343	142
ϵ coefficient[2]	-4.0%	-5.5%	-0.4%	+1.2%	+0.4%
Females (%)	70.5	69.9	75.8	75.4	76.3
Males (%)	21.3	22.1	20.7	23.1	22.4
Unknown sex (%)	8.2%	8 %	3.5%	1.5%	1.3%

[1] Average size of hides >230 cm after correcting for deformation (see text).
[2] Skin deformation coefficient (see text for explanation).

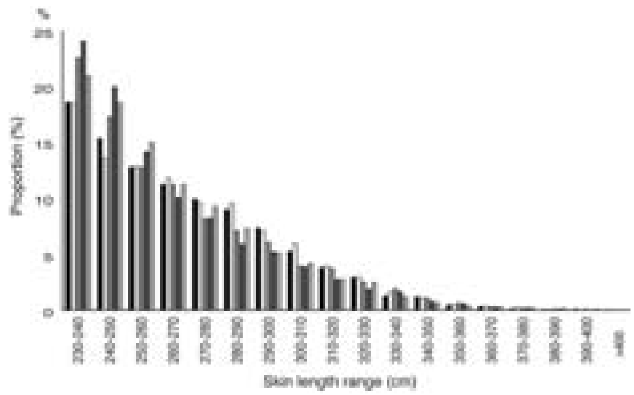
Prior to the introduction of the sustainable use program, anaconda exploitation was not permitted and illegal hunting took place with total disregard of size. According to traders and local dealers, Formosa's annual production was approximately 20,000 skins with widths > 15 cm (Micucci et al. 2002, 2006a). This hide width, according to our data, would correspond to a skin length of 150 cm and a live anaconda of about 135 cm SVL (Micucci et al. 2002). Many of the 500 or so seized Paraguayan skins that we measured confirmed that the minimum size of skins taken during illegal harvests were of that size. That translates to practically all (90%) anacondas of either sex older than 1.5 years of age (Waller et al. 2007) being vulnerable during that market-driven hunting period. That current harvest policy has been able to substantially reduce female hunting, both in terms of juveniles and adults, is indisputable. Current production, without mediation of quotas, represents a management-derived reduction of harvest to a quarter of Formosa's historical values (5,000 vs. 20,000 skins), and a 40% reduction of female vulnerability to hunting. So, the Program has been very conservative in establishing a minimum size limit despite the fact that, upon initial consideration, it appears to promote the hunting of females. What ultimately matters, however, is the overall number, not the proportion of females. If our harvest represents 5% of the total population, a crop that is 75% female equates to an overall female extraction of 3.75%, which is sustainable.

Hunters do not seek anacondas of specific sizes, but collect serendipitously the snakes available in a given area (Waller et al. 2007). During the first years of the Program (2002–2003), different prices were paid for skins of three different size classes (230–290 cm, 291–390 cm, > 391 cm), stemming from industry traditions aimed at promoting the harvest of larger snakes. We were aware that such guidelines were unlikely to produce the desired results for traders. In fact, in 2002 and 2003, instead of encouraging the harvest of large animals, this approach promoted the hunting of undersized snakes and severe skin deformation attributable to hunters stretching skins. Importers complained because stretched skins would inevitably shrink considerably when tanned.

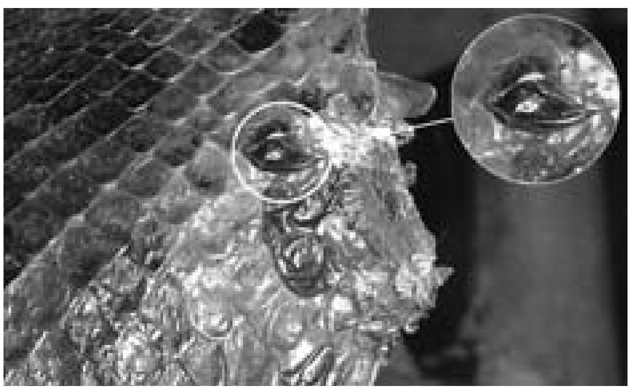
In 2004, we established a single price and demanded that all anaconda hides conform to a standard represented by the



Size distribution of a shipment of Yellow Anaconda skins that were seized and measured in 1996 in Asunción, Paraguay (N = 539).



Size distributions of skins harvested from 2002–2006 (columns in order). Only skins above 230 cm are included. Hide sizes are corrected for intentional stretching (see text).



TOMÁS WALLER

The cloacal region of a Yellow Anaconda skin with spurs (insert) that allow sexing of the skin (in this case, a male).

equation: skin width at midbody = 0.10 × skin length. In order to correct hides for hunter-induced deformation and be able to perform demographically sound interpretations of population structure for any year, we developed the following formula to convert rough skin length values to corrected skin length values: Skin length$_c$ = (skin length + (skin width × 10))/2. This formula assumes (due to the cross pattern of skin fibers) that, for any increment in one dimension, a reduction in the other will compensate. To control for skin deformation, we also devised a stretching coefficient that permits us to determine the degree of bias (%) of a harvested skin (uncorrected length) from its "real" (corrected length) shape. When we compared sizes of harvested skins corrected for length, we found no significant difference in population size structures for prior years that may have been attributable to the stratified price scheme, confirming our views on the stochastic nature of hunting.

If a population is overexploited, we would expect to see a reduction in the average size of skins harvested. Instead, we see an oscillating pattern, partly attributable to changes in the skinning guidelines since 2004 and to a progressive reduction of small skins due to the imposition of intensive controls. Because no significant consistent reduction in the average size of snakes (i.e., skins) has been noted (Micucci et al. 2007), we suggest that current harvest guidelines are appropriate for continued sustainable management of the anaconda populations.

Harvest Economics

The economic structure of YAMP includes government (federal and provincial), exporters (7), hunters (about 350), local buyers (10–13), and the NGO in charge of the technical program. The government sector receives the smallest portion (4.2%) of partitioned benefits. In fact, the government delegates the administration of the program to an NGO in order to encourage prompt and direct allocation of funds for research and monitoring (14.8%). Hunters and local buyers collectively earn 13.3%, but three-fourths of this amount goes into hunters' pockets. Consequently, about one-third of the international value of a skin remains in the region. Although actual earnings at the local community level represent a three-fold increase over prices paid by illegal traders just a few years ago, we strongly encourage higher prices to enhance the local allocation of benefits.

Table 4. Yellow Anaconda Management Program benefit partitioning (based on a US $50 skin price).

Stakeholder	US $	%
Provincial and export taxes	2.1	4.2
Program running costs (NGO)	7.4	14.8
Hunters and local buyers	6.7	13.3
Stockpiling logistic expenses	3.1	6.2
Total expenses per skin	19.3	38.5
Exporters income	30.7	61.5

Conclusions

The Yellow Anaconda Management Program has been in operation for five years. Aside from the beneficial local economic impact, it has generated intense research on aspects of the species' biology (Waller et al. 2007) and population genetics (Mendez et al. 2007). The conservation biology of this species had been completely ignored until the establishment of YAMP, and ongoing results are being incorporated into the model to reduce uncertainty levels.

No discernible negative, harvest-related population trend has been detected. CPUE values, as well as the descriptive statistics for harvested skins, exhibit an oscillating but safe pattern of variation. CPUE values responded in direct relation to environmental factors that affect anaconda vulnerability (i.e., autumn temperatures). Observed differences in average skin size or sex ratio during this period relate to changes in the skinning guidelines and sexing procedures since 2004, and to an improvement in the control of undersized hides. Yield is determined by the number of active hunters, showing that controlling effort is a viable method of monitoring and limiting the harvest.

The program impacts about 20–30 thousand ha of wetlands, representing 2–3% of suitable habitat available in Formosa, which is relatively insignificant if we consider the species' total distribution. Assuming that current controls are maintained, the sustainable management of Formosa's anaconda populations is possible.

The tools applied to control and monitor for harvest sustainability have been effective, and could be replicated in other developing nations with marketable wildlife resources at a very low cost. Considering the economic constraints that developing countries face in implementing sound wildlife management practices, our experiences are encouraging.

Wildlife management must consider sociology, economics, and a generous dose of psychology in addition to biology (Webb 2002). In this broader context, whether the management procedures presented herein are optimal and the methods by which Yellow Anacondas can be successfully managed for the long-term benefit of local communities are appropriate questions that will require more than five seasons to be answered.

Acknowledgements

We express our deep thanks to Victoria Lichtschein (Biodiversity National Coordination Agency), Obdulio Menghi and Guillermo A. Puccio (Fundación Biodiversidad) for their constant support throughout the years; to Carlos A. Micucci for his help with data management; also to current and past Program team members: Ernesto Alvarenga, Emilio Buongermini, Emilio White, and Martín Mendez; and to Juan Carlos Orozco (Wildlife Agency Director) and Luis Basterra (Ministry of Production) in Formosa for trusting in us.

Literature Cited

Callicot, J.B. 1986. On the intrinsic value of nonhuman species, pp. 138–172. In: B.G. Norton (ed.), *The Preservation of Species, the Value of Biological Diversity.* Princeton University Press, Princeton, New Jersey.

Caughley, G. and A.R.E. Sinclair. 1994. *Wildlife Ecology and Management.* Blackwell Scientific Publications, Boston, Massachusetts.

Dirksen, L. 2002. *Anakondas. Monographische Revision der Gattung* Eunectes *Wagler, 1830 (Serpentes, Boidae).* Natur und Tier-Verlag, Münster.

Dodd, C.K., Jr. 1993. Strategies for snake conservation, pp. 363–393. In: R.A. Seigel and J.T. Collins (eds.), *Snakes: Ecology and Behavior.* McGraw Hill, New York.

Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. *Transactions of the American Fisheries Society* 1: 80–88.

Gorzula, S., W.O. Nsiah, and W. Oduro. 1997. Survey of the status and management of the Royal Python (Python regius) in Ghana. Unpublished report, CITES Secretariat, Gland, Switzerland.

Gruss, J.X. and T. Waller. 1988. Diagnóstico y recomendaciones sobre la administración de recursos silvestres en Argentina: La década reciente. TRAFFIC Sudamérica, WWF, Secretaría CITES, Buenos Aires, Argentina.

Henderson, R.W, T. Waller, P.A. Micucci, G. Puorto, and R.W. Burgeois. 1995. Ecological correlates and patterns in the distribution of Neotropical boines (Serpentes: Boidae): A preliminary assessment. *Herpetological Natural History* 3: 15–27.

Holling, C.S. 1978. *Adaptive Environmental Assessment and Management.* J. Wiley & Sons, London.

Jenkins, M. and S. Broad. 1994. International trade in reptile skins. A review and analysis of the main consumer markets, 1983–1991. A TRAFFIC Network Report, TRAFFIC International, Cambridge, United Kingdom.

Mendez, M., T. Waller, P.A. Micucci, E. Alvarenga, and J.C. Morales. 2007. Genetic population structure of the Yellow Anaconda (*Eunectes notaeus*) in northern Argentina: Management implications, pp. 405–415. In: R.W. Henderson and R. Powell (eds.), *Biology of the Boas and Pythons.* Eagle Mountain Publishing LC, Eagle Mountain, Utah.

Micucci, P.A., T. Waller, and E. Alvarenga. 2006a. Programa Curiyú. Para la conservación y aprovechamiento sustentable de la Boa Curiyú (*Eunectes notaeus*) en la Argentina. Etapa experimental piloto 2002–2004, Formosa, pp. 77–92. In: M.L. Bolkovic and D. Ramadori (eds.), *Manejo de Fauna Silvestre en la Argentina. Programas de Uso Sustentable.* Dirección de Fauna Silvestre, Secretaría de Ambiente y Desarrollo Sustentable, Buenos Aires, Argentina.

Micucci, P.A., T. Waller, and E. Buongermini P. 2002. Programa para la conservación y aprovechamiento sustentable de la Boa Curiyú (*Eunectes notaeus*) en Argentina. Estudio de Prefactibilidad.). Informe Técnico # 1. Unpublished report, Fundación Biodiversidad Argentina, Buenos Aires.

Micucci, P.A., T. Waller, E. Alvarenga, and G.E. Lerea. 2006b. Programa para la conservación y aprovechamiento sustentable de la Boa Curiyú (*Eunectes notaeus*) en Argentina. Formosa. Informe Técnico # 4 (2005). Unpublished report, Fundación Biodiversidad Argentina, Buenos Aires.

Micucci, P.A., T. Waller, E. Alvarenga, and G.E. Lerea. 2007. Programa para la conservación y aprovechamiento sustentable de la Boa Curiyú (*Eunectes notaeus*) en Argentina. Formosa. Informe Técnico Zafra 2006. Unpublished report, Fundación Biodiversidad Argentina, Buenos Aires.

Micucci, P.A., T. Waller, E. White, and E. Alvarenga. 2003. Programa para la conservación y aprovechamiento sustentable de la Boa Curiyú (*Eunectes notaeus*) en Argentina. Etapa Experimental Piloto. Año I (2002). Formosa. Informe Técnico # 2. Unpublished report, Fundación Biodiversidad Argentina, Buenos Aires.

Rivas, J. 2007. Conservation of Green Anacondas: How Tylenol conservation and macroeconomics threaten the survival of the world's largest snake. *Iguana* 14: 74–85.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bulletin of the Inter-American Tropical Tuna Commission* 1(2): 27–56.

Scott, N. J. (Jr.) and R. A. Seigel. 1992. The management of amphibian and reptile populations: Species priorities and methodological and theoretical constraints, pp. 343–368. In: D.R. McCullough and R.H. Barrett (eds.), *Wildlife 2001: Populations.* Elsevier Science Publishers Ltd., Oxford, United Kingdom.

Shine, R., P.S. Harlow, Ambariyanto, Boeadi, Mumpuni, and J.S. Keogh. 1998. Monitoring monitors: A biological perspective on the commercial harvesting of Indonesian reptiles. *Mertensiella* 9: 61–68.

Singer, P. 1976. *Animal Liberation.* Avon Books, New York.

Waller, T., P. A. Micucci, and E. Alvarenga. 2007. Conservation biology of the Yellow Anaconda (*Eunectes notaeus*) in northeastern Argentina, pp. 340–363. In: R.W. Henderson and R. Powell (eds.), *Biology of the Boas and Pythons.* Eagle Mountain Publishing LC, Eagle Mountain, Utah.

Webb, G. 2002. Conservation and sustainable use of wildlife: An evolving concept. *Pacific Conservation Biology* 8: 12–26.