Eur J Wildl Res (2006) 52: 69–80
DOI 10.1007/s10344-005-0020-4

REVIEW

W. T. Flueck · J. M. Smith-Flueck

Predicaments of endangered huemul deer, *Hippocamelus bisulcus*, in Argentina: a review

Received: 30 July 2005 / Accepted: 19 October 2005 / Published online: 6 December 2005

Abstract A total of 350–600 huemul (*Hippocamelus bisulcus*) remain as fragmented groups along 1,850 km of Argentine Andes. Their conservation depends on accurate knowledge of the species' requirements and the factors preventing their recovery. The Regional Delegation for Patagonian National Parks (RDP) erroneously alleged that huemul status is satisfactory, and current in situ efforts are sufficient to guarantee recovery. Therefore, conservation centers are regarded unnecessary and the associated risks too high, especially because previous attempts with manipulations have failed. No data support these claims, instead many subpopulations have disappeared recently even in national parks (NP) which hold <0.01 huemul/km^2. Causes preventing recovery or recolonization are unknown. Current pressures on huemul subpopulations include increased economic activities and alien species. Normal ranges for many biological parameters or population performance of huemul are unknown. Focus is on habitat studies using presence as surrogate for what should be studied on survival and reproduction. Factors important to small-sized populations or preventing recovery remain unstudied. RDPs insistence on indirect methodology prevents implementation of other potentially more promising research approaches. The lack of consensus regarding the necessity and feasibility of a conservation center prevented its establishment and related census flights in unprotected sites. RDP currently forecloses aerial census and capturing and thus prospects for a huemul conservation center, and the proposition of establishing such a center was neither discussed nor incorporated into the national recovery plan. Helicopter captures have been used successfully on deer in huemul habitat. Captures and translocation of huemul occurred since 1830; several zoos kept them successfully up to 10 years, and natural tameness facilitated husbandry. Recently, Chile successfully caught and transported huemul by helicopter to stock a private center. Unknowns can be addressed easily on semicaptive deer; other questions can be studied through reintroductions, employing adaptive management. RDP places faith in NP providing viable subpopulations. However, it remains doubtful whether some 220 huemul living in >22,000 km^2 of parks can guarantee species survival. For Argentine cervids, absence of studies and management plans due to lack of funds is typical. Considering the actual situation and future perspectives, it appears doubtful that recovery will be achieved based on strategies similar to those employed in the past.

Keywords Conservation biology · Deer conservation · Captive program · Adaptive management · Extinction

Introduction

Huemul (*Hippocamelus bisulcus*; Fig. 1), an endemic cervid of Chile and Argentina, is considered at risk of extinction due to numeric reductions by >99% and in distribution by >50% (Díaz and Smith-Flueck 2000). The remaining 350–600 Argentine huemul are dispersed along 1,850 km of Andes in roughly 50, mostly fragmented, subpopulations. As both countries continue to lose subpopulations (total numbers 1,000–1,500), their status is critical (Díaz and Smith-Flueck 2000; Serret 2001).

Recovery depends on understanding factors affecting individual subpopulations, and on well designed in and ex situ projects. Information gaps impeding conservation can be filled via research on semicaptive huemul, which would also provide animals for reintroductions or restocking. Reintroductions using adaptive management principles (AMP) could determine factors presently preventing recovery (Walters and Holling 1990). The fact that huemul

W. T. Flueck (✉)
CONICET,
C.C. 176,
8400 Bariloche, Argentina
e-mail: deerlab@baritel.com.ar

J. M. Smith-Flueck
DeerLab,
C.C. 176,
8400 Bariloche, Argentina

Fig. 1 The Patagonian Huemul, *Hippocamelus bisulcus* (photo by Smith and Flueck)

remain in remote small clusters at low densities limits the efficacy of field research (CONAF and CODEFF: Plan para la conservacion del huemul del sur en Chile, 2001), especially if funding for such research is low. Considering the demands for professional standards of capture and treatment of animals at risk of extinction (IUCN 2001a), we analyze methodologies based on the characteristics of huemul and its habitat.

Serret (2001) stated that huemul cannot be captured and confined as easily as other cervids, which was also emphasized in the Chilean recovery plan (CONAF and CODEFF: Plan para la conservacion del huemul del sur en Chile, 2001). According to the Argentine recovery plan, ex situ conservation shall be evaluated when necessary, yet a clear opposition to centers with semicaptive huemul prevails. The dominating Argentine group in huemul conservation, the Regional Delegation for Patagonian National Parks (RDP), claimed in an official statement that (a) Argentine huemul have not yet reached a critical population size justifying implementation of ex situ programs; (b) risks, therefore, associated with captive huemul are too high; (c) ample areas contain huemul populations in a good conservation state; (d) other activities have much higher conservation value than those obtained from ex situ programs; (e) current in situ efforts are sufficient to guarantee long-term survival of huemul, and therefore, conservation centers are unnecessary; and (f) previous attempts to keep huemul in captivity have failed (Ramilo 2001). Consequently, RDP prevented a feasibility study as a first step towards establishing a conservation center.

Scientific data contradict the claim that huemul's conservation status is satisfactory. Many subpopulations have disappeared recently, even within national parks (NP) (Franke 1949; Serret 2001). Low numbers and severe population fragmentation indicate high risks of extinction (Pimm and Bass 2002). Chilean huemul conservation is also losing ground, even in protected areas (PA) (Povilitis 2002). We posit that (a) historic events caused fragmentation and reduced subpopulations (Díaz and Smith-Flueck 2000); (b) new factors, like invading red deer (*Cervus elaphus*), are now acting on remaining huemul (e.g. Flueck et al. 2003; Smith-Flueck 2003); and (c) subpopulations are so reduced that they are subjected to constraints of biology of small populations (Caughley 1994). Given the situation in Argentina, conservation benefits from semicaptive huemul would thus be significant. As we will show, huemul have been successfully maintained in captivity, and the risks from manipulation are negligible. Thus, this review may serve as a feasibility analysis for the establishment of a conservation center as an additional strategy for huemul recovery.

Current predicaments of Argentine huemul

Economic developments

Since 1980s, human populations in provinces with huemul increased 57–100% (Elustondo, 12/9/2003, Clarín, Argentina). Increasing roads, resource use, large-scale constructions and mining, some even encroaching on NP (Martin and Chehebar 2001), limit wildlife conservation (Laliberte and Ripple 2004; Parera 2002; Saucedo 2002). Neither Argentina nor Chile have regulations regarding huemul management or habitat on private land. Tourism, including helicopter rides, has steadily increased and reached all huemul areas (Serret 2001; Braun 2002; Moyano 2004). In 2003, recreation in Patagonian NP increased by 56% (Administración de Parques Nacionales, Argentina 2004; Sabatini and Iglesia 2001). Ranches are rapidly being converted to tourist centers. Poaching still occurs in both countries but has not yet been quantified.

Alien wildlife

Introduced red deer threaten huemul (Flueck et al. 2003; Smith-Flueck 2003). Sometimes illegally, enterprises import wildlife, like 26 red deer from New Zealand (NZ) in 2002 (Sympson 2003). Mountain tahr (*Hemitragus jemlahicus*), highly invasive and difficult to control, arrived from NZ in 2000. Interestingly, they do not appear in any of the government's alien species lists and are likely to eventually roam huemul habitat. Imports of exotics are associated with risks of introducing diseases, such as chronic wasting disease or parasitoses. In Argentina, exotic *Taenia krabeii* may now exist in a sylvatic cycle (Flueck and Jones 2005), and several exotic nematodes are already reported in red deer.

Huemul likely first went extinct in more favorable habitats like ecotones and former winter ranges due to human settlements and associated introductions of exotics. From such source areas, red deer are invading huemul refuges and may displace huemul (Díaz and Smith-Flueck 2000); they may cause interference competition (Stephens et al. 2003) or may introduce diseases. Regardless, huemul are at substantial risks from the 'mass effect' alone of invading red deer (Thompson et al. 2003).

Limitations of protection in Argentina

While Lanin NP, since its establishment, has lost all subpopulations, Nahuel Huapi NP lost many if not most (Serret 1993, 2001). Patagonian NP (22,618 km^2) contain only about 220 huemul, or <1 individual/100 km^2 (Serret 1993, 2001). Huemul densities average 0.7/km^2 (Díaz and Smith-Flueck 2000), indicating that >98% of NP are presently void of huemul. Hence, Serret (2001) cautioned that NP may not contain viable subpopulations: according to Reed et al. (2003), no group qualifies as viable. Settlers within NP raise livestock (Martin and Chehebar 2001), utilizing up to 56% of park areas (Simberloff et al. 2003), but commonly run several fold more livestock than permitted (Serret et al. 1994). Although parts of NP with huemul were declared 'Critical Areas', 90% of the area is still exclusively used by cattle and only 10% by huemul. Reducing livestock is hampered by lack of control, fencing, and prevailing policies (Martin and Chehebar 2001; Sabatini and Iglesia 2001), hence fueling the tragedy of the commons. IUCN's category II for NP requires absence of exploitation, yet extensive parts within huemul ranges are exploited, even "intangible" areas, mainly through unauthorized livestock and hunting. Low-impact areas of NP occur at higher elevation (="highest protection") due to diminished human interests. In contrast, favorable habitats in NP are privately owned, intensely utilized, characterized by lower elevations with greater proportions of flat slopes and wet meadows, served as winter habitat for many species, and likely provided source populations. Low-impact portions of NP today (Ramilo 2002) mainly represent suboptimal conditions for huemul. Elsewhere, species have gradually gone extinct in PA due to laissez-faire management, whereas they recovered in areas brought under state-of-the-art management (Saenz et al. 2001). Thus, all factors in NP considered detrimental (APN, Proc. First Huemul Conf., 1992) should be eliminated, including livestock, dogs, and consumptive and nonconsumptive uses. Once subpopulations are shown to recover, it could be evaluated if certain land uses should be permitted again. Whereas most PA are 'paper parks' with scarce or absent implementation (Martin and Chehebar 2001; Rusch 2002), a substantial proportion of subpopulations are outside of PA (Serret 2001). NP contain extensive huemul habitat, making it a prime candidate for contributing significantly to huemul recovery.

Small population characteristics

More effort into surveying new sites might reveal some new small groups, but the larger subpopulations are already known. Two subpopulations contain around 100 deer each (Serret 1993; Smith-Flueck and Flueck 2001a), another contains about 40 deer, and the remaining quasi-extinct subpopulations may each contain <15 individuals and can be considered quasi-extinct (Berger 1990). Even if estimates would be 300% higher, subpopulations still could not be considered viable (Pimm and Bass 2002; Reed et al. 2003). To date, no cases of dispersal nor recolonization exist. Thus, while potential corridors can be established, they might not benefit huemul presently. Levels of fragmentation, reduced subpopulation sizes, site fidelity, absence of recolonization, and continued loss of groups indicate a tendency towards reduction in occupied area and numbers.

State of knowledge

There are 3 doctoral thesis (1816, 1979, 2003), 2 books (Díaz and Smith-Flueck 2000; Serret 2001), and a Cross-Search of ISI Web-of-Knowledge and 17 external databases (1945–present) listed 16 entries on *H. bisulcus* (9 original studies). According to CONAF and CODEFF (Plan para la conservacion del huemul del sur en Chile, 2001), Chilean data obtained during 25 years were mainly descriptive and were neither collected systematically nor statistically analyzed. Most information from Argentina appears as in-house reports. RDP recorded warden observations between 1990 and 1998 (Martin and Chehebar 2001): only 12 groups were seen. Such data lack precision to determine absence and serve mainly to confirm presence (Sutherland 2000). Mortalities were analyzed only once for huemul (Smith-Flueck and Flueck 2001b). Although initial "diagnoses" of huemul status were mere hypotheses (APN, Proc. First Huemul Conf., 1992), reassertions in other workshops (1995, 1998, 2002) resulted in dogmas without evidence. Successful diagnoses must be based on scientific monitoring (Sutherland 2000) which is notoriously lacking. In essence, no information has yet been generated on factors preventing recovery of any subpopulation.

Current management and conservation in Argentina

The past 15 years resulted in new PA, stricter laws, awareness programs, and confirmation of huemul presence. While neglecting nonprotected subpopulations, efforts focused on NP (local NGOs and the Wildlife Conservation Society, WCS: huemul project 1998–present), determining habitat availability and selection and developing predictive models of potential habitat based on signs. RDP defined huemul research priorities for NP (Ramilo 2003) as determining (a) habitat size and location for rearing young, (b) habitat for summer/winter maintenance, (c) unused areas (transit), (d) factors affecting fecundity and mortality, (e) abundance trends, and (f) interactions with red deer, livestock, puma (Puma concolor), and tourism. However, no such research has been conducted so far, and no projects address issues important to small population size or with respect to factors preventing recovery.

Proposed research needs

Methodological considerations

RDP does not have research programs, but determines research needs (Ramilo 2003). For huemul, only specific methods are allowed. Such rigidity impedes progress (Sutinen et al. 2004). For instance, for habitat and monitoring studies, researchers are obliged to use unified methods to supposedly facilitate comparisons. However, different results from applying one method would likely be interpreted as real differences, when actually it was due to personnel, especially if members change constantly as through volunteering (Sutherland 2000; Johnson 2002). Another insistency concerns applying only indirect methods—inaccurately claimed to be consented by all stakeholders in huemul conservation (Proc. 4th binational reunion on huemul conservation). Limiting trend evaluations of tiny populations to only fecal surveys is unwarranted and ignores the enormity of this task at the required precision. Given low density, remoteness, environmental variability, change of sites by huemul (Ortega et al. 2003), personnel variability to 35%, and dependence of fecal counts on population sex and age structure (Smart et al. 2004), to name a few, other methods are superior. We suggest that traditional fecal surveys will not provide the required accuracy and precision to monitor trends for most remaining subpopulations.

Habitat studies

Current habitat selection may be different from that prior to European colonization, due to abnormal density, sex or age ratios; that is, subpopulations may be disorganized sociobiologically (Bubenik 1982). Huemul now occur possibly in marginal or sink areas (Flueck 2003). Current habitat choice is sometimes erroneously used as a surrogate for survival and reproductive success, which is likely no longer true (Battin 2004). It is a fallacy to claim currently inhabited areas as optimal areas because huemul today may be displaced into peripheral areas by human activity, where their habitat requirements can hardly be realized. High-elevation Andes likely do not represent the core of huemul distribution, rather two cores exist: one each in Chile and Argentina at mid to low elevations. Contractions of huemul range were thus towards peripheral habitat and driven by anthropogenic extinction forces (Channell and Lomolino 2000). Other endangered species have likewise been driven into refuges shown afterwards to be marginal (Craig 1994; Caughley 1994). Nutritional constraints for current low-density huemul appear improbable (except winter range inaccessibility, see Flueck 2003), considering equivalent habitats support high densities of exotic herbivores. Past distributions predict existence of ecotypes and adaptive feeding behavior, as corroborated by diet studies (Flueck 2003; Smith-Flueck 2003). Annual variations in habitat variables preclude defining static requirements and explain site use changes (Ortega et al. 2003; Osko et al. 2004). Consequently, research within PA should be directed at obtaining confident population parameters (reproductive rates, recruitment, survival, mortality causes, trends) rather than habitat studies. Studies on spatiotemporal movements are essential to determine source-sink dynamics and discover reasons for lack of recolonization.

Need for direct methods

Huemul captures using net gunning as best available method in remote areas are currently not possible because RDP considers helicopter and huemul to be incompatible. Although aerial surveys of eight *nonprotected* subpopulations were initially accepted, with government observers already assigned, they were unexpectedly denied without explanations; these would have been the first systematic estimates in Argentina. Helicopter censuses have been permitted with other endangered Argentine cervids like *Ozotoceros bezoarticus*, for which helicopter net gunning was proposed as the best capture method. Whereas one-time census flights in areas *outside* of NP was unacceptable to RDP, commercial use of helicopter for mining exploration, tourism, as well as private use, is commonly practiced there (Moyano 2004).

Reasons for establishing a huemul conservation center in Argentina

IUCN (1987) emphasized that (a) vulnerability of small populations is consistently underestimated (see Wharton 1995); (b) timely recognition is critical and depends on valid information on population status; and (c) to reduce extinction risk, supportive centers should be established when wild populations still count thousands of individuals. In 2001, IUCN declared huemul to be at "very high risk of extinction." This was justified by all subpopulations having <250 individuals and with <2,500 total mature individuals in decline (category C2a). Furthermore, reported densities indicate that the actual extent of occurrence is <5,000 km^2, with severe fragmentation and declining tendency, justifying even applying category B1a. Captive huemul provide research opportunities that would now be difficult or impossible with wild populations. Accordingly, IUCN (2002) recommended explicitly that ex situ programs foster research on questions relevant for in situ conservation.

In Argentina, RDP currently considers a conservation center as irrelevant (Ramilo 2001), although the available scientific information justifies this supportive tool. Yet as late as in 1971, the Argentine government launched the 'Operativo Nacional Huemul,' trying to establish a center to avoid extinction (Díaz and Smith-Flueck 2000), though these plans were never realized.

A center's main objectives would include conservation biology and education, as well as fund raising. Scientific data are fundamental for (1) diagnosing in situ problems, (2) decision making, (3) mitigating negative impacts on huemul and its habitat, and (4) evaluating conservation actions through monitoring. While limited data exist on basic life history strategies, data on variability of parameters important to conservation efforts are completely lacking (Table 1). Only *twice* have neonates been observed, and 11 parturition dates were based on fawns roughly aged at 1–6 weeks (Smith-Flueck 2003). Currently, huemul cannot be judged regarding normal ranges of basic anatomical, morphological, physiological, biochemical, and genetic parameters (Díaz and Smith-Flueck 2000). Limited or no baseline data exist to determine if individuals or populations are performing adequately, whether huemul are highly susceptible to bovine disease, as was assumed (E. Ramilo, cited in Wemmer 1998), and whether *Cysticercus tenuicollis* causes death (Simonetti 1995). While several unknowns can be addressed directly on semicaptive deer, other important questions (Table 2) can be studied through reintroductions (Riney 1967; IUCN 2001b), such as to whether current distribution and habitat use by huemul are artifacts of recent changes.

Due to past equivocal results and continuous loss of opportunities, it is highly advisable to professionally design the next center, as soon as possible, supported by long-term financial commitments so as not to curtail success and future attempts by others (IUCN 2002). Also, funds for ex situ programs are frequently available for complementary parallel in situ studies (Wharton 1995).

Establishing and running a financed center with parallel field research in Argentina (Smith-Flueck and Flueck 2001c) was considered unnecessary (Ramilo 2001). In contrast, Chile, with many more huemul, recognized the need and had already proposed a center in 1989 (CONAF, Proposal to San Diego Zoological Society). Recently, they established a huemul center (SAG permit 1535, April 2005) with the main purpose to restock the surrounding reserve. It is highly unlikely that Argentina will benefit, as surplus animals will be used for reintroductions and public education in Chile.

Modern techniques to manipulate huemul

Critical features of future studies, centers, or reintroductions should include capture, transport, handling, and management. Guidelines recommend mechanical over chemical restraint (Jessup et al. 1996). For flighty cervids, modern methods—by considering behavior, biology, nutrition, and environment—reduce risks of exertional myopathy (Kreeger 1999).

Capture methods for huemul include trapping, chemical immobilization, or net gunning. We have used clover and panel traps, drive nets, drop and cannon nets, and drive traps to capture cervids in USA and Patagonia (1983–1994). Baiting in Patagonia did not work during vegetative periods due to surplus natural forage. Access in winter was difficult, unselective traps captured omnipresent livestock, and monitoring twice a day and readiness of capture teams were costly. Drive netting in typical huemul habitat was only possible by helicopter, and permanent drive traps are costly and impractical given the low density of huemul.

Large darts are disadvantageous, but unavoidable with drugs like xylazine/ketamine, even after concentrating by lyophilizing. The recently introduced thiafentanil allows the use of small darts and enables highly effective reversal. Thiafentanil, with faster induction time than medetomidine/ketamine, even working in hyperexcited animals, can therefore be recommended as one of the best options for immobilizing huemul (Kreeger 1999). Low densities, close approach, small targets, deer disappearing in vegetation during induction, and required time and personnel make darting a challenging and risky method and should only be attempted by experienced personnel.

Table 1 Unknown or assumed traits of huemul to study in a conservation center

Trait	Published parameters	Source
Age at first conception	As fawn; at 3 or 4 years	Díaz and Smith-Flueck 2000; Serret 2001
Gestation period	200–220 days	Díaz and Smith-Flueck 2000
Parturition dates	October–January	Diaz and Smith-Flueck 2000
Weight at birth	Up to 3.5 kg; 5 kg	Flueck and Smith-Flueck 2005
Weaning	At 4 months	Diaz and Smith-Flueck 2000
Growth pattern for both sexes	?	
Morphometry by sex and age	?	Reviewed in Diaz and Smith-Flueck 2000
Maximum/mean life expectancy	?	
Life time reproductive success	?	
Social behavior	Territoriality?	Serret 2001
Scent glands (anatomy, function)	?	Reviewed in Diaz and Smith-Flueck 2000
Biological parameters and variability[a]	?	
Defecation rate (sex, age, season, feed)	?	
Mineral metabolism and requirements	?	
Annual biological cycle of both sexes	?	
Nutritional requirements	Which habitat types allow reproduction?	

[a]Physiology, clinical biochemistry, hematology, endocrinology, immunology, hormones, phermones, genetics, pathology, parasitology

Table 2 Questions about huemul which can be studied through reintroduction or reinforcement with radio-collared animals

Population dynamics	Rates of survival, fecundity, recruitment; causes of mortality; population trends, etc.
Dispersal behavior	Source-sink and metapopulation dynamics; types of barrier; migrations; corridors, etc.
Physiological ecology	How adaptable are huemul in relation to habitat types, disturbances, etc.
Behavioral ecology	Responses to livestock, alien species, tourism, roads, etc.
Genetic variation	How is it reflected in persistence or growth of a population?
Reproductive biology	Life-time reproductive success of wild females; Allee effect
Habitat use	Seasonal changes, year-to-year variation; in relation to density, sex, reproductive status
Predation	Effect of natural and alien predators; poaching
Population estimates	Ratio of marked to unmarked individuals; calibration with indirect methods
Natural history	Details often reveal factors behind a decline or recovery, especially if evaluating and comparing several sites (Sutherland 2000)

Mortality rates of 17–23% have occurred with cervids, and nearly 50% were from dart trauma (Bates et al. 1985). Capturing several huemul dispersed over a large remote area will make darting very costly and will require much manpower.

Helicopter captures

Helicopter captures are most appropriate where huemul are widely dispersed and in difficult terrain. Helicopter darting has been replaced by net gunning due to reduced trauma, distress, morbidity, mortality, and costs (Jessup et al. 1988). It permits (a) no drug-related side effects, (b) collection of chemically unaffected tissues, (c) capture of whole social groups, (d) capture in difficult areas, (e) capturing over large areas and all day, and (f) reducing costs per animal. As group sizes average about 2–3 (Díaz and Smith-Flueck 2000), capture of these can readily be accomplished. Net gunning resulted in 6.68% mortality in stress-prone *Ovis canadensis* (n=306) and 1.96% in several other ungulates (n=2598; L.H. Carpenter 1996. Survey of post-capture mortalities. Helicopter Wildlife Management, Utah, unpublished). Net gunning was the safest and least distressful of five methods and 56% less risky than darting (Kock et al. 1987; Jessup et al. 1988): it was used successfully in Patagonia (Fig. 2) to mark red deer dispersed over 130 km^2 of former huemul habitat (Flueck et al. 2005).

Huemul and helicopter

While net gunning huemul in Argentina is currently hampered because of concerns related to disturbance, darting from the ground has been used for a WCS project (Parera 2002). Aircrafts including helicopters have been employed on cervids since the 1940s, and reactions towards noise are well known. Cervid hearing differs completely from humans, who hear better at <8 kHz, whereas cervids hear better at >8–10 kHz (Krausman et al. 2004). Machinery noises usually produce low frequencies: aircrafts typically <2 kHz. Consequently, these sounds are perceived 63 times stronger by men vs ungulates (Krausman et al. 2004). To compare, noise at a busy Buenos Aires intersection was 101 dB (Río Negro, Argentina, 19/11/2001:11). Helicopters producing 100 dB to humans represents about 80 dB to cervids, equivalent to lorries passing people at 30 m and 60 km/h. Krausman's group concluded that low-level flights have little consequences for ungulates, even in NP. In contrast, Chile, where huemul helicopter census is valued for their great utility (SAG, letter 12.3.2003), proposed huemul helicopter captures 17 years ago, and in April 2005, they caught and transported huemul over 1,500 km by helicopters, without mortalities (Saucedo,

Fig. 2 Net gunning of red deer in habitat used by huemul only decades earlier

personal communication). Also in Chile, huemul did not leave areas subjected to prolonged, intensive, and repeated low-flying helicopters for logging.

Transportation, restocking, reintroduction, husbandry, and research opportunities

Modern handling methods can minimize distress in captured wild cervids (Jessup et al. 1996). Huemul have been transported over large distances as exemplified by successful translocation to NZ and Europe, and recently by helicopter within Chile. Capturing whole social groups, as feasible by net gunning, substantially reduces distress during translocation and release. All huemul should be radio-collared and closely monitored during the initial weeks after release.

Assuring well-being of captive huemul requires natural environments with minimal human interference. Centers should be exclusively used for huemul, be located within the natural habitat of the species, and provide semicaptive environments with natural forage by having pens up to 50 ha (Smith-Flueck et al. 2004). This optimizes research variety and quality by minimizing human contact and providing natural stimuli. It requires double fencing 2.7 m high, electric fencing, barbed external wire, and buried fencing to keep out puma and dogs. Details regarding genetic, demographic, behavioral, and disease issues and other recommendations about facility design, husbandry, and research topics were elaborated in Smith-Flueck et al. (2004).

Natural tameness facilitates huemul husbandry (Franke 1949; Rottmann 2003; Smith-Flueck et al. 2004). The first huemul received by Franke, student of Konrad Lorenz and caretaker of a zoological station in Nahuel Huapi NP, was tied hours in the rain with myriad dog bite wounds and transported several hours by truck and boat. Franke brought the soaked female inside and placed her in a box containing hay next to the fire. During the night, she jumped into his bed and remained there. A few days later, she accompanied him, and his great Dane dog on a stroll (Franke 1949). Taruca (*H. antisensis*) also adapted well to man's presence. For many years in a Berlin Zoo enclosure of 100 m^2, they were exposed to constant visitors, yet still reproduced regularly (Frädrich 1978). They were one of the easiest cervids to keep at the zoo (Frädrich, personal communication).

Even when >1,500 km from natural habitat, huemul adapted well to feed provided at the Buenos Aires Zoo. Several births occurred in the Dehesa Zoo, in Puerto Radal, in southern Argentina, and possibly in the Buenos Aires Zoo (Smith-Flueck et al. 2004). The only contemporary person having worked with captive huemul found no indication that captive conditions would impair huemul husbandry (Rottmann 2003).

Concerns about manipulating huemul in the light of history

Inappropriate captures and transports, inadequate management after confinement, and lack of attention to diseases were the main reasons for failed past attempts to breed huemul in captivity. Huemul, chased by dogs for hours or long distances until cornered, exhibited dog bites, fractured legs, lesions, and trauma from brutalities (Díaz 2002) and often died within hours or days after being captured (Franke 1949). In 1932, Holmberg acclimated 16 huemul to individual crates to be transported from the Andes to Buenos Aires. Adverse climatic conditions resulted in deer being taken out and hoisted into the ship against instructions; all animals died from "nervous shock" (Smith-Flueck et al. 2004). In 1937, a male arrived at Puerto Radal with a fractured hind leg and died from internal hemorrhages (Franke 1949). In 1941, two huemul, lassoed for the Santiago Zoo, received fatal dog wounds (Díaz 2002). Then in 1973, a male died from injuries and three others died soon after arriving to Dawson Island, having lost >50% of their weight; it was speculated that declined physical conditions were aggravated by small pen sizes and low variety of food (Smith-Flueck et al. 2004).

These past failures resulted in current conjectures in Argentina that manipulating huemul is too risky (Ramilo 2001). Nonetheless, numerous successes occurred, which surprisingly have been overlooked. Possibly the first huemul arrived at the London Zoo (1830) and died 6 months later. Three huemul were translocated to NZ in 1870. Then, in 1881, the London Zoo obtained, from the Paris Jardín de Aclimatación, a male who survived capture and transport by ship to France and then to England, aside from all terrestrial transports (Smith-Flueck et al. 2004). The Buenos Aires Zoo captured a male and two females in 1936 and tamed them before transportation across several hundred kilometers of dirt road and by sea to Buenos Aires. They adapted rapidly to small pens and human presence (Fig. 3), and only recently discovered by Díaz (2002), some animals were still present in 1942. The zoo collector also had maintained huemul on his property where they reproduced successfully (Díaz and Smith-Flueck 2000). Puerto Radal began operating in 1936 with Franke, whose meticulous notes, compiled over several years, were unfortunately lost, leaving only his book documenting tameness, births, and husbandry conditions (Fig. 4; Franke 1949). It terminated because all huemul were accidentally released during Franke's absence in 1941. Between 1942 and 1952, new individuals arrived including a female that gave birth and a male that survived 4 years, but the program closed in 1956 for lack of funds (Smith-Flueck et al. 2004).

In Chile, huemul were brought to Dehesa Zoo in 1979: two males survived, three females were added in 1982, and three birth were recorded (Smith-Flueck et al. 2004). Huemul kept there in large pens during 10 years had no difficulties with the diet (Iriarte, personal communication).

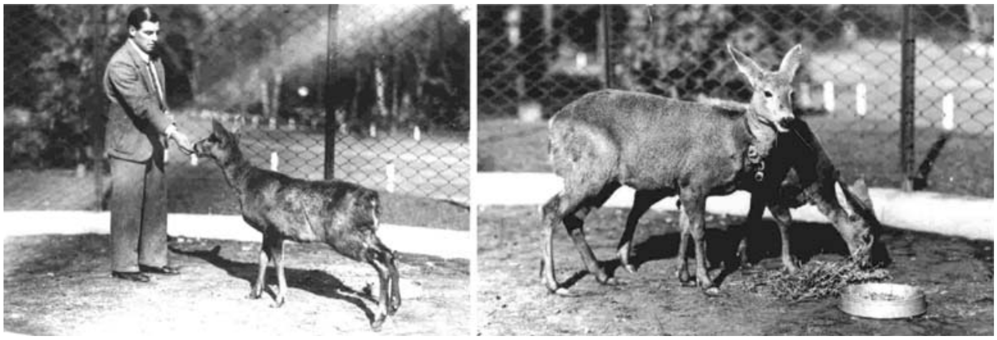

Fig. 3 Huemul lived in the Buenos Aires Zoo at least from 1936 to 1942 where they adapted well (Díaz 2002; photos courtesy of the Editorial Atlántida, Buenos Aires)

Eight huemul were reintroduced between 1977 and 1981 to Torres del Paine NP, Chile (Rau 2003). In 1989, a Chilean proposal to capture 60 additional huemul using helicopter (CONAF, Proposal to San Diego Zoological Society) to stock a center for repopulating this park never materialized. Fortunately, the population has increased regardless (Rau 2003).

Taruca came to the Berlin Zoo in 1889, surviving for 3.5 years. In 1891, a female arrived at the Hamburg Zoo, and in 1929, a male arrived at the Hagenbeck Zoo (Frädrich 1978). The Berlin Zoo was most successful where one taruca pair resulted in 12 offspring born following their 1931 arrival, and a male lived 11 years before the zoo was destroyed during WWII (Frädrich 1978). A female survived in the Bronx Zoo from 1938 to 1943 (Frädrich 1978). A male currently in a Zoo in Lima, Peru, lives on commercial cattle feed, alfalfa hay, and carrots.

We like to emphasize that stress is an inevitable side effect of manipulation of wild animals. However, "stress" is only of relevance if excessive (called distress), when it negatively affects survival or fecundity (Gill et al. 2001).

Future challenges for huemul conservation in Argentina

Aerial censuses of eight nonprotected subpopulations, which were proposed by the authors, were denied by the responsible authorities before a formal proposal could be submitted. Subsequently, we secured private financing to unite nearly 70 participants for the national recovery workshop (2001), including experts from the USA, three representatives of WCS, and Chileans who had elaborated their recovery plan shortly before. The meeting was sponsored by Bodega Norton, Turner Endangered Species Fund,

Fig. 4 Huemul in Puerto Radal, Nahuel Huapi National Park, 1936–1941 (Franke 1949; photos courtesy of H. Franke-Giron)

IUCN SSC, Earth Restoration Alliance, and Island Foundation (www.iibce.edu.uy/citogenetica/deer). In our presentation, we outlined a conservation center for semicaptive huemul, based on existing long-term financial commitments by international NGOs, allowing application of modern methods (Smith-Flueck and Flueck 2001c). Surveys of eight nonprotected subpopulations again formed the basis of the planned study that included placement of four GPS- and two VHF-radios per site. The proposal, although a first public presentation, was considered irrelevant for discussion during the recovery plan elaboration by an organized opposition, which included representatives of WCS, who had been provided previously with the official position of RDP that huemul in semicaptivity are unnecessary (Ramilo 2001). Yet the resulting plan concluded (2001) that the actual huemul situation demands major improvement in amount and quality of information within a few years, to avoid risks of gradually losing many subpopulations. Per agreement, signed by all stakeholders, volunteers prepared the draft plan, but contrary to this agreement, no scientific commission was established afterwards to review drafts before delivery to government authorities, and no consideration was given for public review. No budget exists, external funding is assumed, and hence, implementation is speculative. Initial recommendations towards huemul conservation (APN, Proc. First Huemul Conf., 1992) were reiterated in subsequent workshops (1995, 1998, 2002), but most recommendations were not accomplished. These were therefore again incorporated into the recovery plan (Table 3). If the goal is recovery, measures should be applied to most subpopulations, yet two of three provinces with huemul still have not approved the plan. Lack of funds prevented implementing the plan thus far (IUCN SSC, quadrennial report, 2005). Unfortunately, recommendations from the Chilean recovery plan were not considered, and the need for an Argentine center has never been evaluated. Meanwhile, Chile recently stocked its first private center with huemul brought from nonprotected areas and considered the situation critical enough that its National Science Council is supporting the cloning of huemul using red deer as surrogate mothers (www.conicyt.cl).

Prevailing reluctance also relates to procuring founders. RDP claimed that knowledge on Argentine huemul indicates that efforts should be in situ; furthermore, a donating subpopulation would first have to be found, unlike Chile, which has a potential donor population (Ramilo 2001). However, our outline, in accordance with IUCN policy (2002), recommended that captured animals represent as much genetic variability as possible. Thus, the approach was to census eight potential donor subpopulations and evaluate if one social group (2–3 animals) per site could be captured subsequently, and together form the initial stock. Wharton (1995) concluded that removal of few animals has virtually no impact even for threatened populations. Insisting that founders must come from one sole subpopulation is unwise, considering that subpopulations had been very reduced, isolated, and likely genetically affected. Ironically, the assertion by RDP that no sole population is in a condition to risk removal of several members only further emphasizes the critical status of the Argentine huemul.

Conclusions

One challenge to establish a comprehensive conservation center had been overcome: long-term financial commitments allowing modern approaches. However, important obstacles were the lack of consensus regarding necessity and feasibility to use this conservation tool, and a

Table 3 Chilean–Argentine workshops (1992, 1995, 1998) and the Argentine draft recovery plan of 2001: biologically and ecologically relevant studies urged to be priorities, and analysis in subsequent meetings as to having made advances in these issues in Argentina

Issue	1992	1995		1998		2001	
	Urged	Advances	Urged	Advances	Urged	Advances	Urged
Population							
Density	Yes	No	Yes	No	Yes	No	Yes
Population tendency	Yes	No	Yes	No	Yes	No	Yes
Sex and age structure	Yes	No	Yes	No		No	Yes
Group composition	Yes	No		No		No	Yes
Health and nutritional status	Yes	No	Yes	No		No	Yes
Seasonal habitat use	Yes	No		No		No	Yes
Reproduction	Yes	No	Yes	No	Yes	No	Yes
Predation	Yes	No	Yes	No	Yes	No	Yes
Determine factors causing declines	Yes	No		No		No	Yes
Interaction with alien species	Yes	No	Yes	No		No	Yes
Control spread of red deer	Yes	No	Yes	No	Yes	No	Yes
Interaction with tourism, forestry, livestock	Yes	No	Yes	No	Yes	No	Yes
Protected areas							
Provide personnel, infrastructure	Yes	No	Yes	No	Yes	No	Yes
Prepare management plan	Yes	No	Yes	No	Yes	No	Yes
Increase control of areas, hunting	Yes	No		No	Yes	No	Yes

controversy centered around different views of what constitutes recovery. Judging the predicament of Argentine huemul differs fundamentally. Are the 350–600 huemul, fragmented into several dozen subpopulations, viable and will they remain so? Will the roughly 220 huemul living in nearly 23,000 km^2 of NP guarantee survival of the species? Is the claimed low level of urgency an expression of excess confidence due to ignoring uncertainties? Reed et al. (2003) calculated mean minimum viable population size to be 7,316 adults in order to last 40 generations. We are not aware of any data showing that current conditions of huemul groups could be considered viable. Also, recovery implies ecologically effective densities rather than only viability (Soulé et al. 2003).

One can postulate that measures, if applied as up to now, will also be sufficient for recovery—the current dogmatic policy of the RDP (Ramilo 2001). Serious problems discerned for Argentine cervids include absence of studies and management plans (Dellafiore and Maceira 1998), and considering economics and politics, chronic financial constraints are likely to continue. Postponing a center likely hinders timely advances in knowledge and thus development of efficient conservation plans. NP with similar sizes have lost >27% of large mammals since establishment, and small initial population size was the most critical determinant of extinction (O'Grady et al. 2004). Likewise, Chilean PA have not prevented that >50% of vertebrate populations are now endangered, and 55% of PA are too small to allow viable large mammal populations. Huemul possibly will follow extinction patterns of wild sheep (Berger 1990), and without confident knowledge on factors preventing recovery, conservation efforts might simply amount to documenting the loss of further subpopulations.

Different views about huemul conservation are worthwhile and need to be discussed. RDP determines research needs, authorizes projects, but effectively prevents others from determining scientific needs and priority setting. For instance, scientists working in NP cannot obtain permits from RDP (Martin 2003) to collect unanticipated wildlife remains having scientific value, on the grounds that it impedes hypothetical future studies on such remains. Although remains could persist for years, incidental encounters may provide invaluable information which is lost if not collected. Most remains, however, even bones, disappear rapidly (Cook et al. 2004). Thus, endangered huemul can only be studied through RDP-approved projects, and incidental finds and observations are valueless because they cannot be collected.

Unresolved issues were published by editors of binational conference proceedings as "consented" conclusions and recommended to be incorporated in binational treaties without reevaluations by participants. Yet, monopolizing important issues will likely not be beneficial to huemul recovery. Errors translated into official policy are cardinal under the likelihood that no funds for adequate monitoring will be available to detect consequences in appropriate time. Scientific input in recovery plans has major positive effects on success (Boersma et al. 2001), and guidelines, even federal laws (Sutinen et al. 2004), are available on current standards for science-based conservation planning, emphasizing involvement of qualified scientists during all phases, rigorous replicable methodology, repetition of studies by different groups, use of best scientific information available, acknowledgment of critiques and alternative points of view, transparency, full public access and participation, and peer review. The assertion that Argentine huemul status is not critical enough to justify the implementation of modern tools like aerial surveys or ex situ programs, that there are ample subpopulations with good conservation status, and that current in situ efforts are sufficient to guarantee long-term survival (Ramilo 2001) is subject to serious doubts. This review indicates that sufficient grounds exist to consider the status of Argentine huemul highly precarious.

In 1936, Argentine NP created Puerto Radal station to rear huemul for repopulating park areas already devoid of deer. In 1971, the 'Operativo Nacional Huemul' was launched to prevent huemul from extinction. Institutions included NP Administration, National Directory for Renewable Natural Resources, Argentine Scientific Society, Institute of Continental Ice, Buenos Aires Zoo, National Border Police, Museum of Natural Sciences, Nature Association, and Argentine Mountain Federation. Objectives were to capture and breed huemul and repopulate NP areas. For unknown reasons, this program never materialized. The indications are that today, the situation is much worse. Taking this into account, the *precautionary principle* would not allow waiting until more subpopuations are lost before more active strategies are considered warranted again.

Acknowledgements We thank colleagues from the following institutions whose insights have shaped our views: Center of Reproduction of Endangered Species in San Diego, Wildlife Pharmaceuticals, Turner Endangered Species Foundation, and the Eyes of the Wild Foundation. We thank the Wildlife Conservation Society, the Lincoln Park Zoo, the World Nature Association, but especially G. Langes, the Club Mil Rosas and Bodega Norton for supporting research on huemul. Bodega Norton also covered costs of the Argentine national recovery plan workshop, permitting that all stakeholder could unite. L.H. Carpenter kindly provided information on capture success. N.I. Díaz, G. Bubenik, U. Kierdorf, J. Marshall, A. Povilitis, S. Ranney, Dan Wharton, and several anonymous reviewers provided many challenging suggestions. We like to dedicate this work to the late Victor Arrechea, formerly superintendent of the Nahuel Huapi National Park, for his foresight to organize the National Recovery workshop for huemul.

References

Administración de Parques Nacionales, Argentina (1992) Primera Reunión binacional Argentino-Chilena sobre estrategias de conservación del huemul, Bariloche, Argentina

Administración de Parques Nacionales, Argentina (2004) La Naturaleza sigue sorprendiendonos. Rev South Winds 64:17

Bates JW, Bates JW, Guymon JG (1985) Comparison of drive nets and darting for capture of desert bighorn sheep. Wildl Soc Bull 13:73–76

Battin J (2004) When good animals love bad habitats: ecological traps and the conservation of animal populations. Conserv Biol 18:1482–1491

Berger J (1990) Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conserv Biol 4:91–98

Boersma PD, Kareiva P, Fagan WF, Clark JA et al (2001) How good are endangered species recovery plans? Bioscience 51:643–649

Braun P (2002) El secreto mejor guardado. Aventura (Argent) 4:21

Bubenik AB (1982) Physiology. In: Ward Thomas J, Toweill DE (eds) Elk of North America. Stackpole Books, Harrisburg, pp 125–179

Caughley G (1994) Directions in conservation biology. J Anim Ecol 63:215–244

Channell R, Lomolino MV (2000) Dynamics biogeography and conservation of endangered species. Nature 403:84–86

Cook WE, Williams ES, Dubay SA (2004) Disappearance of bovine fetuses in Northwestern Wyoming. Wildl Soc Bull 32:254–259

Craig JL (1994) Meta-populations: is management as flexible as nature? In: Olney PS, Mace GM, Feistner AC (eds) Creative conservation. Interactive management of wild and captive animals. Chapman & Hall, London, pp 50–66

Dellafiore C, Maceira N (1998) Problemas de conservación de los ciervos autóctonos de la Argentina. J Neotrop Mamm (Arg) 5:137–145

Díaz NI (2002) Experiencias Históricas en la Conservación del Género *Hippocamelus*. In: Cosse M, Paz Barreto D, Gonzalez S (eds) Actas del Taller: Hacia un Plan Nacional de Conservación y Recuperación del Huemul en Argentina. IUCN Deer Specialist Group, Montevideo

Díaz NI, Smith-Flueck JM (2000) The Patagonian huemul. A mysterious deer on the brink of extinction. Literature of Latin America, Buenos Aires, p 149

Flueck WT (2003) Consideraciones acerca de la calidad nutritiva de hábitat, hábitat óptimo, y evaluación de hábitat para huemul. In: Acosta G (ed) 4ta reunión Chileno-Argentina sobre estrategias de conservación del huemul. CONAF and CODEFF, Chile, pp 30–34

Flueck WT, Jones A (2005) Potential existence of a sylvatic cycle of *Taenia ovis krabbei* in Patagonia, Argentina. Vet Parasitol 127 (in press)

Flueck WT, Smith-Flueck JM (2005) Hoof growth in neonatal Patagonian huemul (*Hippocamelus bisulcus*), a tentative tool for aging. J Neotrop Mammal 12 (in press)

Flueck WT, Smith-Flueck JM, Naumann CM (2003) The current distribution of red deer (*Cervus elaphus*) in Southern Latin America. Eur J Wildl Res 49:112–119

Flueck WT, Smith-Flueck JM, Bonino NA (2005) Adult mortality among red deer in the northwestern Patagonia: a preliminary analysis. Ecol Austral 15:23–30

Frädrich H (1978) Bemerkungen über Nord-Andenhirsche (*Hippocamelus antisensis*) im Berliner Zoo. Bongo (Berl) 2:81–88

Franke FR (1949) Mein Inselparadies. Verlag A, Francke AG, Bern, Switzerland, p 181

Gill JA, Norris K, Sutherland WJ (2001) Why behavioral responses may not reflect the population consequences of human disturbance. Biol Conserv 97:265–268

IUCN (1987) The IUCN policy statement on captive breeding. IUCN, Gland

IUCN (2001a) IUCN policy statement on research involving species at risk of extinction. IUCN, Gland

IUCN (2001b) IUCN/SSC guidelines for re-introductions. IUCN, Gland

IUCN (2002) IUCN technical guidelines on the management of ex-situ populations for conservation. IUCN, Gland

Jessup DA, Clark RK, Weaver RA, Kock MD (1988) The safety and cost-effectiveness of net-gun capture of desert bighorn sheep (*Ovis canadensis nelsoni*). J Zoo Anim Med 19:208–213

Jessup DA, Jones K, Clark W, Hunter D (1996) Wildlife restraint handbook. State of California Department of Fish and Game. Wildl Invest Lab, p 238

Johnson DH (2002) The importance of replication in wildlife research. J Wildl Manage 66:919–932

Kock MD, Jessup DA, Clark RK, Franti CE et al (1987) Capture methods in five subspecies of free-ranging Bighorn sheep: an evaluation of drop-net, drive-net, chemical immobilization and the net-gun. J Wildl Dis 23:634–640

Krausman PR, Harris LK, Blasch CL, Koenen KK et al (2004) Effects of military operations on behavior and hearing of endangered Sonoran pronghorns. Wildl Monogr 157:1–41

Kreeger TJ (1999) Handbook of wildlife chemical immobilization, 3rd edn. Wildlife Pharmaceuticals, Fort Collins, p 342

Laliberte AS, Ripple WJ (2004) Range contractions of North American carnivores and ungulates. Bioscience 54:123–138

Martin C (2003) Note 214-03 of the Delegación Regional Patagonia. Administración de Parques Nacionales, Argentina

Martin CE, Chehebar C (2001) The national parks of Argentinian Patagonia—management policies for conservation, public use, rural settlements, and indigenous communities. J R Soc NZ 31:845–864

Moyano A (2004) El heliesqui amplía la frontera de las sensaciones. Neo Magazíne (Arg) 3:14–19

O'Grady JJ, Reed DH, Brook BW, Frankham R (2004) What are the best correlates of predicted extinction risk? Conserv Biol 118:513–520

Ortega IM, Guineo O, Garay G (2003) Estatus y comportamiento del huemul del parque nacional Torres del Paine. In: Acosta G (ed) 4ta reunión Chileno-Argentina sobre estrategias de conservación del huemul, CONAF and CODEFF, Chile, p 69

Osko TJ, Hiltz MN, Hudson RJ, Wasel SM (2004) Moose habitat preferences in response to changing availability. J Wildl Manage 68:576–584

Parera A (2002) Cara a cara con el huemul. Vida Silv (Arg) 80:12–15

Pimm SL, Bass OL (2002) Rangewide risks to large populations: the Cape Sable sparrow as a case history. In: Beissinger SR, McCullough DR (eds) Population viability analysis. University of Chicago Press, Chicago, pp 406–424

Povilitis A (2002) Current status of the huemul (*Hippocamelus bisulcus*) in central Chile. Gayana (Chile) 66:59–68

Ramilo E (2001) Cría en cautiverio del huemul, consideraciones generales. Delegación Regional Patagonia. Administración de Parques Nacionales, Argentina, p 2

Ramilo E (2002) Programa conservación del huemul de la administración de parques Nacionales. In: Cosse M, Paz Barreto D, Gonzalez S (eds) Actas del Taller: Hacia un Plan Nacional de Conservación y Recuperación del Huemul en Argentina. IUCN Deer Specialist Group, Montevideo

Ramilo E (2003) Programa conservación del huemul. In: Acosta G (ed) 4ta reunión Chileno-Argentina sobre estrategias de conservación del huemul. CONAF and CODEFF, Chile, pp 19–21

Rau JA (2003) Crecimiento poblacional de huemules del sur nativos y reintroducidos en la zona austral de Chile. In: Acosta G (ed) 4ta reunión Chileno-Argentina sobre estrategias de conservación del huemul. CONAF and CODEFF, Chile, pp 43–45

Reed DH, O'Grady JJ, Brook BW, Ballou JD et al (2003) Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biol Conserv 113:23–34

Riney T (1967) Ungulate introductions as a special source of research opportunities. IUCN Publ New Ser 9:241–254

Rottmann JS (2003) Experiencias con huemules en cautividad. In: Acosta G (ed) 4ta reunión Chileno-Argentina sobre estrategias de conservación del huemul. CONAF and CODEFF, Chile, pp 40–42

Rusch V (2002) Estado de situación de las areas protegidas de la porción Argentina de la ecoregión valdiviana. Fundacion Vida Silvestre, Argentina, p 98

Sabatini MC, Iglesia RM (2001) A global context for the evolution and current status of protected areas in Argentina. Nat Areas J 21:274–281

Saenz D, Conner RN, Rudolph DC, Engstrom RT (2001) Is a "hands-off" approach appropriate for red-cockaded woodpecker conservation in twenty-first-century landscapes? Wildl Soc Bull 29:956–966

Saucedo C (2002) Investigación sobre la ecología del huemul (*Hippocamelus bisulcus*) como contribución a su conservación en el Sur de Chile. Rev Vida Silv (Arg) 80. www.vidasilvestre.org.ar

Serret A (1993) Estado de conservación del huemul (*Hippocamelus bisulcus*) en el parque Nacional Perito Moreno, provincia de Santa Cruz. Bol Técn 15, Fundacion Vida Silvestre, Argentina, p 17

Serret A (2001) El Huemul: Fantasma de la Patagonia. Zagier & Urruty, Ushuaia

Serret A, Borghiani F, Ostrosky C, Moreno D (1994) Relevamiento de poblaciones de huemules en el Parque Nacional Los Glaciares. Bol Técn 24, Fundacion Vida Silvestre, Argentina, p 21

Simberloff D, Relva MA, Nuñez, M (2003) Introduced species and management of a Nothofagus/Austrocedrus forest. Environ Manage 31:263–275

Simonetti JA (1995) Wildlife conservation outside parks is a disease-mediated task. Conserv Biol 9:454–456

Smart JC, Ward AI, White PC (2004) Monitoring woodland deer populations in the UK: an imprecise science. Mamm Rev 34:99–114

Smith-Flueck JM (2003) The ecology of huemul (*Hippocamelus bisulcus*) in Andean Patagonia of Argentina and considerations about its conservation. Doctoral thesis, Universidad Nacional del Comahue, Argentina, p 361

Smith-Flueck JM, Flueck WT (2001a) Problemas de conservación para una concentración inusual de huemules (*Hippocamelus bisulcus*) en la zona del lago La Plata, provincia de Chubut. J Neotrop Mamm 8:72–83

Smith-Flueck JM, Flueck WT (2001b) Natural mortality patterns in a population of southern Argentina huemul (*Hippocamelus bisulcus*), an endangered Andean cervid. Eur J Wildl Res 47:178–188

Smith-Flueck JM, Flueck WT (2001c) Una visión conceptual sobre la conservación del huemul en Argentina. In: Cosse M, Paz Barreto D, Gonzalez S (eds) Actas del Taller: Hacia un Plan Nacional de Conservación y Recuperación del Huemul en Argentina. IUCN Deer Specialist Group, Montevideo

Smith-Flueck JM, Diaz NI, Flueck WT (2004) Cría de huemules en cautiverio: las perspectivas actuales considerando las experiencias históricas. In: Iriarte A, Tala C, González B, Zapata B et al (eds) Cría en cautividad de fauna Chilena. SAG, Santiago, pp 459–470

Soulé ME, Estes JA, Berger J, Martinez del Rio C (2003) Ecological effectiveness: conservation goals for interactive species. Conserv Biol 17:1238–1250

Stephens RM, Alldredge AW, Phillips GE (2003) Aggressive interactions of Rocky Mountain elk, *Cervus elaphus nelsoni*, during the calving season toward Mule deer, *Odocoileus hemionus*, in Central Colorado. Can Field Nat 117:316–317

Sutherland WJ (2000) The conservation handbook: research, management and policy. Blackwell, Berlin, p 278

Sutinen, J, Boehlert G, Botsford L et al (2004) Improving the use of the “Best Scientific Information Available” standard in fisheries management. National Academy Press, Washington, DC, p 118

Sympson P (2003) Red deer in Argentina. Deer 12:358

Thompson CJ, Thompson BJ, Burgman MA (2003) Risks from competitively inferior immigrant populations: implications of mass effects for species conservation. Conserv Biol 17:901–915

Walters CJ, Holling CS (1990) Large-scale management experiments and learning by doing. Ecology 71:2060–2068

Wemmer C (1998) Deer: status survey and conservation action plan. IUCN SSC Deer Specialist Group, Gland

Wharton D (1995) Zoo breeding efforts: an ark of survival? Forum Appl Res Public Policy 10(1):92–96