# Patagonian huemul deer (*Hippocamelus bisulcus*) under captive conditions: an historical overview

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**Abstract.** Huemul (*Hippocamelus bisulcus*) is a native deer of Patagonia whose endangered status has raised concerns for several decades, and yet conservation efforts to reverse this situation have not succeeded for most populations. Captive breeding projects attempted in the past were short-lived; animals were often lost due to poor methodology or unsanitary conditions during capture, transport stresses and rudimentary husbandry, and reintroductions could not be realised. Despite inappropriate capture and transport techniques of the past, a few individuals did make it to captive centres where they managed to survive for several years, with a minimum of eight births recorded. Regardless of the successes, it is the past failures that impinge upon today's conservation efforts. In Argentina, a recent financially backed proposal – establishing a huemul breeding centre and including an *in situ* reintroduction program – was prevented by the prevailing opinion that captive breeding was neither feasible nor a necessary conservation tool for huemul. In Chile, the Huilo Huilo Foundation was able to obtain government consent and to establish the only captive breeding project in the last two decades with the main objective of reintroducing individuals in the future. Here we present some of the historical accounts to demonstrate the suitability of the species to captivity. We then describe the Chilean semi-captive breeding program (begun in 2005) including capture, transport, site selection, construction design and maintenance procedures of the two centres. The first centre has grown from an initial two adults to nine individuals. The second centre, which initially served for rehabilitation of an injured male, is awaiting arrival of some females. The success of the current program demonstrates that huemul can do well in captivity, and wherever considered beneficial, could serve as a significant conservation tool for the recovery of the species, inclusive of a research program and reintroductions to qualified sites.

**Additional keywords:** captive breeding, conservation, *ex-situ*.

## Introduction

During the 1990 International Deer Biology Congress (IDBC), a workshop was held by Jacobsen and English on endangered cervids.[1] The concern was that of the 39 endangered deer species in the world, many had inadequate captive populations. South American cervids were considered the most vulnerable. Captive studies on reproductive biology and physiology were suggested as a priority for endangered species such as the Patagonian huemul (*Hippocamelus bisulcus*). The consensus was reached that the outlook for management of endangered deer worldwide was not encouraging. The pressures that cause extinction, principally habitat loss, poaching and other human disturbances are not likely to change in the near future; this provided the participants with a strong argument in favour of establishing captive populations as an additional conservation tool.

The policy statement of the International Union for the Conservation of Nature (IUCN) on captive breeding recommends that captive programs be a component of conservation strategies when wild populations still count thousands of individuals[2] and species are still categorised as vulnerable.[3] In the case of huemul some 1000–1500 remain; however, for the little more than 100 herds recognised, 60% amount to only 10–20 individuals each.[4] Small and isolated herds, as observed for most huemul subpopulations, run a high risk of extinction and intensive management may become necessary to assure their survival and recovery. Strategies and priorities for captive breeding programs should intend to maximise options and minimise risks, and should consider captive populations as a support, not a substitute, for wild populations. The worst-case scenario is to wait until a population is drastically reduced (Fig. 1), such as occurred

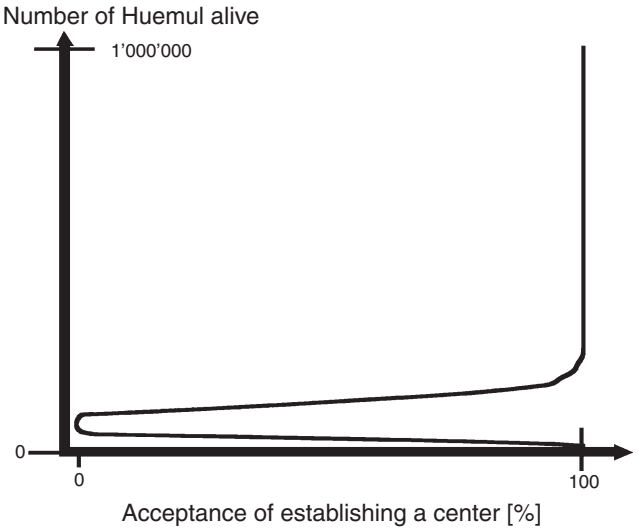



**Fig. 1.** A frequent scenario in accepting *ex situ* centres for endangered species that face political imperilment.

with the Tule elk,[5] the black-footed ferret,[6] and the California condor.[7]

Although the precarious state of huemul was recognised over eight decades ago and led to several early uses of *ex situ* methods towards recovery, these projects terminated prematurely for lack of support or other problems. More recently, attempts to re-employ *ex situ* strategies with long-term financial backing were faced with strong opposition, based on various claims: that funds are taken from *in situ* projects; that huemul cannot be raised in captivity since previous such attempts have failed; that the necessary manipulating of huemul is too risky; and, that additionally for Argentina, huemul in semi-captivity are unnecessary, that stated despite the fact that the numbers are reduced there to 350–600 animals, which are fragmented into ~60 populations.[8] Concerns about huemul being an unfit species for *ex situ* strategies and their manipulations being too risky continue to play an important role in decision making by authorities.

In this review we elaborate on historic manipulations and captivity of huemul and report on the only captive breeding program currently in existence, which began in 2005; we also present the standards adopted and the performance of the huemul in the two functioning centres in Chile [the Huemul Conservation Centre in the Huilo Huilo Reserve, and the Villarica Rehabilitation Centre in the Central Valley of Chile (Fundación Fauna Andina – Los Canelos Project)]. We also describe the procurement and transport of huemul to the first Centre, describe the facility's design, taking into account preventative measures for predation, disease and disturbance, and present management procedures practised within the enclosures. Finally we report on the performance of the two captive populations since inception of the first Centre in 2005.

## Past experiences

In the past, animals were accidently killed when poor methods were used to capture and transport them.[9] Techniques were so inadequate that in two attempts to bring animals to the Buenos Aires Zoo in the early 1900s all animals died during transport; the second attempt in 1932 involved the loss of 15 individuals (Fig. 2*a*). Four years later, one male, who was brought to a zootechnical station in the Nahuel Huapi National Park, arrived with a broken hind leg and died 2 days later from internal haemorrhages. Shortly after in 1941, an attempt to capture animals for the Santiago Zoo in Chile also ended in failure. Although an enclosure for huemul and several other species had been built in 1965 in the Neuquén province (Argentina), for several years it was impossible to find huemul in the region.[10] Eventually, a pair was brought to the facilities, but the presence of too many people resulted in one animal thrashing against the fence and dying from injuries (B. Affolter, pers. comm.). Then in November 1973, during a first intent to reintroduce huemul to Torres del Paine National Park, one of four animals brought to the Instituto de Patagonia in southern Chile died during transport due to injuries from the dogs used to capture the animals. Drouilly[11] and Texera[12] recognised the technical problems of their era and recommended improving the capture and transportation techniques to minimise stress and injuries. The following example further illustrates the problems that occurred when using the old capture methods. In 1968, there was a capture operation of Pampas deer (*Ozotoceros bezoarticus*) to bring individuals to La Carona for breeding.[13] From a population of 66 deer, 25 were captured by chasing them individually to water with a helicopter, where a man would then jump on top of them; 16 of these died before reaching the enclosure. Of the 41 remaining in the population, 13 died from stress related to the capture operation. With modern methods and experienced personnel, a mortality number in such an operation today, also using helicopters, would be no more than one or two individuals.

Additional problems in the past included a lack of both sanitary conditions and inadequate husbandry methods. Of the three animals that made it to the captive breeding centre at the Instituto de Patagonia in Chile in 1973, a female gave birth, but all individuals died within several months as a result of inadequate husbandry and diseases. Texera[12] acknowledged that huemul were confined in very reduced space with a low variety of food; the newborn fawn lived only 1 day weighing merely 2 kg when wild fawns weigh on average 6.7 kg ($n = 13$).[14] The attendants at the centre appeared to be very conscientious of the animals' health and yet they could not save them with the techniques available to them at the time. In the case of the fawn, they were giving it cow's milk instead of the special formulae used today. We can assume that they also did not know how to induce defecation and urination in the fawn, the problem most frequently encountered when people try to save fawns of any deer species found without their mothers in the wild. The mother, who did not produce milk, died shortly after at 26 kg, when adults normally weigh 70–80 kg. Texera[12] also noted the existence of other health problems, even before a sheep with coccidiosis was brought to the same enclosure. Even though Texera already concluded that the animals did not receive adequate rations, it highlights how little was known about the huemul's feeding behaviour at the time.

The subject of breeding huemul in captivity is a very sensitive issue for many Argentines and Chileans. Several past failed attempts have resulted in the opinion that handling of this

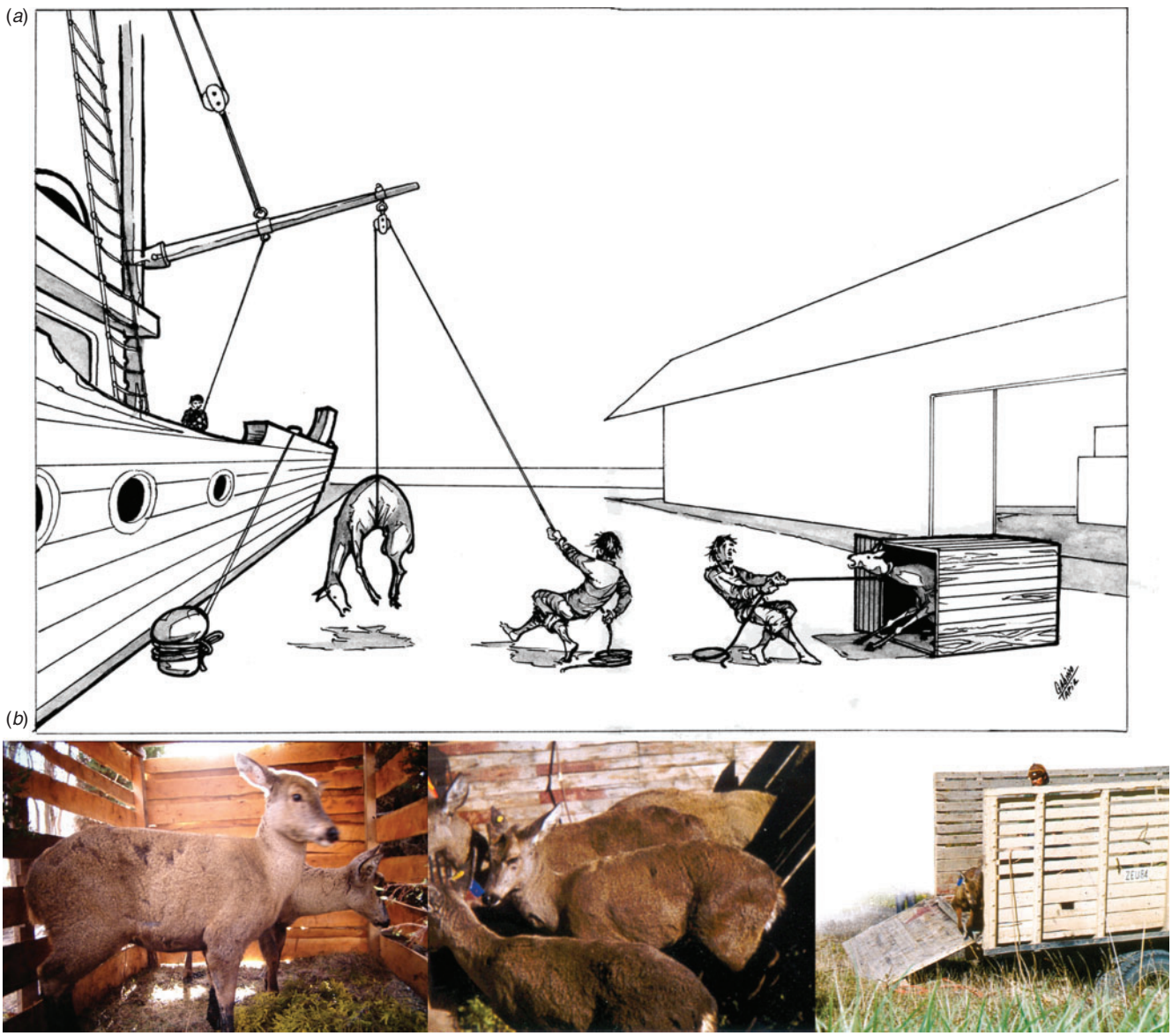



**Fig. 2.** (*a*) In 1932, Holmberg acclimated 16 huemul to individual crates and transported them several hundred kilometres from the Andes across the Patagonian plains to the Atlantic coast. Adverse climatic conditions resulted in deer being taken out and hoisted with belts into the ship against instructions; all animals died from 'nervous shock[54].' (*b*) In 1977, huemul were captured, translocated and released to repopulate Torres del Paine National Park (Chile). Photos courtesy of Gladys Garay and Oscar Guineo.[14]

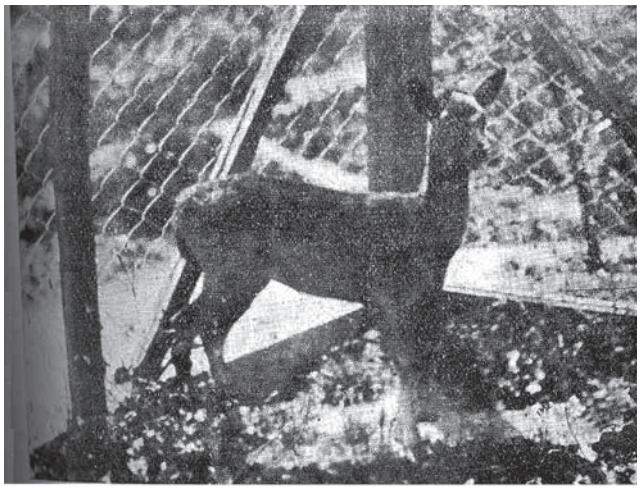
species is difficult and its survival in captivity is low. Much of this anxiety has originated from a lack of awareness of several successful historical cases of captive breeding. As early as 1830, a 'Chilean deer' was shipped as far as the Gardens of the Zoological Society of London,[15] indicating that animals were resilient enough to survive long trips across the Atlantic ocean from South America to Europe. Another record of this species at the same Gardens is that of a male brought in 1881 from the Jardin d'Acclimatation of Paris. Although no records can be found on how many years he lived in captivity,[15] this example shows an animal surviving an ocean voyage to France, and then a second trip to England. The Auckland Acclimatisation Society also succeeded in a long transport, when in 1870 they released three huemul in New Zealand.[16] One-hundred years later, several translocations to Torres del Paine National Park have resulted in several groups of huemul recolonising new areas (Fig. 2*b*);[14] although it cannot be discarded that some remnant groups from neighbouring areas might have played a role in the recolonisation. During that same era (in 1974), a young male huemul caught by a fisherman in the southern Chilean region of Aysén was brought to Peñuelas National Reserve near Valparaiso, where he lived for 2 years. Thereafter, he spent a month at the Santiago Zoo before being transported to the multi-species Dehesa Zoo, where he lived several more months.[14,17] In 1982, three female huemul caught near the coastal logging community of Tortel in the Aysén region,

were transported more than 2400 km by land, sea and air over a 2–3-day period to become part of the Dehesa Zoo breeding program.[18] All these examples support the view that huemul, just like other cervids, are able to handle the stress of translocation, which has been substantiated by the current Huilo Huilo project.

The literature and information gleaned from interviews with local inhabitants revealed several other examples of huemul in captivity. Huemul were kept in the Zoological Garden of Concepcion in Chile, which was founded in 1902 by Carlos Reed to exhibit native species (Fig. 3*a*).[19,20] Unfortunately, records could not be found on numbers of individuals, time spent in this zoo or any potential births. Also in the early 1900s, huemul were raised on at least two private properties in Argentina: one by Traful, in Neuquén province (Fig. 3*b*), and one in the Santa Cruz province owned by Santiago Radboone (collector for the Buenos Aires Zoo), where several fawns were born.[21] By 1936, the Buenos Aires Zoo finally managed to transport several huemul successfully (Fig. 4).[22] This captive population, last documented in 1942, had one female who survived there the entire 7 years.[23] Although not specifically mentioned, these individuals possibly vanished from a foot and mouth outbreak in the zoo in 1942.[24] In 1936, the Argentine National Park service had already initiated a captive program to prevent extinction of huemul, with the ultimate goal to reintroduce huemul to formerly occupied habitat.[25] To accomplish this, they employed the German Friedrich R. Franke – a specialist in animal behaviour who had studied under the Nobel Prize laureate Konrad Lorenz – to establish a zootechnical station on Victoria Island. That same year, the first huemul arrived. Several successful births followed, but in 1941 the captive individuals were accidently released during Franke's short-term absence, never to be found again.[26] In 1942, huemul were again brought to this station, which remained opened until 1956, during which time there was one birth recorded. The private Chilean zoo, La Dehesa received two males in 1979 and three females in 1982,[18] from which there were at least three births over the course of 10 years: though two died soon after birth and one died at 4 months of age for reasons undetermined.[9,17] A tally of the births in historical records of *Hippocamelus* spp. shows a minimum of eight huemul and 12 taruca fawns (*H. antisensis*) born in captivity.

The huemul's closest relative, taruca, has been successfully bred in European and North American zoos. Occurring closer to accessible transportation routes and areas more densely populated by people, capture of the taruca was more common than with huemul. Consequently, there are more records of this animal being kept in zoos. In 1931, the Berlin Zoo obtained a male and female. From this group, there were at least 12 registered births until the animals were killed during the bombing of the Second World War. One of these males holds the record for the longest known recorded time in captivity for *Hippocamelus*, at 10 years, 7 months and 18 days. In the Bronx Zoo, a female taruca was held for 5.5 years (1938–43).[27] Other records include the first male received by the Berlin Zoo in 1889 as an adult, which lived for 3 more years. At least two other zoos in Germany received taruca. Already in 1890, it was known that the taruca did not need anything special in its diet, doing well on the same food given to all other captive cervids in the Berlin Zoo.[28] Also, climatic influences were of no importance because the taruca was adapted to the heat as well as the cold, due to the climatic conditions of its native

(*a*)



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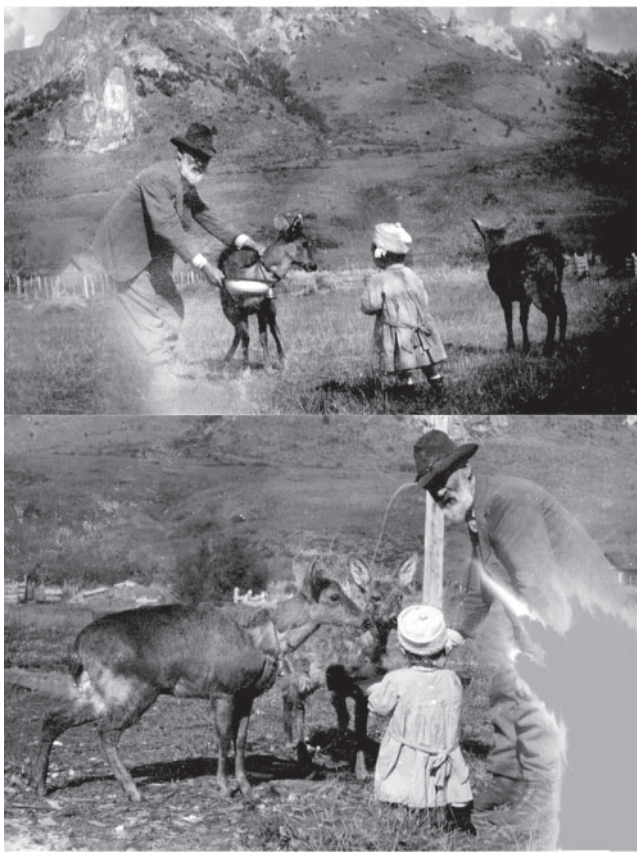

**Fig. 3.** (*a*) In 1902, huemul were kept in the Zoological Garden of Concepcion, Chile.[19,20] (*b*) In 1911, huemul were raised in Neuquén province (Argentina), and showed interest in June Taylor (courtesy Taylor). The animals clearly are not skittish in the presence of humans, instead being rather curious.

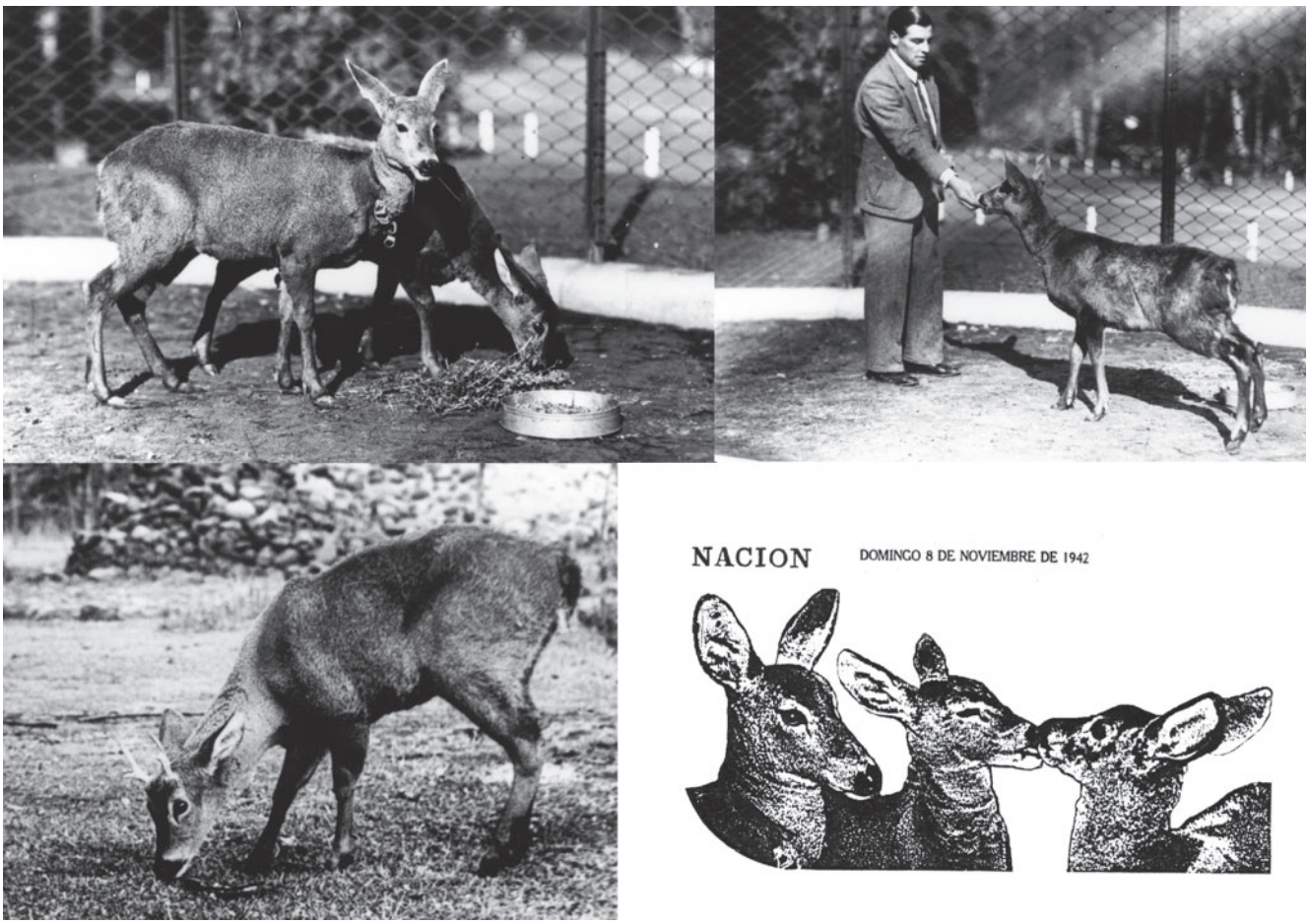


**Fig. 4.** Huemul arrived in 1936 to live for several years at the subtropical Buenos Aires Zoo (photos courtesy of the Editorial Atlántida, Buenos Aires[9]); there were births, and the last known record dates 1942 (after[23]).

environment. From his personal experience in the Berlin Zoo from 1930 to 1944, Frädrich confirmed that the taruca adapted well to captivity and remarked that it would have to be counted as one of the easier species to maintain in captivity.[27,29] Huemul likely would behave similarly based on successfully living 7 years in subtropical Buenos Aires, and Frädrich concluded that their excellent behavioural disposition and dietary diversity guarantee a successful breeding program just as with taruca (H. Frädrich, pers. comm.).

## Current experience: selecting the place for the semi-captive centres in Chile

For establishment of the new captive breeding centre and projects in Chile, a semi-captive regimen was selected and designed to provide as natural an environment as possible to allow individuals to maintain their normal social and feeding behaviours. Each of the two centres currently operating today were set up in the countryside, located within the historical distributional range with the plant community predominated by native vegetation, while keeping in mind cover requirements so as to minimise disturbance from the project's caretakers or the occasional predator circulating outside the premises. Grasslands (pastures) and forest are present inside the enclosures with a dominance of *Nothofagus* and *Festuca* species. Many plant species found at the centres also occur in the region of the capture sites, and with the centres being situated further north than the capture localities, there are some new plant species that the animals will likely use. The plant communities at both centres also consist of a higher diversity and density of plant species than at the capture sites because of their proximity to the Valdivian rain forest. Fresh water is available year round from streams and springs and does not come in contact with any domestic animal or livestock before reaching the huemul.

The first centre was established at the Huilo Huilo Reserve, which forms part of an area designated as a World Biosphere Reserve in 2007 by UNESCO, located in the Andes at 720 m a.s.l. (39°51′S, 71°57′W), and contains an enclosure of 64 ha built to hold approximately seven adults (density of 10/km$^2$), while the other centre, Fauna Andina – Los Canelos, in the central valley near Villarrica, has an enclosure of 13 ha at 330 m a.s.l., which is intended for three breeding animals (two females, one male, density of 23/km$^2$). This second centre also contains some 28 pudu (*Pudu puda*).

## Sourcing animals for the captive breeding projects

### *Fundacion Huilo-Huilo Project*

The project's first objective was to capture and transport animals from threatened wild populations not currently in any protected area. Such a population was identified after two exploratory trips into the Aysén region, south of Coyhaique (48°03′S, 73°00′W). Permits were then obtained from the Chilean government wildlife agency (Secretaria de Agricultura y Ganadería – SAG) and the landowner to capture six animals (two males and four females), and the search for individuals began on 18 April 2005. After capturing the first male and female, the project was halted by a court order initiated by local inhabitants of the tiny village O'Higgins. By the time legal authorisation to continue the project was reinstated by the courts, the federal permits from SAG to capture the remaining four animals had expired.[30]

In 2005, a female just under 1 year old was confiscated by the SAG authorities after being found restrained with a bitless bridle in a stable near the border of the Futaleufu National Reserve of CONAF (Corporación Nacional Forestal, Chile) (43°10′S, 71°50′W). She was then transported 370 km to the Universidad Austral, Valdivia. After being attacked by dogs, she was moved with the permission of SAG under the direction of F. Vidal to the Huilo Huilo Centre, where she arrived in January of 2006 in a thin and extremely weak condition to have since become part of the breeding stock following her rehabilitation.

### *Fundación Fauna Andina – Los Canelos Project*

Unfortunately, examples like the one above are not uncommon, and government officials too often learn of wildlife species that call for rehabilitation that are injured or illegally confined. The Los Canelos Project's main objective is to serve as a rescue, rehabilitation and breeding centre for Chilean indigenous species. Animals are provided to the centre through SAG, which involves several legal formalities obligating both the private and government sectors. Under such circumstances, a huemul buck was transported to the centre on 9 March 2009. Before his arrival, a life-threatening, exposed fracture of the distal radius growth plate (Salter–Harris type-I fracture) on his left foreleg led initially to corrective surgery aimed at saving the leg. Unfortunately, the fixtures broke after 3 days and resulted in an amputation at the scapulohumeral joint that saved his life.[31] Following his subsequent translocation to the centre, a complex process of rehabilitation commenced.

## Capture, transport and release procedures

Free-ranging huemul were chemically immobilised by darting with medetomidine and ketamine, using atipamezole for the reversal.[32] This method was considered by the team (F. Vidal, D. Velasquez, L. Solis, C. Saucedo, R. Millacura, P. Corti, R. Alvarez) to be the safest and to cause the least amount of stress.[30] A wooden crate (150 × 100 × 50 cm for males, 130 × 93 × 50 cm for females) reinforced with a metal frame and fresh air vents was used for transporting the captured animals such that the individual was unable to see outside. The crate was also equipped with a non-slip rubber floor that was covered with fresh leaves. Once the immobilised individual was placed safely inside the crate, the anaesthetic was reversed. As soon as complete consciousness returned, the crate was sealed shut. No tranquilisers were administered. The first two individuals were flown >1500 km to the Huilo Huilo Centre via a plane and two helicopter flights, involving the Chilean army. The male with the amputation brought to the Fundación Fauna Andina Centre was also transported in a crate by aircraft.

The maximum time limit to transport individuals was set to 6 h, based on an experience during a pudu project. Prolonged hours of stress decreased the animals' physical condition and the lapse of 6 h was considered to be the upper limit for guaranteeing success (F. Vidal, unpubl. data). The first male flown to Huilo Huilo was the only animal to show signs of excitation during transport. During the first 15 min of a 45-min helicopter flight to the airfield, in two separate episodes, this male kicked vigorously at the crate. During the following airplane flight, his vital signs were normal with no more signs of stress. After a second helicopter flight and upon arrival to the Huilo Huilo Centre, he and the female were given ~30 min to relax before opening the crate. These two huemul at Huilo Huilo left the crates by themselves but not in the dash-and-run style often pictured at wildlife releases. Instead they slowly stepped out of their crates as if investigating their environment, revealing no apparent sign of fear, and then walked off in a slow, steady gait. Almost immediately after release, all individuals began feeding and drinking water, and soon after they were observed exploring their new environment, as if with great curiosity. Some fatigue was noted, especially for the male with the amputation released at the rehabilitation centre.

## Management of the animals in the enclosures

Avoidance of stress is a main consideration, and thus human contact with the animals is kept to a minimum. Caretakers, who are housed adjacent to the Huilo Huilo enclosure, are responsible for regularly monitoring the animals. Radio-collars are checked remotely twice a day, morning and evening. Additionally, each individual is checked visually approximately every third day or more often if something unusual is observed in the animal's behaviour: time period between observations depends on the season, situation and requirement of each individual. For instance, females about to give birth are monitored more frequently by telemetry. Once she has given birth, the area is restricted to everyone until she starts moving with her newborn. When the caretakers enter the enclosure to evaluate the deer, they remain only briefly.

Once animals reach 1 year of age, they are captured using chemical immobilisation and fitted with a VHF radio-collar for monitoring.[32] During this procedure, a routine physical examination is performed, the animal is then weighed, and blood samples are collected for laboratory tests to evaluate the individual's general health and for DNA research. Animals are all deparasitised when entering the centres.[33,34] As a control, coprological exams are performed twice a year to determine any parasitic loads. Thus far, all results have been negative. All blood analyses have fallen within the normal range of hematological parameters and clinical biochemistry values of other cervids (F. Vidal, unpubl. data).

Disease avoidance is of utmost concern. For sanitation purposes, a tub with formalin is placed at the entrance for sterilising boots before entering the facility. The general public

is not allowed into the facility, only personnel directly involved in the project, government inspection officers, and supervised people invited for specific objectives.

### Prevention of depredation

Both enclosures were designed to exclude predators such as puma (*Puma concolor*), red and grey foxes (*Lycalopex culpaeus*, *L. griseus*, respectively), and stray domestic dogs. The wire fences are 3.5 m in height and have two electrical circuits installed on the top, a single one in the middle, and another double one at the bottom that operate continuously. The fence design also takes into consideration the potential maximum depth of winter snowfall.

Pumas are monitored by camera traps so as to be alerted to their presence if approaching the vicinity. For further surveillance, whenever feasible, puma are captured and fitted with a VHF collar. We thus far have radio-collared at the Huilo Huilo and Villarica Centres, two and five puma, respectively, not only for surveillance purposes but also for conducting research on the interaction between pumas and huemul and puma and guanacos (*Lama guanicoe*).

### Behaviour of huemul to a semi-captive breeding program

The management procedures as currently applied in the two centres have produced healthy individuals and reproductive success better than expected. Moreover, a confiscated female and a male with an amputated leg recovered significantly compared with their condition before entering the centre. However, one incident revealed the necessity to reconsider group structure and its relation to space availability and social behaviour. Aggressive behaviour had been observed in the Huilo Huilo Centre with a mature buck, who, even when without antlers, would occasionally strike with his forelegs at a juvenile male. Unfortunately, one such interaction, though not witnessed, is assumed to be the cause of the death of the juvenile. While in hard antlers, it was decided to keep the males in separate areas. However, after shedding their antlers, well after the rut (June/July), the physical barrier between these two was removed. Eventually the juvenile was found dead and a necropsy revealed several hemorrhagic bruises that were interpreted to have stemmed from hoof strokes.

An accidental break of the peripheral fencing resulted when an avalanche of snow broke through. One female with her fawn went outside the perimeter, but upon the arrival of people to repair the fence, these two individuals headed back into the enclosure. This phenomenon was described to have occured during several ‘soft releases’ of fallow deer (*Dama dama*), when the gates of the enclosures were intentionally opened. The probability of deer moving out on their own accord was low, and even efforts to herd the animals out were generally unsuccessful.[35] This is in accordance with white-tailed deer (*Odocoileus virginianus*) refusing to leave their familiar home range even when pushed experimentally by dogs.[36]

### Population development: reproduction and mortalities

Even though the project started with only one male and one female, the group has bred every year without any artificial or assisted effort. From the little that is known about the reproductive behaviour in the wild,[14,37–39] the response of these individuals has appeared normal, and the reproductive success over the last 5 years in captivity – six fawns surviving to yearlings plus two fawns born in late November 2010 from nine total births – indicates that the minimal requirements have been met for all potential breeders in this semi-captive environment. One female gave birth in spring of 2005, but was killed just before delivering another fawn in 2006. Her reproductive history and tooth replacement coincide with a case described by Texera,[12] indicating these females apparently became pregnant the first time as fawns as occurs in *Odocoileus*. In general, there have been no indications that huemul cannot be bred or maintained under a semi-captive regimen despite the common belief to the contrary. Even the cases of a seriously injured buck that was submitted twice in a row to complex surgery with long hospitalisation,[31] or the female that had been tied up with a bitless bridle in a barn, resulted in an excellent recovery and demonstrates how well this species reacts to manipulations and adapts to living in a semi-captive environment.

This study population of semi-captive huemul can be summarised as follows: (i) four deer entered the centres – an adult pair, a confiscated subadult female, a subadult male (three legs); (ii) total births of nine fawns; and (iii) three mortalities [one near-term pregnant female was shot (sabotage), one fawn died (weak confiscated mother and thus a tiny fawn), one juvenile male possibly killed by mature buck].

### The near future: the ultimate goal, reintroduction

With the breeding program now established, and anticipating similar success over the next few years, a new phase of the Huilo Huilo Project will soon begin: the reintroductions. The release of huemul has been planned using a ‘soft release’ by allowing a group of deer to leave the release enclosure on their own in order to start repopulating the surroundings. The issues around reintroductions are many[35] and for the present situation will be elaborated in another paper.

### General discussion

The initiation of the Chilean captive breeding project is timely, when considering the precarious state of huemul[40] and the continuing pressures from human development projects either close to or right where remnant populations exist today. The huemul captive breeding program was to a large degree a private initiative that received ample government support. However, reaction by local villagers at the onset of the captures resulted in a severe drawback when, instead of the authorised six huemul, only two could be captured. A founder stock, made up of only a few individuals, faces a much higher risk of failure, such as losing the only male or only female. Although numbers now total 10 deer between the two centres, the project is still in a highly critical phase. Our concern also remains on the reduced founder population at the centre, as the project was designed originally to capture as much wild genetic variability as practicable, as recommended by the IUCN so as to avoid loss of genetic diversity.[41]

However, given all the factors that could have potentially terminated this project prematurely, the success so far is encouraging. All females reproduced every year since

initiation of the project, similar to wild females that also have been observed to have fawns continuously up to at least 6 consecutive years.[14,39] All animals responded well to handling during the capture and transport to the centres, including a long transport via helicopter and airplane (1500 km) for the first two individuals. The latter two of the four deer that entered the two centres had to first undergo extensive rehabilitation due to prior injuries: one from a dog attack and malnutrition and the second, from two separate surgeries ending in leg amputation for a wound suffered in the wild. This indicates that past failures were a matter of inappropriate or inadequate procedures during some phase of the captive operations. Furthermore, it strengthens Chile's history of captive success, which accounts for over 90 wild animals being marked successfully over the last 20 years. [14,39,42,43]

The relaxed way that the individuals left their transport crates upon release at the centres is reminiscent of an experience by Franke[26] when receiving an older huemul fawn that had been attacked by dogs. Although this fawn had been injured by dogs, Franke was able to take it for a walk with his dogs the very next days and later it would walk freely with either him or the dogs through the open forests.

The loss of a juvenile male in the centre, possibly from hoof strokes by a mature buck during the antlerless period, required adjusting the herd structure in this semi-captive situation by keeping the mature male in a separate partition. In a wild population during the rut, Povilitis[37] noted that a subdominant buck stayed apart from a dominant adult buck with a female, and although several males may each try to get access to a receptive female, usually the largest and dominant male remains closest to the female,[14,44] resulting in a dominance group mating system[38,44,45] as described for the sister species taruca.[46] Disputes among huemul are infrequent, and if they do occur between males of similar status, fighting generally is not violent and involves engaging antlers and pushing, lasting only briefly.[14,39,47] In other cervids after the rut, and particularly when males have shed antlers, a mature male may fall in rank even below that of females, but aggressive behaviour continues all year among all members.[48,49] Disputes may be over food or simply as reactions to the critical physical distance being invaded, and may intensify under crowding.[49,50] However, there is a clear pattern as aggressiveness escalates, particularly among members having experienced previous encounters, which tends to lead to stable social systems and thereby reduces energy spent during fighting.[50] In dominant antlerless males and females it commonly starts with 'ear-drop', then 'hard-look', followed by 'sidle' (or circling), then striking and finally flailing.[48,49] Subordinate animals eventually retreat, and among many observed aggressive interactions in *Odocoileus*, striking or flailing was rarely involved, and even less commonly were injuries incurred.[49,50] Furthermore, juveniles and subordinate members do not engage in fights with mature individuals.[51] The present event with huemul occurred during the post-rut antlerless period: it thus appears unlikely related to territorialism, which has not been described in any other cervid for this season. Even when territoriality does occur during the intensive rut in some cervids, it rarely results in casualties, particularly of juveniles.[51] Moreover, although recently claimed,[42] no indications of huemul being territorial with active defence were found in a 10-year study,[14] and the sister species taruca also is not territorial but exhibits a dominance system.[51] In comparison, after velvet shedding, mature roe bucks (*Capreolus capreolus*) may defend exclusive territories for breeding, and afterwards revert back to a dominance hierarchy in mixed groups.[52,53] Larger juvenile roe males experience a higher attack rate than smaller juveniles from such bucks exhibiting territoriality, with attacks increasing as the season progresses and fostering dispersal of approximately half the juveniles.[52] Moreover, roe deer also express a range of threat behaviours of distinct severity, as a means to avoid fights, which are potentially expensive due to risk of injury or death. Juveniles do not engage in fights, but instead retreat immediately after receiving the initial threatening cues.[53] In captivity, adult roe bucks can be compatible with younger males (i.e. father and son) or between males with large difference in strength, particularly as long as the size of the enclosure is adequate for escape routes of 100 m or more.[54,55] However, if the target animal being threatened cannot get away, a roe buck will even kill it, be it a male, female or fawn.[54] Mature roe bucks are thus kept in strongly secured pens during the territorial breeding period.[54] In winter, groups are then allowed to mix, including several mature bucks. In general, a dominant male in the aggression-threatening mode may react according to the stimuli.

Male deer have been observed to immediately arrive to gore repeatedly another male that accidently got his antlers wedged in a forked branch or fence, or had just been shot,[49,56] and they may return numerous times to an already dead male to continue stabbing its body (W. T. Flueck, unpubl. data). Similarly, injuries to the captive juvenile male huemul could have been due to a variety of reasons such as not retreating in time because he did not see the threat behaviour of the adult male, merely failing to respond,[49] or other circumstances like accidently tripping or falling during a chase, resulting in a disaster due to this individual being unusually exposed to the older dominant male.[48,57] In fact, one interaction was observed of the mature buck flailing at this juvenile huemul while pushed up against the fence. Animal movements within enclosures, being more restricted than in the wild, can also result in social responses quite different from that of free-ranging animals of the same species.[58] Taruca bred successfully over 14 years in the Berlin Zoo in a space of only 100 $m^2$, but separation of individuals was practised.[27] Thus, the most plausible scenario for the death of this juvenile huemul buck might have involved his inability to retreat to a minimal distance, which caused the mature male to keep striking at him. The incidence might also have had an origin in sympathy/antipathy, which has been considered an important factor in deer husbandry,[55] with preventive separation as the best solution.

Although the centre at Huilo Huilo is getting close to reaching the anticipated carrying capacity (10 adults/$km^2$), there is good indirect historic evidence that huemul once lived at densities substantially higher. For instance, two early explorers shot 15 huemul with an arquebus in just 1 h,[45] Prichard remarked he 'could have very easily shot 10 huemul in a day'[59,60], and large crews of early expeditions lived off huemul while traveling several weeks through the region.[61,62] Lastly, former huemul habitat of good quality currently produces 3000–5000 kg/$km^2$ of exotic ruminant biomass,[4] equivalent to ~40–60 huemul/$km^2$.

Such densities are common for similar-sized *Odocoileus* in good habitat. Based on these considerations, forage is judged not yet to be limiting in the enclosures, however, physical condition of huemul will be monitored closely to this regard.

In the past, wildlife was reared in captivity for products or for public display of animals in zoological gardens.[63] Today, however, with the list of threatened and endangered species continually increasing, the role of zoos has changed, with captive breeding taking on the responsibility of conservation, being considered an important tool in the recovery of species. Many programs today are thus designed to include research and eventual reintroduction of the species back to the wild. Conservation *in situ* and *ex situ*, recognised as integral strategies for the conservation of biodiversity, can increase our knowledge about the species when they are integrated to work in harmony, the latter being for the benefit of the first.[8,64] An effective integration between the two approaches should be sought whenever possible.[41] Research on *ex situ* populations should focus on biological and ecological questions relevant to *in situ* conservation.[9,41] Efforts should be directed to gain a maximum of information through research under controlled conditions,[40] and through reintroductions based on adaptive management approaches. For unknown species like huemul, this also allows us to address specific questions and hypotheses regarding habitat requirements, or factors currently assumed to prevent recovery.[65] With this vision, the Chilean government launched the National Plan for Conservation of Huemul during the 7th IDBC (2010) with the objective to foster more *ex-situ* conservation approaches for subsequent reintroductions and population reinforcements, and to reduce the lack of information of this species through promoting scientific research.

The recent Chilean example to incorporate *ex situ* strategies in the recovery of the huemul, was preceded in 1971 by the 'Operativo Nacional Huemul', which was launched in Argentina to prevent the huemul from extinction.[45] Various institutions (including National Park Administration, Argentine Scientific Society, Buenos Aires Zoo) collaborated with the objective to capture, breed, and repopulate huemul to national park areas. For unknown reasons this program never crystallised. There are now only a few hundred huemul remaining in the country, yet the Argentina National Plan of Conservation and Recovery of the Huemul (ratified in 2005) maintains that the necessity for and cost-benefits of an *ex situ* conservation plan must first be evaluated, insisting that 'In all cases, it is recommended that the criteria of the IUCN Specialist Groups be followed' (http://ambiente.gov.ar/default.asp?IdArticulo=3532, verified 1 March 2011). Meanwhile, IUCN[41] recommends that *ex situ* conservation ideally be initiated before the taxa becomes threatened in the wild. Yet the huemul has been enlisted as endangered since 1973 (CITES, appendix I) and the situation is worsening.[40]

## Conclusion

Through the efforts of various private and government institutions, a Conservation Centre including a captive program with plans to reintroduce individuals into the wild has been running successfully since 2005 in Chile. Interference, however, from uninformed opponents has hindered the program such that fewer animals were able to be brought to the centre than had been anticipated, despite government permits in place. To prevent similar obstacles, contact needs to be established and maintained with people living near the breeding and rehabilitation centres and those living in villages close to populations from which huemul will be extracted for any similar such breeding program. To ensure the success of any conservation program involving animals in captivity or semi-captivity, the local people must be informed of the program's objective, while being educated about the grave status of the huemul and the importance of the role of the breeding centres in the conservation and the recovery of this species in the wild.

The many facts of past and certainly the current successes of this conservation breeding program in Chile demonstrate that huemul lend themselves very easily to *ex situ* programs. It therefore opens the venue for reintroduction programs, whereby adaptive management strategies could assist in determining factors limiting recovery. However, considering the lack of response from huemul populations over the last decades, and if public resistance in applying *ex situ* tools continues, we might conceptualise the causal arrow of time as follows: (i) further population declines and local extinctions; (ii) the increasing difficulty to research original ecological relationships; (iii) increasing difficulty to secure founding animals for a centre; and (iv) perhaps regrettably, a decreasing probability of achieving an eventual recovery of the huemul.

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