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Abstract: The results of three years of research on jaguars *Panthera onca* in the Pantanal region of Brazil are used to develop a comprehensive conservation plan for the species in the region. The plan attempts to integrate space and ecological requirements of the species with existing land features and socio-economic realities of the region. A reserve of at least 2000-3000 km^2 is recommended for each of two areas which still support relatively undisturbed populations of jaguars. Second, the plan calls for the protection of riverine forests between the two reserves as corridors for inter refuge movement. Lastly, several recommendations are made to address jaguar-cattle conflict.

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A conservation plan for the jaguar *Panthera onca* in the Pantanal region of Brazil

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The results of three years of research on jaguars *Panthera onca* in the Pantanal region of Brazil are used to develop a comprehensive conservation plan for the species in the region. The plan attempts to integrate space and ecological requirements of the species with existing land features and socioeconomic realities of the region. A reserve of at least 2000–3000 km² is recommended for each of two areas which still support relatively undisturbed populations of jaguars. Second, the plan calls for the protection of riverine forests between the two reserves as corridors for inter-refuge movement. Lastly, several recommendations are made to address jaguar–cattle conflicts.

INTRODUCTION

The jaguar *Panthera onca* is the largest felid in the Western Hemisphere. Although originally distributed from the southern United States to northern Patagonia (Guggisberg, 1975), the jaguar's range has been considerably reduced since European settlement of the Americas. The present range has not been precisely defined, although some recent surveys (Mercado & Sanchez, 1978; Vaughan, 1983; Melquist, 1984; Swank & Teer, 1989) have aided in the status assessment of the species. In Mexico and Central America, Swank and Teer (1989) found that jaguar populations existed in only 33% of their former range, and 75% of those populations were considered to exist in reduced numbers; in South America, jaguars existed in 62% of their original range, and were considered reduced in 36% of that area (Swank & Teer, 1989). The range of the jaguar continues to decrease rapidly despite its protected status internationally (Emonds, 1981; IUCN, 1982*a*; Fuller & Swift, 1985).

Until recently, little scientific information was available on the ecology of the jaguar (Schaller & Crawshaw, 1980; Rabinowitz & Nottingham, 1986; Emmons, 1987). New findings, however, present biological information on which to base conservation efforts. These findings have shown substantial variation in several aspects of its ecology (Quigley, 1987). Additional variation exists with regard to human impact on the species. Although direct killing and habitat destruction are responsible for its decline (Ojeda & Mares, 1982; Brown, 1983; Melquist, 1984; Swank & Teer, 1989), the importance of these activities varies regionally due to differences in habitat, prey availability, economic development, and cultural mores. As a result, many areas require site-specific conservation strategies for the jaguar. Such regional approaches have the greatest hope for success (Dourojeanni, 1980).

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This paper presents a status report and conservation strategy for the jaguar in the Pantanal region, Mato Grosso do Sul, Brazil. The plan includes a proposal for reserve design and a strategy for reducing jaguar–livestock conflicts. The presentation is based on recent research on the ecology of the jaguar in the region (Quigley, 1987).

DESCRIPTION OF REGION

The Pantanal is an area of over 100000 km², situated on the frontiers of Brazil, Bolivia, and Paraguay at approximately 16° to 20° S Latitude and 55° to 58° W Longitude. The region is the largest naturally flooded land area in the world (Alho *et al.*, 1988). More than 50% of the annual rainfall of 1200 mm occurs from December through March. During this period, rivers overflow into a floodplain which slowly drains through the Paraguay River. A dry season occurs from July through November; during high-water years, however, many areas remain inundated the entire year.

The region supports a vegetation matrix largely determined by the degree of flooding. Lower areas are dominated by open habitats such as grassland and open woodland (cerrado). On slightly more elevated ground within lower areas are forest patches which flood little and vary in size from a few hectares to several square kilometers. These low areas also contain meandering streams and sloughs, normally bordered by closed forest. Riparian forest averages approximately 50 m in width, but can form large, forested blocks at the confluences of water courses or near oxbows. Semi-deciduous forest occurs on higher, non-flooding areas. Prance and Schaller (1982) present a detailed description of Pantanal vegetation.

In the past, the region was sparsely populated with indigenous peoples (Guato, Bororo, and Caudiueu groups); it now supports a population of about 250000 ethnically mixed people, living mostly in towns on the periphery of the floodplain. The dominant economic base is cattle ranching. Although farming has been attempted, flooding interferes and the soil over large portions of the Pantanal has low fertility (Sioli, 1986).

CONSERVATION PLAN

Schaller (1979) considered the jaguar already extirpated or reduced to scattered individuals in much of the Pantanal. Our observations, combined with the interviews of landowners and managers, confirmed the extant populations defined by Schaller for the region (Schaller, 1979; Quigley, 1987). Individual cats and small populations are reported locally, but, compared to other areas in the Pantanal, relatively undisturbed, intact populations exist only in the north-central and the extreme southern parts of the region (Fig. 1; Schaller, 1979; Quigley, 1987). Future development, both in and around the Pantanal, will eliminate populations. Such increased isolation of populations and habitat alteration are major influences in the local extinction of species (Salwasser *et al.*, 1983; Soulé, 1983; Samson *et al.*, 1985).

At present, the Pantanal National Park (Parque Nacional do Pantanal; 1370 km²) is the only major, officially dedicated, reserve in the Pantanal ecosystem (Fig. 1) and there is a pressing need for additional protected areas (Dourojeanni, 1980). Not only has the park's administrative effectiveness been questioned (Alho *et al.*, 1988), but its small size and extremely low percentage of dry land during the wet season offer minimal protection for jaguars. Outside of the park, most of the Pantanal is privately owned and wildlife protection on private lands in Brazil and elsewhere depends largely on the individual desires of the owner or manager. A large, more integrated system of protective measures within the Pantanal would enhance survival of the jaguar in the region. We present a three-faceted, integrated approach to jaguar conservation in the Pantanal. Rather than standing on its own, each facet is meant to be a complement to, and be augmented by, the other two.

Preservation

More than 95% of the Pantanal is privately owned. The persistence of jaguars within the two areas described above (Fig. 1) is likely to be a result of protective attitudes of private landowners towards wildlife, inaccessibility of the areas, and patterns of annual flooding which have discouraged intensive ranch management. Over the past several decades, ranches of this region have decreased in size as land was divided by family members. This trend is likely to continue, thus intensifying the need for increased access, the destruction of forests to create pasture, and attempts at water control. Conservation of the jaguar in the Pantanal will depend heavily on the

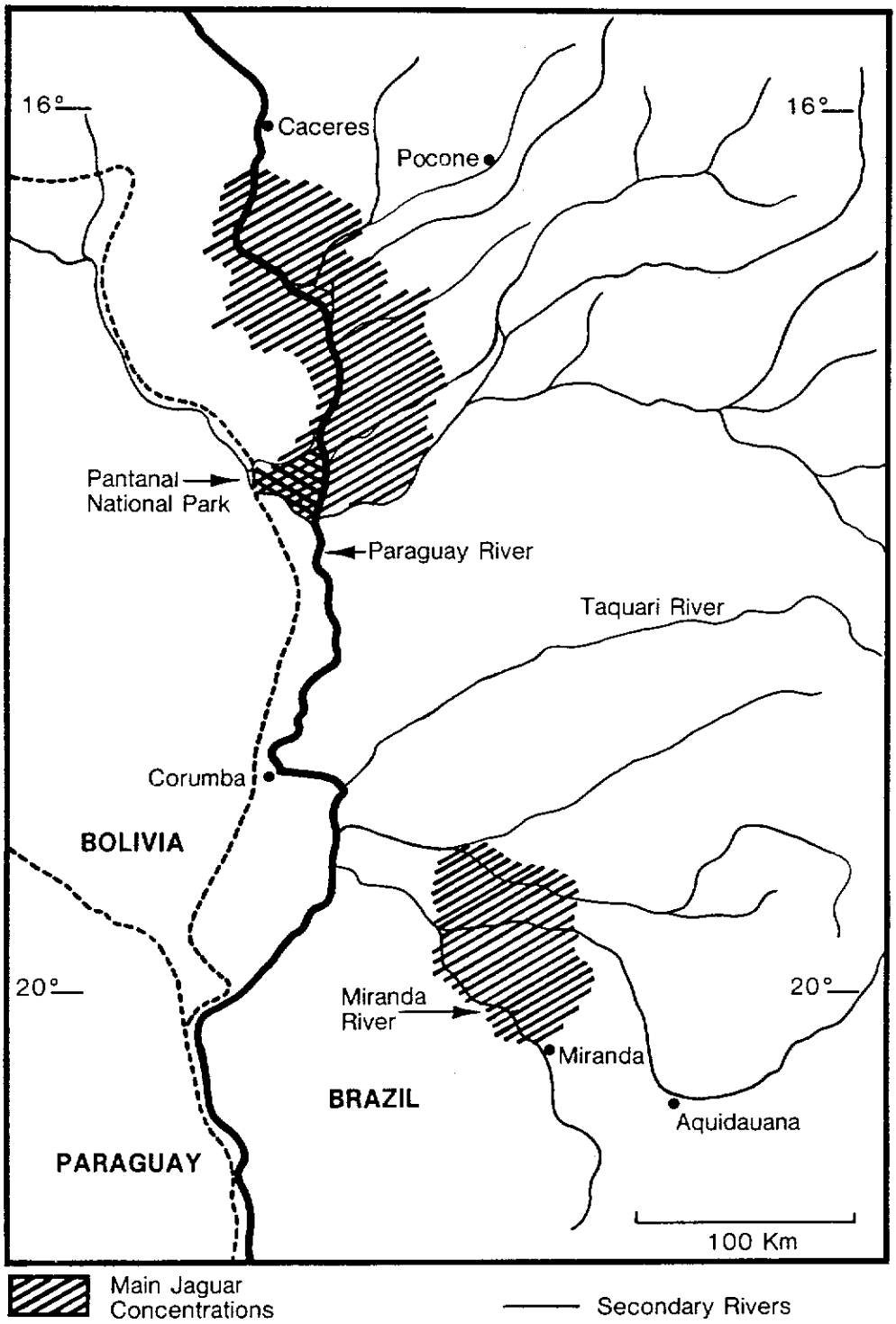

Fig. 1. Distribution of the jaguar in the Pantanal region, Mata Grosso do Sul, Brazil.

acquisition and protection of large blocks of land within each area occupied by the two large subpopulations.

A species protection plan must provide for support of enough individuals to maintain population viability and provide for the protection of an area large enough to maintain those individuals. Despite recent information on the ecology of the jaguar, insufficient data are available to allow calculation of a precise minimum viable population size (MVP) for the species (see Reed *et al.*, 1986; Soulé, 1987*a*). In the absence of species-specific information, attempts must be made to protect as large a population as is economically and politically feasible. These populations can be used as a 'starting point for assessing viability' and for making further recommendations (Salwasser *et al.*, 1983).

Inevitably, discussions of reserve size conclude that saving the largest possible area is best for the

ecosystem or species involved (e.g. Soulé & Simberloff, 1986). An effective population of 500 individuals or greater has been recommended for long-term survival (Franklin, 1980; Soulé, 1980; Salwasser *et al.*, 1983). Further analyses in population viability may result in numbers in the low thousands for long-term persistence (Soulé, 1987*b*). However, the preservation of a reserve capable of encompassing and protecting even 500 jaguars is unrealistic given the political, cultural, and economic realities in the Pantanal. The two areas still supporting relatively intact, undisturbed jaguar populations in the northern and southern Pantanal (Fig. 1) are approximately 10 000 and 5000 km². We recommend that 2000–3000 km² be acquired for protection within each of the two areas.

To estimate the number of jaguars an area will support, their natural density in the region must be known. The mean home range size in our study was 142 km² (Quigley, 1987); however, a high degree of overlap was found between individuals. Thus, only jaguars with sympatric home ranges were used to determine density. Four of the seven individuals radio-tracked during our study had overlapping home ranges. The boundary encompassing the home ranges of all four individuals was 320 km². Through the examination of fresh sign, in conjunction with the known locations of radio-collared individuals over a three-year period, we determined that at least one, and possibly two, male jaguars also used the area, but we were unable to capture and radio-collar these individuals. Using the minimum of at least one adult male resident, the density of resident adult jaguars was one per 64 km². This estimate will change with variations in jaguar densities due to local variations in prey density, habitat composition, and human exploitation (see Rabinowitz & Nottingham, 1986). However, we feel this density is generally applicable in the Pantanal region in undisturbed populations, given the similarity in vegetation, prey, and physical characteristics between our study area and the rest of the region. Furthermore, these home range estimates are taken from a dynamic situation in which individuals were followed for more than 12 months and in which some females were barren while others were in the company of offspring; at times, seasonal and annual home range estimates were much smaller than the area used for the above calculation (Quigley, 1987). Our aim in this approach was to err on the conservative side (if at all) for the sake of species conservation security. Thus, the reserve sizes recommended above would support 30 to 50 adult jaguars.

Should the above populations of 30 to 50 individuals become isolated, even short-term survival is not assured (Schonewald-Cox, 1983; Lehmkuhl, 1984; Samson *et al.*, 1985; Shaffer & Samson, 1985). Further actions, however, can moderate the effects of population isolation by integrating the proposed reserve design with existing natural features and the socioeconomics of the region.

Travel corridors

The interconnectedness of populations is a strong influence on their survival (see Noss, 1983; Gilpin, 1987). Shaffer (1987) identifies four stochastic processes which affect the extinction potential of populations: demographic uncertainty, environmental uncertainty, natural catastrophes, and genetic uncertainty. Corridors between refuges can alleviate the pressures that at least two of these factors, demographic uncertainty and genetic uncertainty, have on small populations (Simberloff & Cox, 1987; Forney & Gilpin, 1989). This seems especially true for the latter.

Although our practical knowledge of the dynamics of genetic resources in wild populations remains somewhat crude, population genetics models and computer simulations have revealed much about the potential of dispersals for conserving genetic viability. Inter-refuge dispersals conserve genetic resources (Boecklen, 1986) and reconstitute subpopulation genetic variation (Chesser, 1983), thus countering potentially debilitating effects of inbreeding and demographic stochasticity (Simberloff & Cox, 1987). As such, the genetic viability of species with discontinuous distributions is strengthened through their use of corridors between local populations (Samson *et al.*, 1985). Such a situation is preferable to genetically isolated refuges (Harris, 1984; Soulé & Simberloff, 1986), especially when isolated refuges support very small populations.

The Pantanal offers an opportune situation for establishing corridors between the two proposed refuges. Jaguars are closely associated with closed forests and permanent water sources in the Pantanal (Schaller & Crawshaw, 1980; Quigley, 1987), as they are elsewhere (Rabinowitz & Nottingham, 1986; Emmons, 1987). Our study animals used riparian forest more than expected given its availability ($n=4$, $p<0{\cdot}10$). In addition, the mean

distance radio-collared jaguars were located from permanent water sources (500 m, $n = 318$) was significantly different (t-test, $p < 0.001$) than the distance from water of randomly generated points within jaguar home ranges (1700 m, $n = 318$). The borders of major rivers in the Pantanal have received little development and riparian forests remain intact over most of the region. This river system could provide natural corridors between protected blocks of land. The enforcement of existing deforestation laws could protect these travel corridors.

The direct distance between the subpopulations in Fig. 1 is 150 km, but is greater by river corridor. Single dispersing male and female jaguars in our study established home ranges 30 km and 8 km, respectively, from their natal area (Quigley, 1987). If these represent standard dispersal distances in the Pantanal, small, intermediate pockets of resident jaguars, or 'stepping stone' islands of habitat (Harris, 1984), may promote gene flow between the two subpopulations. Simulations by Boecklen (1986) indicate an interchange rate as low as 0·03 (genetic exchange every 33 generations, or about 100 years for jaguars) can preserve heterozygosity longer in two subpopulations of 50 individuals than in a single population of 100. Periodic capture and relocation of jaguars from one subpopulation to the other is an alternative to natural dispersal. Such intervention may be the only means of maintaining large, low-density species in disjunct populations (Miller, 1979; Soulé *et al.*, 1979; Goodman, 1987).

Jaguars and livestock

Historically, direct killing has been the primary cause of jaguar losses in the Pantanal, although habitat loss has become increasingly important as economic pressures have increased. Local people usually justify jaguar killing on the basis of their cattle-killing habits. That jaguars kill cattle is not in question, but misconceptions and surrounding circumstances need clarification if the problem is to be dealt with realistically.

Schaller (1979) noted that cattle management in the Pantanal was so poor that only one cow in four or five successfully raises her calf, and many cattle were 'wholly feral'. Although feral cattle cannot be caught and cared for, even controlled cattle receive little attention. Improved husbandry and herd management would lessen losses to disease, starvation, malnutrition, and related factors, such as predation. Increased access to veterinary personnel, education of ranch managers, and the economic rewards of husbandry improvements show much promise in reducing cattle losses and jaguar problems.

Typically, cattle are moved into lower areas as flood waters recede. After the dry season, attempts are made to move them back to non-flooding ground. If wet-season rains begin early, manpower is limited, or the drive is begun too late, many cattle remain in these lower areas for the wet season. During this time, grass becomes inaccessible under water and cattle gather on small patches of forested land which quickly become devoid of accessible vegetation. Malnutrition follows, and many starve before the flood waters recede. Cattle in this weakened state are easy prey for jaguars and other predators. Mondolfi and Hoogesteijn (1986) found a similar situation in the Venezuelan Llanos region where jaguar depredation is a problem and management of cattle is 'rudimentary', thus exposing them 'to the hazards of floods, droughts, epidemic disease, parasites and malnutrition...such conditions favor predation'. Increased effort should be applied before the wet season to move cattle from lands highly susceptible to flooding.

Increased control over calving could also lessen predation losses. One-third of cattle killed by jaguars ($n = 24$) on Miranda Ranch were calves (Quigley, 1987). Since, as stated above, jaguars are closely associated with riparian forest and permanent water courses, limiting calving to areas with a high percentage of open grassland and a minimum amount of permanent water courses would likely decrease jaguar predation on cattle. Most large ranches in the Pantanal have this habitat option available to them.

Unregulated hunting and the decimation of wild game also affect jaguar predation on cattle. Hunting of native wildlife on the Miranda Ranch in Brazil was prohibited and strictly enforced; thus, much prey other than cattle was available to jaguars (Quigley, 1987). This policy, however, appears to be the exception in the Pantanal and in much of Latin America (Dourojeanni, 1980; Ojasti, 1984). On most ranches native species are severely decimated and cattle are the most abundant prey. The maintenance of other prey populations would lessen the jaguar's reliance on cattle. In most cases, when jaguar predation on cattle is discovered, trained dogs are used to hunt and kill the suspected predator.

In some instances, the selective removal of individual depredating jaguars can be a justifiable option. Since there is evidence that individual jaguars and other felids sometimes specialize on particular prey species (Brock, 1963; Kruuk, 1986; Mondolfi & Hoogesteijn, 1986; Rabinowitz, 1986), removal of targeted, cattle-killing jaguars may reduce losses. Moreover, cats develop their killing skills through exposure to prey and practice (Leyhausen, 1979). If the mother has predilection for killing cattle, her offspring may develop the same behavior. Therefore, the highest priority in a selective removal program would appear to be the depredating female jaguar.

Relocating depredating jaguars is largely untested. Rabinowitz (1986) radio-tracked two relocated jaguars known to be cattle killers and considered relocation to be of limited utility. Experimental relocation of other large cats as a remedy for depredation problems is also largely untested. Hamilton (1976) relocated two stock-killing leopards with equally discouraging results, but added that successful relocation (i.e. the animal takes up residence in or near the release area) may depend in part on the availability of openings in the territorial matrix of resident conspecifics. The relocation of a problem tiger *Panthera tigris* by Seidensticker *et al.* (1976) failed when the cat was killed by a resident tiger at the release site. Further research on relocation techniques is necessary.

Some observers have noted age or health disabilities in cattle-killing jaguars (Rabinowitz, 1986). In addition, Rabinowitz (1986) believed jaguars were reluctant to cross man-made 'boundaries' where forest patches were cut for use as grazing land. A. De Almeida (pers. comm.) describes a similar situation in Amazonia. In contrast, it seems that healthy jaguars in the Pantanal attack cattle as prey items little different from native prey (Schaller & Crawshaw, 1980; Quigley, 1987). The natural mosaic of grasslands and forests in the Pantanal could be a factor since cattle move freely between the two habitats. In parts of the Venezuelan Llanos region, which is comparable to the Pantanal in vegetation and flooding characteristics, the jaguar–cattle relationship appears to be similar to that found in the Pantanal (Mondolfi & Hoogesteijn, 1986).

Since unlimited access to forest habitats may predispose cattle to jaguar attacks, restricting their access to forested lands may reduce jaguar predation. This is especially true during calving. Thus, fencing can become a valuable tool in reducing jaguar predation. Such action will be most practical and most economically beneficial in naturally open, non-flooding high ground or in planted pasture in the Pantanal.

DISCUSSION AND CONCLUSIONS

As Barriga and Byers (1982) point out, comprehensive Latin American conservation strategies 'must consider not only a country's conservation priorities, but also its economic and cultural character'. This sentiment is echoed by a number of scientists and conservation organizations working in developing countries (IUCN, 1980). Such action can best be performed on a local or regional level. We feel our proposed conservation plan meets this goal by integrating regional conservation needs and socioeconomic considerations on two levels: the establishment of reserves and the integration of conservation into the culture and economics of cattle ranching.

A high potential for tourism exists in the Pantanal (Dourojeanni, 1980), due in part to the visibility of many species, such as caiman *Caiman crocodilus*, capybara *Hydrochaeris hydrochaeris*, and a large number of wading birds. Tourism in the region is already on the rise and is increasingly considered a viable economic alternative (Alho *et al.*, 1988). However, the Pantanal's culture and economy currently revolve around cattle ranching. Conservation of the jaguar in the Pantanal, with or without the establishment of reserves, will depend heavily on the resolution of jaguar–ranching conflicts, which to date have been poorly addressed not only in the Pantanal, but in Latin America in general (see Melquist, 1984; Rabinowitz, 1986).

Moreover, in comparison to other consumptive development options, cattle ranching may be the economic use most compatible with conservation in the Pantanal (Dourojeanni, 1980; Prance & Schaller, 1982; Alho *et al.*, 1988). Realistic predator management programs should be developed based on sound ecological information, with professionally developed and applied control methods, and public education (Berryman, 1972; Hornocker, 1972; McCabe & Kozicky, 1972; Talbot, 1976). Implementation of such programs will ensure survival of jaguars in the Pantanal and enhance the effectiveness of its reserves.

Additionally, experimentation with well-managed cattle ranching in the reserves or in buffer zones around the reserves has the potential to provide a valuable integration of conservation and economics. These approaches will offer a regional conservation program for the jaguar, and mediate conflicts which exist between its survival and the only proven economic base of the region.

Conflicts between conservation efforts for large predators and the activities of humans are not unique to jaguars. In all cases of successful program development, there was a need for governmental agency involvement and leadership; this is likely a key to success. Thus, if jaguar–ranching conflicts are to be overcome, ranching interests must be shown the success and learn by example.

Ranching in the Brazilian Pantanal, as in many regions of the world, is an economic activity which has displayed little change in the past century. Those changes which have occurred (i.e. changes in cattle breeds or pasture grasses) were introduced from within the historical ranks of the ranching community, and spread to other ranches after economic benefits were proven. In light of this, we suggest that one effective method for implementing some of the husbandry and management changes in Pantanal ranching is through example.

Many conservation-minded ranchers still exist in the Pantanal. By contract (and with help from government and non-governmental agencies and organizations working in the region), model ranching operations could be established to test and showcase the management alternatives suggested herein. The benefits, financial and otherwise, will provide incentive for other ranches to adopt these approaches. This type of experimental showcase has been used in African ranching for many years (Darling, 1960).

The conservation strategy presented herein contains implications and applications in a larger framework outside of the conservation of the jaguar.

(1) Although Brazil has performed an admirable job in dedicating lands for reserves (Padua, 1981; IUCN 1982*b*; Camara, 1983), the Pantanal is underrepresented in the park system, or presents a 'gap' (Scott *et al.*, 1987; Burley, 1988) in conservation efforts for the country. This may be a result of a simple lack of recognition, since many maps of the major global ecological types do not delineate the Pantanal as a separate entity, but incorporate it into surrounding types (e.g. Udvardy, 1975; IUCN, 1982*b*)—this despite the fact that the Pantanal is the largest seasonally flooded wetland in the world (Alho *et al.*, 1988). Although its recognition nationally has been maintained (Alcantara, 1983), the Pantanal has only recently drawn international attention (National Research Council, 1980; Schaller *et al.*, 1984; Alho *et al.*, 1988). Still, less than 3% of the Pantanal is in official reserve status (Fig. 1).

(2) A single-species protection plan centered on a large predator offers protection for large 'functioning ecosystems' (Soulé & Simberloff, 1986) because of the ecological and spatial requirements of large predators (Belovsky, 1987). This 'ecosystem approach' to conservation has worked well in conservation efforts for the tiger in India and the spin-off benefits to other species (Panwar, 1987). The Pantanal has been called the 'largest faunal concentration in the Americas, at least in the forms and numbers of individuals' (Padua & Coimbra-Filho, 1979; see also Dourojeanni, 1980). A conservation program emphasizing the jaguar, one of the lowest density vertebrates in the neotropics (Eisenberg, 1980; Schaller, 1983; Arita *et al.*, 1990), would create a 'coattail effect' (Soulé, 1985) not only securing a number of abundant species, but also many threatened and endangered species. This includes the giant otter *Pteronura brasiliensis*, the maned wolf *Chrysocyon brachyurus*, the marsh deer *Blastocerus dichotomus*, the hyacinth macaw *Anodorhynchus hyacinthus*, and the giant armadillo *Priodontes giganteus*.

Even in relatively well-protected, well-managed ecosystems, large carnivores are often obvious only by their absence (Harris, 1984). The Pantanal offers a rare chance to counter this trend through (1) the acquisition and protection of strategically located lands as they become available; (2) the enforcement of forest protection laws, especially as they affect riparian forests; and (3) the development and application of sound policies relating to jaguar–livestock conflicts.

Such an approach addresses shortcomings in land protection for the region, directs conservation efforts toward one of the most human-impacted wildlife species, and deals directly with the socioeconomic conflicts which exist between this species and man. These efforts may require international cooperative assistance due to financial and personnel limitations of the national government.

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