



Effects of artificial night lighting on endangered ocelots (*Leopardus pardalis*) and nocturnal prey along the United States-Mexico border: A literature review and hypotheses of potential impacts

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Abstract. Artificial night lighting is one of the least studied outcomes of urbanization. While the effects of night lighting on mammals and their habitats seem obvious, they remain difficult to quantify. By reviewing laboratory and field studies conducted on mammals since 1943, this paper summarizes the most salient effects of artificial night lighting on activity patterns and behavior. These studies assist us in generating hypotheses regarding the effects of lights, erected across the militarized U.S.-Mexico border, on the endangered Ocelot and its nocturnal prey. We predict that activity patterns for Ocelots and their nocturnal prey would be altered under artificial night lighting conditions. Specifically, evening activity levels would either be reduced or redirected towards areas with dense vegetation. In addition, Ocelot foraging success would likely be altered as a result of turning night into day. Recommendations are made for Ocelot recovery and future research on surrogate species.

Keywords: artificial lighting, endangered species, ocelot, activity patterns, nocturnal

Introduction

Strayhorn (2002) estimates that 16 counties in Texas, stretching from Del Rio to Brownsville, will comprise the fastest growing economic region of the state between 2000 and 2005. This region also provides habitat for the remaining populations of endangered Ocelots (*Leopardus pardalis*) in the U.S. These nocturnal predators once occupied Arkansas, Louisiana, Arizona and Texas, but are now found only in south Texas (Tewes and Everett, 1986). Current ocelot habitat along the Rio Grande River is bordered on the south by urbanization and on the north by physical barriers used to deter the flow of illegal aliens and contraband from Mexico into the U.S.

Ocelots were listed as an endangered species in 1982 (U.S. Fish and Wildlife Service, 1982), and their decline can be attributed to habitat alteration (U.S. Fish and Wildlife Service, 1990). In south Texas, approximately 60 ocelots inhabit Laguna Atascosa National Wildlife Refuge (LANWR; Laack, 1991). Adjacent to the refuge is the Lower Rio Grande Valley National Wildlife Refuge (LRGVNWR). The Rio Grande River, which borders LRGVNWR to the south, lies between the refuge and northern Mexico. Protected refuge tracts are

interspersed with non-protected corridors. These corridors are not always vegetated, thereby reducing movement opportunities for Ocelots between protected areas.

Despite protection afforded to Ocelots by the refuges of south Texas, artificial night lighting along the Rio Grande River may be reducing the availability of Ocelot prey and restricting movements of Ocelots themselves. Successful recovery of Ocelots in Texas will require an understanding of the impacts of artificial night lighting on the distribution and abundance of both Ocelots and their prey. This paper summarizes laboratory and field studies conducted on mammals since 1943 that have assessed the effects of artificial lighting on activity patterns and behavior. These results elucidate the potential impacts of artificial night lighting on both Ocelots and their prey.

Operation Rio Grande

The Rio Grande River and the international border are patrolled by the Immigration and Naturalization Service's (INS) Border Patrol (BP). The role of BP is to prevent the flow of illegal aliens and contraband into the United States (Bureau of Citizenship and Immigration Services, 2002). "Operation Rio Grande" is a BP operation that covers 17,000 mi² of southeast Texas (Bureau of Citizenship and Immigration Services, 2002).

In order to patrol the border most efficiently, vegetation is burned and mowed along the U.S. border, fences are installed, parallel roads are built, and hundreds of permanent and portable lights are erected adjacent to the river (U.S. Fish and Wildlife Service, 2002). These activities have the potential to create a conflict in land use between the refuge, whose mission is to restore and acquire habitat for wildlife adjacent to the river, and the INS, whose duty is to detect illegal aliens entering the United States. Currently there are approximately 186 diesel powered portable lights and 235 permanent lights running 52.4 miles along the U.S. border of the Rio Grande River (U.S. Fish and Wildlife Service, 2002).

In an attempt to curtail the activities of Operation Rio Grande, in 1999 plaintiffs filed suit against the INS. As part of their suit, the plaintiffs claimed that artificial night lighting has an impact on nocturnal species, such as the endangered Ocelot. While it was known that Ocelots are primarily crepuscular/nocturnal (Konecny, 1989; Laack, 1991; Tewes and Shindle, 1997), there were no data to indicate the effects of artificial night lighting on hunting, foraging and dispersal success of Ocelots. Because of this shortcoming, plaintiffs received less from their settlement than they had originally intended. What was clearly needed at the time was a quantitative study on the effects of artificial night lighting on Ocelots. However, problems with initiating such a study were manifold, including the small population size of Ocelots, problems tracking Ocelot movement, and the need to collect long-term data (U.S. Fish and Wildlife Service, 2002). Indeed, a study on Ocelots was initiated in December of 1999 to investigate these issues, but was terminated in January 2001 because of poor statistical power resulting from low sample size (U.S. Fish and Wildlife Service, 2002).

Additionally, no studies have been conducted on the effects of artificial night lighting on Ocelot prey. Ocelots feed on a wide variety of prey but small mammals make up a large proportion of their diet (Bisbal, 1986; Tewes *et al.*, 1997; De Villa Meza *et al.*, 2002). Eleven nocturnal rodent species inhabit the area where Operation Rio Grande has

been implemented (Davis and Schmidly, 1997). At least two of these eleven nocturnal species and one diurnal species are known prey of Ocelots (Tewes *et al.*, 1997). Laboratory experiments have demonstrated that artificial night lighting alters rodent activity patterns (Blair, 1943; Kavanau, 1968; Kavanau and Rischer, 1968; Kavanau and Havenhill, 1976).

Although it has been difficult to quantify the effects of artificial night lighting on Texas Ocelots and their nocturnal rodent prey, it would be useful to develop hypotheses and generate predictions about the negative impacts of artificial night lighting on these species. Therefore, by understanding the effects of artificial night lighting on closely related species, previous studies can aid in the generation of hypotheses regarding the impact of artificial night lighting on Ocelots and their prey along the U.S.-Mexican border in southeast Texas.

Natural and artificial light experiments

Table 1 summarizes lighting studies conducted on mammals since 1943. Three studies summarized in Table 1 are relevant to Ocelot prey—nocturnal rodents either found in Ocelot habitat and/or in Ocelot scat in south Texas.

Sunlight and moonlight greatly influence activity levels of nocturnal rodents (O'Farrell, 1974; Brusseo and Barry Jr., 1995). In the wild, nocturnal rodent activity can decrease due to increasing illumination of moonlight (Lockard and Owings, 1974; Kaufman and Kaufman, 1983; Price *et al.*, 1984). Nocturnal rodents exposed to natural light in laboratory experiments shifted activity from open areas to cover as the light level of moonlight increased (Wolfe and Summerlin, 1989).

Laboratory experiments have been conducted to determine the influence of light level on activity of nocturnal rodents (Blair, 1943; Kavanau, 1968; Kavanau and Rischer, 1968; Kavanau and Havenhill, 1976; Clark, 1983). These experiments fall into two categories: manipulative or volitional light level experiments.

Manipulative light-level experiments permitted researchers to control the level of illumination, duration at each level, and the length of each light cycle (Blair, 1943; Kavanau and Rischer, 1968; Clarke, 1983). Volitional light-level experiments allowed rodents to incrementally change the level of illumination by stepping on micro switches inside enclosures (Kavanau and Havenhill, 1976).

Results from both manipulative and volitional light level experiments on rodents indicate that the optimum light level for maximum activity found in the laboratory nearly coincided with periods of peak activity for the same species in the wild (Blair, 1943; Kavanau and Havenhill, 1976). When luminance exceeded the average luminance of the full moon, rodent activity ceased (Blair, 1943).

Therefore, laboratory experiments indicate that artificial lighting can alter rodent activity patterns substantially. Artificial sunrise and sunset were cues for the onset or cessation of rodent activity (Kavanau, 1968; Kavanau and Rischer, 1968). While nocturnal and crepuscular rodents decreased activity as light level increased (Blair, 1943; Kavanau, 1968; Kavanau and Havenhill, 1976), a sudden onset of bright light caused bursts of activity (Kavanau, 1968).

Kavanau and Havenhill (1976) also monitored activity levels of both rodents and carnivores over 24-hour periods and they concluded that activity levels of carnivores do not

Table 1. Summary of lighting studies on mammals

Genus and species	Foraging group	Temporal activity pattern	Lab or field study	Manipulative light level, volitional light level, or natural light experiment	Result of light level experiment	Reference
<i>Peromyscus leucopus</i> **	Herbivore Insectivore	Nocturnal	Lab	Manipulative	Use moon, twilight sun, and landmarks as navigational aids.	Kavanau, L.J. (1968)
<i>Tamias striatus</i>	Omnivore	Diurnal	Lab	Manipulative	Activity stimulated by artificial dawn	Kavanau, L.J. (1969)
<i>Mustela nivalis</i>	Carnivore	Arrhythmic	Lab	Manipulative	Activity stimulated by artificial dusk and inhibited by artificial dawn	Kavanau, L.J. (1969)
<i>Eira barbara</i>	Omnivore	Diurnal	Lab	Manipulative	Relatively insensitive to abrupt light changes during activity periods	Kavanau, L.J. (1971)
<i>Vulpes vulpes</i>	Omnivore	Arrhythmic	Lab	Manipulative	Primarily nocturnal activity pattern, activity peaked at twilight. Activity inhibited by dim light and darkness.	Kavanau, L.J. (1971)
<i>Lynx rufus</i>	Carnivore	Arrhythmic	Lab	Manipulative	Activity peaked at twilight. Activity inhibited by dim light and dusk.	Kavanau, L.J. (1971)
<i>Gallinago vittata</i>	Carnivore	Diurnal	Lab	Manipulative	Insensitive to temporary changes in light intensity during activity periods.	Kavanau, L.J. (1971)
<i>Bassariscus astutus</i>	Omnivore	Nocturnal	Lab	Manipulative	Activity peaked at lowest light levels. Decreased activity with abrupt alternations in light intensity from dark to light.	Kavanau, L.J. (1971)
<i>Macaca nemestrina</i>	Frugivore	Diurnal	Lab	Manipulative	Insensitive to temporary changes in light intensity during activity periods.	Kavanau, L.J. (1971)
<i>Peromyscus maniculatus blandus</i>	Herbivore Insectivore	Nocturnal	Lab	Manipulative	Activity decreased as light intensity increased.	Blair, Frank. W. (1943)

<i>Peromyscus maniculatus nubiterrae</i>	Herbivore Insectivore	Nocturnal	Field	Natural	Peak activity soon after sunset. Other peaks in activity later in night depending on season.	Brusseo, A.J. and Barry, R.E. (1995)
<i>Peromyscus leucopus noveboracensis</i>	Herbivore Insectivore	Nocturnal	Field	Natural	Peak activity soon after sunset and declined as night progressed. Season did not effect activity pattern.	Brusseo, A.J. and Barry, R.E. (1995)
<i>Peromyscus truei</i>	Herbivore Insectivore	Nocturnal	Field	Natural	Moderate intensities of moonlight depressed activity. In summer activity was positively related to cloud cover.	Scheibe, S.J. (1984)
<i>Peromyscus polionotus</i>	Herbivore Insectivore	Nocturnal	Lab	Manipulative	Twilight changes were the main factor influencing the time when activity began and ended.	Kavanau, L.J. and Rischer, C.E. (1968)
<i>Mustela nivalis</i>	Carnivore	Arrhythmic	Lab	Volitional	Preferred brightest or second-brightest light available.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Mustela frenata</i>	Carnivore	Arrhythmic	Lab	Volitional	Preferred brightest or second-brightest light available.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Genetta genetta</i>	Carnivore	Nocturnal	Lab	Volitional	Two of the Genets preferred brightest or second-brightest light available. One of the Genets behavior did not stabilize over the study period.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Bassariscus astutus</i>	Omnivore	Nocturnal	Lab	Volitional	Preferred brightest or second-brightest light available.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Urocyon cinereoargenteus</i>	Omnivore	Nocturnal	Lab	Volitional	Preferred brightest or second-brightest light available.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Eira barbara</i>	Omnivore	Diurnal	Lab	Volitional	Preferred brightest or second-brightest light available.	Kavanau, L.J. <i>et al.</i> (1973)
<i>Bassariscus astutus</i>	Omnivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Potos flavus</i>	Herbivore Insectivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)

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Table 1. (Continued).

Genus and species	Foraging group	Temporal activity pattern	Lab or field study	Manipulative light level, volitional light level, or natural light experiment	Result of light level experiment	Reference
<i>Nasua narica</i>	Omnivore	Diurnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Genetta genetta</i>	Carnivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Urocyon cinereoargenteus</i>	Omnivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Vulpes vulpes</i>	Omnivore	Arrhythmic	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Vulpes macrotis</i>	Carnivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Alopex lagopus</i>	Carnivore	Arrhythmic	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Canis latrans</i>	Omnivore	Arrhythmic	Lab	Manipulative	Diurnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Canis niger</i>	Carnivore	Arrhythmic	Lab	Manipulative	Arrhythmic activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Mustela frenata</i>	Carnivore	Arrhythmic	Lab	Manipulative	Arrhythmic activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Eira barbara</i>	Omnivore	Diurnal	Lab	Manipulative	Diurnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Galictis vittata</i>	Carnivore	Diurnal	Lab	Manipulative	Diurnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)

<i>Mephitis mephitis</i>	Omnivore	Nocturnal	Lab	Manipulative	Nocturnal activity pattern	Kavanau, L.J. and Ramos, J. (1975)
<i>Peromyscus polionotus</i>	Herbivore Insectivore	Nocturnal	Lab	Natural	Activity inversely related to percentage of moonlight. Shifted activity from open to cover under moonlight periods.	Wolfe, L.J. and Summerlin, C.T. (1989)
<i>Dipodomys merriami</i>	Herbivore Granivore	Nocturnal	Field	Natural	Peak activity occurred 3 hours after sunset and 3 hours before sunrise. Activity decreased as percentage of moonlight increased.	O'Farrell, J.M. (1974)
<i>Dipodomys ordii</i> **	Herbivore Granivore	Nocturnal	Field	Natural	Active after midnight in winter. Trimodal activity pattern in Spring. Bimodal activity, most after midnight, in Summer.	O'Farrell, J.M. (1974)
<i>Dipodomys panamintinus</i>	Granivore	Nocturnal	Field	Natural	Bimodal activity after sunset. Activity low or absent towards sunrise.	O'Farrell, J.M. (1974)
<i>Dipodomys microps</i>	Herbivore Granivore	Nocturnal	Field	Natural	Trimodal activity after sunset in Winter and Spring. Bimodal activity after sunset in Summer.	O'Farrell, J.M. (1974)
<i>Onychomys torridus</i>	Omnivore	Nocturnal	Field	Natural	Active in middle and late night.	O'Farrell, J.M. (1974)
<i>Peromyscus maniculatus</i> *	Omnivore	Nocturnal	Field	Natural	Bimodal activity after sunset. Activity low or absent towards sunrise.	O'Farrell, J.M. (1974)
<i>Perognathus longimembris</i>	Herbivore Granivore	Nocturnal	Field	Natural	High peak of activity two hours after sunset. Bimodal activity in the Spring.	O'Farrell, J.M. (1974)
<i>Chaetodipus formosus</i>	Herbivore Granivore	Nocturnal	Field	Natural	Highest activity two hours after sunset. No activity 6 hours after sunset.	O'Farrell, J.M. (1974)

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Table 1. (Continued.)

Genus and species	Foraging group	Temporal activity pattern	Lab or field study	Manipulative light level, volitional		Result of light level experiment	Reference
				light level, or natural light	experiment		
<i>Microdipodops megacephalus</i>	Granivore Insectivore	Nocturnal	Field	Natural	Natural	High peak of activity two hours after sunset. Males have bimodal and crepuscular activity in Summer.	O'Farrell, J.M. (1974)
<i>Reithrodontomys megalotis</i>	Omnivore	Nocturnal	Field	Natural	Natural	Highest activity two hours after sunset.	O'Farrell, J.M. (1974)
<i>Dipodomys merriami</i>	Herbivore Granivore	Nocturnal	Lab	Manipulative/No Natural Light	Manipulative/No Natural Light	Activity was lower under open habitat under bright illumination.	Longland, S.W. and Price, M.V. (1991)
<i>Microdipodops megacephalus</i>	Granivore Insectivore	Nocturnal	Lab	Manipulative/No Natural Light	Manipulative/No Natural Light	Activity was lower under open habitat under bright illumination.	Longland, S.W. and Price, M.V. (1991)
<i>Chaetodipus baileyi</i>	Omnivore	Nocturnal	Lab	Manipulative/No Natural Light	Manipulative/No Natural Light	Activity was lower under open habitat under bright illumination.	Longland, S.W. and Price, M.V. (1991)
<i>Chaetodipus fallax</i>	Herbivore Insectivore	Nocturnal	Lab	Manipulative/No Natural Light	Manipulative/No Natural Light	Activity was lower under open habitat under bright illumination.	Longland, S.W. and Price, M.V. (1991)
<i>Bassariscus astutus</i>	Omnivore	Nocturnal	Lab	Natural	Natural	Twilight had a strong influence on the phasing of the species.	Kavanau, L.J. and Ramos, J. (1972)
<i>Potos flavus</i>	Herbivore Insectivore	Nocturnal	Lab	Natural	Natural	Twilight had a strong influence on the phasing of the species.	Kavanau, L.J. and Ramos, J. (1972)
<i>Genetta genetta</i>	Carnivore	Nocturnal	Lab	Natural	Natural	Twilight had a strong influence on the phasing of the species.	Kavanau, L.J. and Ramos, J. (1972)
<i>Glaucomys volans</i>	Omnivore	Nocturnal	Lab	Volitional	Volitional	Active in very dim light.	Kavanau, L.J. and Haverhill, R.M. (1976)

<i>Microtus californicus</i>	Herbivore	Nocturnal	Lab	Volitional	Activity peaked in darkness and 15% of starlight.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Microtus pennsylvanicus</i>	Herbivore Insectivore	Nocturnal	Lab	Volitional	Activity peaked in darkness and 15% of starlight.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Neotoma lepida</i>	Herbivore	Nocturnal	Lab	Volitional	Active at 50% of full moon illuminance to 3 times full moon illuminance.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Podomys floridanus</i>	Herbivore Insectivore	Nocturnal	Lab	Volitional	Activity peaked at 2% of full moon.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Peromyscus californicus</i>	Herbivore Insectivore	Nocturnal	Lab	Volitional	Activity peaked at 3 times full moon.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Thomomys bottae</i>	Herbivore	Nocturnal	Lab	Volitional	Spent active time in total darkness or in very low light.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Peromyscus crinitus</i>	Herbivore Insectivore	Nocturnal	Lab	Volitional	Active at 50% of full moon illuminance to 18 times full moon illuminance.	Kavanau, L.J. and Havenhill, R.M. (1976)
<i>Peromyscus maniculatus*</i>	Omnivore	Nocturnal	Lab	Manipulative	Significantly reduced activity in full moon in presence of predator.	Clarke, A.J. (1983)

*Found in Ocelot Scat; ** Found in Ocelot Habitat.

change like those of rodents—which show a sharp and consistent dependency on luminance. In a field study that investigated the effects of the moon's luminance on Ocelot movement and their primary prey, spiny rats (*Proechimys*: Rodentia, Echimyidae) in Peru, Emmons (1989) recorded tracks of each species along roadside trails and radio-collared individuals of each species. The results for each species indicate that their activity levels were not influenced by the moon's luminance, however, they were changing their behavior so as to be hidden from view on trails during bright nights. Therefore, ample cover that essentially shields nightlight was critical during full moon periods.

Similarly, radio-collared mountain lions (*Puma concolor*) in California usually avoid habitat corridors that contain artificial lights (Beier, 1995). During overnight monitoring, mountain lions made consistent movements in the direction of the darkest horizon. Dispersers especially avoided night-lights in conjunction with open terrain (Beier, 1995).

In summary, these studies share a common conclusion about the effects of night lighting on nocturnal and crepuscular species: activity levels either cease entirely as the result of night luminance or shift to covered habitat that provides a shield from the effects of night lighting. Hypotheses based on these conclusions would predict that activity patterns for Ocelots and their nocturnal prey would be altered under artificial night lighting conditions. These animals would be expected to either reduce evening activity levels or redirect their evening activity towards areas with dense vegetation. Although we currently do not know the effect of night lighting on ocelot foraging success, it is likely that this too would be altered as a result of turning night into day.

Effects of artificial night lighting on ocelots in Texas

Indeed, ocelots in south Texas are most active during 2000 to 0500 hours. They live almost exclusively in thorn forest communities, which are characterized by an extremely dense woody under story (Laack, 1991). During dispersal, Laack (1991) observed Ocelot movement in forest corridors rather than in open habitat—even if forest routes added considerable distance to their final destinations. Shindle (1995) hypothesized that thorn forest communities provide both structural cover and low-light environments for ocelots.

At present, approximately 186 portable lights and 235 permanent lights are operating along 52.4 miles of the Rio Grande River due to Operation Rio Grande (U.S. Fish and Wildlife Service, 2002). These lights are dispersed amongst protected brush tracts of LRGNWR. Each light uses 1–4 bulbs ranging from 400–1000 watts (U.S. Fish and Wildlife Service, 2002). Both Ocelots and their prey would need to travel across open, lighted areas to move between protected areas of LRGNWF. If activity patterns of Ocelots are similar to the activity patterns of their nocturnal prey species, as has been suggested (Emmons, 1987; Emmons *et al.*, 1989), their movement will either cease or be redirected towards covered areas (i.e. areas with vegetative density) during nights of high luminance. Illumination and noise generated from diesel powered portable lights may in fact cause Ocelots to seek other travel corridors, however limited these are. Portable lighting is found along approximately 31.6 miles of the Rio Grande River and more portable lights may be added in the future (U.S. Fish and Wildlife Service, 2002).

The Texas Ocelot population may be further hindered by a reduction in the number of Ocelots emigrating from Mexico. Ocelots from Mexico have crossed the Rio Grande River and entered the United States (U.S. Fish and Wildlife Service, 2002). However, illumination and noise from permanent and portable lights may deter Ocelots in Mexico from crossing the Rio Grande River (U.S. Fish and Wildlife Service, 2002).

Despite commendable efforts on the part of LRGNWR, protected habitats separated by areas with little cover from artificial night lighting may be of little use for nocturnal species. Possible alteration of rodent activity patterns and/or reduction in the availability of rodents due to artificial night lighting may be hindering the recovery of Ocelots in Texas. To improve this condition, corridors located between refuge tracks should either contain no artificial night lighting or provide animals with enough habitat cover such that little to no light can penetrate, and movement between protected refuge tracks can occur.

Discussion

The main threat to the survival of the Ocelot in the United States is habitat alteration (U.S. Fish and Wildlife Service, 1990), yet *Critical Habitat*, that which is essential for conservation of the species, has not been designated. Critical Habitat has not been designated because poachers may learn of the exact locations of ocelots plus habitat is already protected on the LANWR (U.S. Fish and Wildlife Service, 1982).

The lack of designated Critical Habitat has created a paradoxical Ocelot management strategy along the Rio Grande River. Habitat alteration due to Operation Rio Grande is not expected to jeopardize the existence of Ocelots along the Rio Grande River because no Critical Habitat has been designated for the species (U.S. Fish and Wildlife Service, 2002).

Critical Habitat for Ocelots must be designated in Texas. Once designated, this habitat would be protected and enhanced to promote continued use by Ocelots (U.S. Fish and Wildlife Service, 1990). Designating Ocelot Critical Habitat will require a greater understanding of the associations between predator and prey species (U.S. Fish and Wildlife Service, 1990) and how factors such as artificial night lighting might affect movement patterns of Ocelots and their prey.

By reviewing previous studies, it is possible to generate hypotheses about the effects of night lighting on nocturnal and crepuscular species, such as the Ocelot and their rodent prey. Activity patterns of both will undoubtedly be altered, either ceasing entirely or shifting to other protected habitats that shield the effects of artificial night lighting.

Ocelot Critical Habitat designation in the Lower Rio Grande Valley should provide ample cover for Ocelots and their prey in protected areas and in non-protected corridor areas that connect protected refuge tracks. Doing so will provide nocturnal species with movement opportunities associated with foraging, mating, rearing of young, and dispersal.

Future directions

While ocelots in Texas are endangered species and difficult to study, the hypotheses we generated could be tested on surrogate species, such as bobcats (*Lynx rufus*) or feral cats (*Felis catus*), and nocturnal prey species that inhabit the international border. Future studies

could include experiments with night-lights by placing them around the periphery of refuge tracts. These studies could document whether refuge tracts are used more and whether movement between refuge tracts is reduced during evenings when artificial night lighting occurs. A crucial aspect of this research could include information on intensity of light—specifically, whether there is a threshold of night lighting beyond which activity patterns change. Is all night lighting detrimental, per se, or just certain intensities of it? In addition, foraging studies should be initiated on surrogate species. By quantifying activity, one could hypothesize if feral cats, for example, have reduced levels of foraging success when artificial night lighting occurs.

References

- Beier, P. (1995) Dispersal of juvenile cougars in fragmented habitat. *Journal of Wildlife Management* **59**(2), 228–237.
- Bisbal, F.J. (1986) Food habits of some neotropical carnivores in Venezuela (Mammalia, Carnivora). *Mammalia* **50**, 329–339.
- Blair, F.W. (1943) Activities of the Chihuahua deer-mouse in relation to light intensity. *Journal of Wildlife Management* **7**, 92–97.
- Bruseo, J.A. and Barry Jr., R.E. (1995) Temporal activity of synoptic *Peromyscus* in the central Appalachians. *Journal of Mammalogy* **76**, 78–82.
- Bureau of Citizenship and Immigration Services. (2002) McAllen border patrol sector. <http://www.immigration.gov/graphics/shared/fieldoffices/sectors/Mcallen/aboutus.htm> viewed 2/24/2003.
- Bureau of Citizenship and Immigration Services. (2002) Overview of the U.S. border patrol. <http://www.immigration.gov/graphics/shared/lawenfor/bpatrol/overview.htm> viewed 2/25/2003.
- Clarke, J.A. (1983) Moonlight's influence on predator/prey interactions between short-eared owls (*Asio flammeus*) and deer mice (*Peromyscus maniculatus*). *Behavioral Ecology and Sociobiology* **13**, 205–209.
- Davis, W.B. and Schmidly, D.J. (1997) The mammals of Texas: Online edition. <http://www.nsr.ttu.edu/tmot1/Default.htm> viewed 12/20/02.
- De Villa Meza, A., Meyer Martinez, E. and Lopez Gonzalez, C.A. (2002) Ocelot (*Leopardus pardalis*) food habits in a tropical deciduous forest of Jalisco, Mexico. *American Midland Naturalist* **148**, 146–154.
- Emmons, L.H. (1987) Comparative feeding ecology of felids in a neotropical rainforest. *Behavioral Ecology and Sociobiology* **20**, 271–283.
- Emmons, L.H., Sherman, P., Bolster, D., Goldizen, A. and Terborgh, J. (1989) Ocelot behavior in moonlight. In *Advances on Neotropical Mammalogy* (K.H. Redford and J.F. Eisenberg, eds.), pp. 233–242. The Sandhill Crane Press, Inc., Florida.
- Grigione, M.M., Caso, A., List, R. and Gonzalez-Lopez, C. (2001) Status and conservation of endangered cats along the U.S.-Mexico border. *The Endangered Species Update* **18**, 129–132.
- Kaufman, D.W. and Kaufman, G.A. (1982) Effect of moonlight on activity and microhabitat use by ord's kangaroo rat (*Dipodomys ordii*). *Journal of Mammalogy* **63**(2), 309–312.
- Kavanau, J.L. (1968) Activity and orientational response of white-footed mice to light. *Nature* **218**, 245–252.
- Kavanau, J.L. and Havenhill, R.M. (1976) Compulsory regime and control of environment in animal behavior. Light level preferences of small nocturnal mammals. *Behavior* **59**, 203–225.
- Kavanau, J.L. and Rischer, C.E. (1968) Program clocks in small mammals. *Science* **161**, 1256–1259.
- Konecny, M.J. (1989) Movement patterns and food habits of four sympatric carnivore species in Belize, Central America. In *Advances on Neotropical Mammalogy* (K.H. Redford and J.F. Eisenberg, eds.), pp. 243–264. The Sandhill Crane Press, Inc., Florida.
- Laack, L.L. (1991) Ecology of the ocelot (*Felis pardalis*) in south Texas. Master's Thesis. Texas A&I University, Texas.
- Lockard, R.B. and Owings, D.H. (1974) Seasonal variation in moonlight avoidance by bannertail kangaroo rats. *Journal of Mammalogy* **55**(1), 189–193.

- O'Farrell, M. (1974) Seasonal activity patterns of rodents in a sagebrush community. *Journal of Mammalogy* **55**, 809–822.
- Price, M., Waser, V., Nickolas M. and Bass, T.A. (1984) Effects of moonlight on microhabitat use by desert rodents. *Journal of Mammalogy* **65**(2), 353–356.
- Shindle, D.B. (1995) Habitat use of ocelots in the Tamaulipan biotic province. Master's Thesis. Texas A&M University, Texas.
- Strayhorn, C.K. Window on state government: The south Texas border region. June 2002 update. Texas comptroller of public accounts. [Http://www.window.state.tx.us/ecodata/regional/stxborder/outlook.html](http://www.window.state.tx.us/ecodata/regional/stxborder/outlook.html) viewed 3/4/2003.
- Tewes, M.E. and Everett, D.D. (1986) Status and distribution of the endangered ocelot and jaguarondi in Texas. In *Cats of the World: Biology, Conservation, Management* (S.D. Miller and D.D. Everett, eds.), pp.147–158. National Wildlife Federation, Washington, D.C.
- Tewes, M.E. and Shindle, D.B. (1997) Factors influencing activity patterns of ocelots. In *Current Research of the Caesar Kleberg Wildlife Research Institute July1, 1996 to June 30, 1997* (A.M. Fedynich, ed.), p. 31. Texas A&M University-Kingsville, Texas.
- Tewes, M.E., Young, J., Laack, L.L. and Hayslette, S.E. (1997) Dietary overlap of co-occurring ocelots and bobcats. In *Current Research of the Caesar Kleberg Wildlife Research Institute July1, 1996 to June 30, 1997* (A.M. Fedynich, ed.), p. 37. Texas A&M University-Kingsville, Texas.
- U.S. Fish and Wildlife Service. (1982) Endangered and threatened wildlife and plants; endangered status for the U.S. population of the ocelot. *Federal Register* **47**, 31670–31672.
- U.S. Fish and Wildlife Service. (1990) Listed cats of Texas and Arizona (with emphasis on the ocelot). U.S. Fish and Wildlife Service, New Mexico.
- U.S. Fish and Wildlife Service. (2002) Draft biological opinion for operation Rio Grande. U.S. Fish and Wildlife Service, Texas.
- Wolfe, J.L. and Summerlin, C.T. (1989) The influence of lunar light on nocturnal activity of the old-field mouse. *Animal Behaviour* **37**, 410–414.