Birds and fish as bioindicators of tourist disturbance in springs in semi–arid regions in Mexico: a basis for management

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Palacio–Núñez, J., Verdú, J. R., Galante, E., Jiménez–García, D. & Olmos–Oropeza, G., 2007. Birds and fish as bioindicators of tourist disturbance in springs in semi–arid regions in Mexico: a basis for management. *Animal Biodiversity and Conservation*, 30.1: 29–41.

Abstract

Birds and fish as bioindicators of tourist disturbance in springs in semi–arid regions in Mexico: a basis for management.— Tourist disturbance in semi–arid springs was analysed; birds and fish were selected as bioindicators. Media Luna spring is the biggest and most spatially complex system in the region, with the highest biodiversity levels and tourist use. Areas with the highest bird species richness and abundances showed highest structural heterogeneity and least direct human impact. No differences in species richness of fish were observed between sectors and the most abundant species were found in the sectors least perturbed by human activity. Factors that explained the bird distribution were the species´ tolerance to the effects of direct tourism (noise and direct presence of people) and habitat quality, mainly riparian vegetation. Aquatic vegetation condition was very important for fish. Six bird species and two fish species were relevant as indicators of the habitat quality related to human impact. Anthropic disturbance such as tree plantation favoured some bird species, whereas aquatic vegetation removal was favourable for some fish species, such as the endemic *Cichlasoma bartoni,* however, both types of disturbance were unfavourable for other species; riparian vegetation removal was negative for both groups. Controlled tourism promotes good conditions for *C. bartoni* establishment. Efficient conservation measures such as limiting touristic distribution are necessary for all species, especially for the fish community, in order to conserve biodiversity in general.

Key words: Wetlands, Species distribution, Threatened species, Endemism, Habitat loss, Spatial heterogeneity, Bioindicators.

Resumen

Aves y peces como bioindicadores de las alteraciones debidas al turismo en manantiales de zonas semiáridas en México: bases para la gestión.— Para analizar las alteraciones por el turismo en manantiales de zonas semiáridas se utilizaron aves y peces como bioindicadores. Se seleccionó el manantial de la Media Luna por ser el más grande y complejo, y por incluir la más alta biodiversidad y el mayor impacto turístico en la zona. Los sectores con alta diversidad y abundancias de aves fueron los que tienen la mayor heterogeneidad estructural y menor impacto humano directo. Las mayores abundancias de peces se encontraron en los sectores menos perturbados sin diferencias para la riqueza de especies. Los factores que explicaron la distribución de las aves fueron la tolerancia de las especies a los efectos directos del turismo (ruido y presencia directa de gente) y la calidad del hábitat, principalmente la vegetación ribereña. La condición de la vegetación acuática fue muy importante para los peces. Seis especies de aves y dos de peces fueron relevantes como indicadores de la calidad del hábitat en función del impacto humano. Las alteraciones antrópicas tales como la plantación de árboles favoreció a algunas especies de aves mientras que la eliminación de la vegetación acuática fue favorable para algunos peces como el endémico *Cichlasoma bartoni*, pero estas alteraciones fueron negativas para otras especies; la eliminación de la vegetación ribereña tuvo efectos negativos para ambos grupos. El turismo controlado crea condiciones favorables para *C. bartoni*. Para la conservación de la biodiversidad en general, se requieren medidas eficientes de conservación tales como la restricción geográfica del turismo especialmente importante para la comunidad de peces.

ISSN: 1578–665X

Palabras clave: Humedales, Distribución de las especies, Especies amenazadas, Endemismos, Pérdida de hábitat, Heterogeneidad espacial, Bioindicadores.

(Received: 6 IX 06; Conditional acceptance: 31 X 06; Final acceptance 7 II 07)

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Introduction

Arid and semi–arid zones have limited water resources. The few existing springs are usually isolated, relict in nature, and in poor condition. They may contain endemic fish species with restricted distribution, sometimes limited to a single spring (Contreras–Balderas, 1969). Freshwater environments are especially susceptible to modifications such as overexploitation, pollution and aloctone species introduction, the main factors affecting biodiversity (Cooperrider & Noss, 1994; Curtis et al., 1998). The increasing transformation that such environments are subjected to has negative consequences for ictiofauna and riparian biodiversity in general (Mensing et al., 1998; Fu et al., 2003), as well as for local biodiversity (Angermeier & Schlosser, 1995). An important source of disturbance is tourism. Tourism is an important means of income in Mexico but it is causing increasing environmental degradation in many places due to the lack of planning and preventive measures. Ecotourism strategies related to natural resources, participation of local people and visitor education (e.g. Boo, 1992; Ross & Wall, 1999; Burger, 2000) must be established and adapted to the particular conditions such as the Media Luna system. Media Luna has been used increasingly by tourists since the 1950s (Michelet, 1996), leading to continuous disturbances and transcendental changes during the 1960s and 1970s with the introduction of exotic fish and trees species (Palacio–Núñez, 1997).

The state of an area's conservation can be well evaluated on the basis of bioindicators selected from previous data (Randall, 1992), but this is not usually possible for most protected ecosystems (Heino et al., 2005). Consequently, threatened or endemic species, or other sensitive species are frequently used as indicators (Rubinoff & Powell, 2004). Different indicators cannot lead to the same responses (Duelli & Obrist, 2003) and different combinations of biological and ecological groups have been used (Van Rensburg et al., 2000; Heino et al., 2005; Pineda et al., 2005). Birds (Pyrovetsi & Papastergiadou, 1992; Browder et al., 2002) and fish (Heino et al., 2005; Fu et al., 2003) are important groups as indicators as both have at least the following points in common: 1) individual species are associated with singular habitats, 2) most are short–lived species so any change in their composition may manifest shortly after a disturbance, and 3) some species groups can be used to develop habitat associations which are predictors of relative human disturbance levels, and both groups may be affected by some tourist activities (e.g. Tershy et al., 1997; Higginbottom et al., 2003; Newsome et al., 2004).

Bioindicators most commonly used to estimate effects of habitat transformation on biodiversity are arthropods (Micó et al., 1998; Verdú et al., 2000; Bestelmeyer & Wiens, 2001) or vertebrates (e.g. Flather et al., 1997) such as birds (e.g. Fleishman et al., 2001), mammals (e.g. Lomolino et al., 1989) or fish (e.g. Heino et al., 2005). The location we chose was the Media Luna spring because it is the biggest and the most representative spring in the Rioverde valley, with high tourist affluence and biodiversity (Miller, 1984; Palacio–Núñez, 1997). It includes several bird species and some endemic fish species, mainly the monospecific *Cualac* and *Ataeniobius* genus (Miller, 1984; Contreras–Balderas, 1969). Media Luna was declared a State Park in 2003 due to its biological importance and state of conservation (SEGAM, 2003), but more basic management and ecological research are required. This paper aims to determine the impact of tourism and management on springs in semi–arid areas, using birds and fish as bioindicators, and to propose suggestions for management strategies which should be followed in order to preserve biodiversity in such locations.

Methods

Study area

The Media Luna system is located in the Rioverde Valley, San Luis Potosí, Mexico (between X UTM: 393723 & 395317 and Y UTM: 2417647 & 2418070 coordinates, zone 14 N), at an average altitude of 1,000 m a.s.l. It is a complex of spring–lakes (Media Luna and Los Anteojitos) and channels or rivers with permanent water, two seasonal lakes, and flooding zones with lateral infiltrations which maintain a wet environment at variable distances from the source. This effect contrasts with the aridity of the plain. Media Luna is the largest spring lake (with 15 springs) in the valley and consists of six spring craters that provide a constant flow of about 5,000 l s^{-1} crystalline thermal water (Miller, 1984; Labarthe et al., 1989) that flows through three main channels (fig. 1). These wetlands are an important refuge for many aquatic and riparian bird species (IIZD, 1994). A total of 13 sectors were established for the lake and channels, according to their vegetation and environmental variability, and they are subject to variable anthropic pressure (Palacio–Núñez, 1997).

Riversides contain zones with dense and scarce allochthonous woodland and other zones with native vegetation dominated by *Panicum bulbosum* Kunth and *Andropogon glomeratus* (Walt) BSP grasses (table 1). Riparian vegetation has previously been classified in a range between 0 (bare ground) to 5 for excellent conditions. Aquatic vegetation has been classified between 0 to 3. This vegetation is highly dominated by *Nymphaea* sp. and has two structural forms: 1) big size plants with isolated bases and floating leaves, and 2) small size plants with high population density, creating a close dense layer at leaf level (Palacio–Núñez et al., 1999).

Sampling design

Increasing relevance is being given to the use of spatial scales as bioindicators and the effect of habitat structure on the dynamics of animal and vegeta-

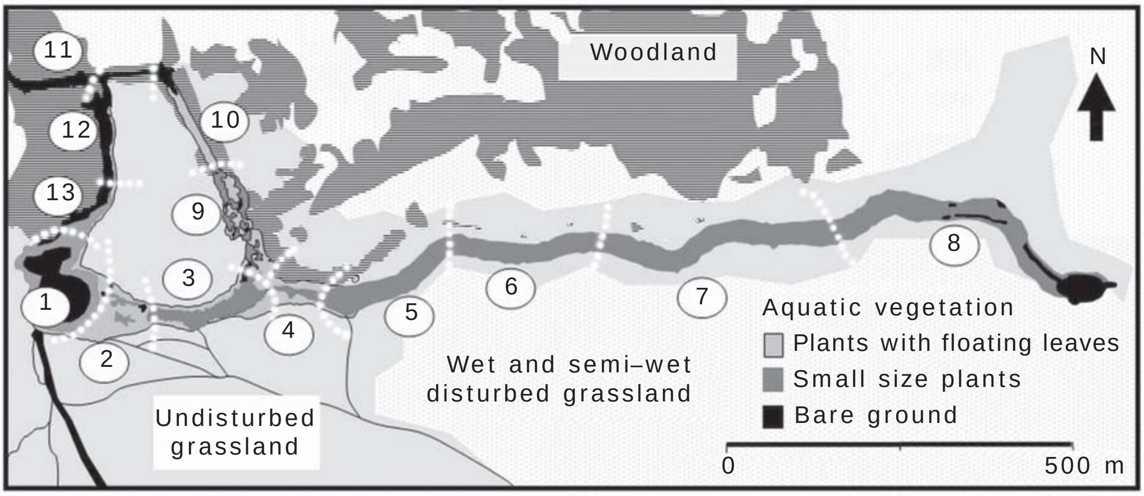

Fig. 1**.** Study area map with aquatic vegetation and adjacent grassland and woodland vegetation. Circled numbers indicate sectors and white lines indicate sector limits.

Fig. 1. Mapa del área de estudio mostrando la vegetación acuática y la vegetación adyacente de pastizal y de arbolado. Los círculos con número indican los sectores y las líneas blancas indican los límites de los sectores.

tion populations, but bioindicators can only show some environmental peculiarities (Duelli & Obrist, 2003). As bird and fish species in Media Luna have different origins, habitat requirements and risks of extinction (table 2) they were used to seek the widest possible environmental representation.

Bird sampling was carried out on monthly field visits between November 1996 and May 1997. Under seasonal variability and two conditions of tourist presence, a single transect was repeated 39 times across the entire 2,498 m distance covering all the Media Luna System sectors. Transect repetitions were made in an inflatable boat and we counted the total number of birds observed through binoculars in each transect. The two cited conditions were based on visitor presence: without people (WP, when there was nobody in the area), with n = 24 transects, and with people (P, when there were people present), with n = 15 transects.

Fish sampling considered three factors: 1) the population of some fish species was very low so it was not appropriate to carry out captures; 2) fish were not distributed among different levels of the water column, but always near the bottom or the banks between *Nymphaea* sp. stems, or over the vegetation cover (fish do not go under leaves of small plants); and 3) the great clarity of the water and the few visual obstacles allowed species sighting and count, even in the case of juveniles (Palacio–Núñez, 1997). Faced with this situation and to avoid altering populations, we carried out the sampling in 54 subaquatic transects; these transects were repeated five times on seasonal visits in spring and summer 1998, winter 1998–99, and summer and autumn 1999. We adapted the Finland transect of Järvinen & Väisänen (Tellería, 1986) for subaquatic use in free diving, determining each transect as 10 m long and 2 m fixed width (20 m^2). We traced each transect with orange cord in a perpendicular position to the riparian line. We made three repetitions per riverside, per sector.

Biodiversity analysis

We constructed species–accumulation curves to assess the adequacy of our sampling. Species–accumulation curves relate sampling effort to the cumulative number of species to evaluate sampling effectiveness (e.g. Longino & Colwell, 1997; Gering et al., 2003). Species accumulation curves and richness estimators (Chao 2, Jack 1 and ACE) were calculated using EstimateS 7.0 (Colwell, 2000).

The rarefaction technique corrects unbalanced sample sizes, the main problem in diversity comparisons (Gart et al., 1982). For different sample sizes for birds, we calculated species richness expected for each situation WP or P through rarefaction curves for 1,000 randomizations, using EcoSim 7.0 software (Gotelli & Entsminger, 2001). For fish, sampling size was identical (see above), so rarefaction was not used.

Statistical analysis

To evaluate population distribution of the bioindicator groups in the sectors, we used the

Kruskal–Wallis non–parametric test (KW) with the STATISTICA package (StatSoft, 2001), and multiple comparisons of average range pairs using the Dunn test (Gardiner, 1997). We analysed bird and fish abundance and richness; in both WP and P conditions for birds. Interrelationships among birds and fish in each sector (for both WP and P conditions) were analysed by a Factorial Correspondence Analysis (FCA), using the STATISTICA software. For each sampling site we used the relative abundance of each species. FCA is an ordination–multivariate technique which simultaneously arranges species and habitats. As there was no discontinuity between habitats, they were grouped in ecological series, thus reducing complex patterns into simple and interpretable forms (Braak, 1985; Moreno, 2000).

Results

Species richness

Accumulation curves showed 20 bird species for both conditions WP and P. Eleven fish species were present in the 13 sectors of the Media Luna. There are two particular species of the *Cichlasoma* genus that could not be differentiated and were thereforeanalysed together (*C. labridens* + *Cichlasoma* sp.). Our inventories showed 100% completeness for both bioindicator groups according to the Chao 2, Jack 1 and ACE estimators. Bird species richness was statistically different between both WP and P conditions (fig. 2).

Species distribution among sectors

Species richness and abundance of bird species distribution were statistically different among sectors. Differences in fish abundance were also significant but species richness was statistically indistinguishable among sectors (see table 3 for KW probabilities).

The largest differences in the Dunn and KW test in bird species richness and abundance were between sectors 9 and 4 (highest figures), and sectors 13, 11 and 12 (the poorest; fig. 3). In these five sectors there is woodland presence but, in sectors 9 and 4 there is little human impact and riparian grassland. Sectors 13, 11 and 12 have no grassland and human impact is very high (see table 1, fig. 1).

Species richness between sectors 8 and 3 (without woodland and low human impact) was statistically non–significant compared with the high richness sectors, whereas sectors 1 and 10 (with woodland and very high human impact) were similar to the poorest sectors.

For fish abundance the greatest differences were observed between sector 4, with dense aquatic vegetation coverage and highest abundance values, and the poorest 12, 13 and 1 sectors (fig. 4) with scarce *Nymphaea* sp. coverage.

Species distribution among sectors was confirmed by species grouping in the FCA analysis. Bird species ordination showed three main groups for both WP and P conditions related to axis 1 (fig. 5). In the WP plot the first two axes accounted for 64.6% of the variance in the data (fig. 5A). According to the distribution of sectors and species, axis 1 could be explained as the level of disturbance originated by tourists. In this sense, the first species group was determined by low human impact (sectors 6, 7 and 8, see table 1) with the more intolerant species such as *Bubulcus ibis* and *Anas diazi*. The second species group (*Ardea herodias* and *Casmerodius albus*) corresponded to intolerant species and was related to the well–conserved sector 5, whereas the third group containd generalist species such as *Phalacrocorax olivaceus* and *Podylimbus podiceps* in the most disturbed sectors (1, 11, 12 and 13) and well conserved (2, 3, 4, 9 and 10) sectors. In the P plot, the first two axes

Table 1. Characteristics of the sectors (S) of Media Luna system for aquatic area (A, in ha), physical variables (W, woodlands), estimated human environmental impact (HI), state of riparian vegetation (RV) and terrestrial vegetation (TV) (qualification average). Sectors with low human impact show high riparian and aquatic vegetation quality.

Tabla 1. Características de los sectores del sistema de la Media Luna para el área acuática (A, en ha), variables físicas (W, bosques), impacto ambiental antrópico estimado (HI) y estado de la vegetación ribereña (RV) y de la vegetación terrestre (TV) (calificación media). En general los sectores con bajo impacto humano mostraron los valores más altos en la calificación de ambos tipos de vegetación.

S	A	W	HI	RV	TV
1	1.379	Yes	Very high	2.35	0.86
2	0.619	No	Very low	4.75	2.78
3	0.637	No	Very low	4.90	2.66
4	0.389	Yes	Very low	5.00	2.78
5	0.687	Yes	Very low	4.63	2.79
6	0.607	No	Very low	3.65	2.93
7	1.219	No	Very low	3.45	2.96
8	1.513	No	Low	2.90	2.78
9	0.606	Yes	Very low	5.00	2.35
10	0.251	Yes	High	3.65	2.10
11	0.216	Yes	Very high	0.40	0.20
12	0.271	Yes	Very high	2.18	0.45
13	0.235	Yes	Very high	2.17	0.43

Table 2. List of the 20 bird and 11 fish species and taxonomic family found in the Media Luna system. Abbreviations (Abbr) used in this study, origin information (O) and extinction risk (ER) according to the Mexican Red List NOM 059 (INE, 2002) and IUCN Red List (2004). Bird list based on Peterson & Chalif (1989), and fish list based on List for Mexican Fish of Espinosa Pérez et al. (1993). For birds habitat requirements (HR): SW. Superficial water; DP. Open water for dive with close rocks or trunks for perching; OW. Open water; P. Branches or rocks close to the water; FV. Floating vegetation; BT. Big trees near the water. For population status (PS): T. Threatened; E. Endangered; CR. Critically endangered; V. Vulnerable. [1]These two species of fish are reported together

Tabla 2. Lista de las 20 especies de aves y las 11 de peces habitantes del sistema de la Media Luna. Se señalan las abreviaturas (Abbr) utillizadas en este trabajo, información sobre el origen (O) de las especies así como su situación de riesgo de extinción (ER) de acuerdo con la NOM 059 (INE, 2002) y la lista roja de UICN (2004). El listado de aves está basado en Peterson & Chalif (1989) y el de peces está basado en la Lista de Peces Mexicanos de Espinoza Pérez et al. (1993). (Para otras abreviaturas ver arriba.)

						ER	
	Family	Species	Abbr	O	HR	NOM	IUCN
Birds							
	Ardeidae	*Casmerodius albus* L	alb	Native	SW	–	–
		Nycticorax nycticorax L	nyc	Native	SW	–	–
		Ardea herodias L	her	Native	SW	–	–
		Butorides striatus Rackett	str	Native	SW	–	–
		Bubulcus ibis L	ibi	Exotic	SW	–	–
		Egretta thula Medina	thu	Native	SW	–	–
		E. caerula L	cae	Native	SW	–	–
		E. tricolor Müller	tri	Native	SW	–	–
		N. violacea L	vio	Native	SW	T	–
	Ciconiidae	*Mycteria americana* L	mam	Native	SW	T	–
	Phalacrocoracidae	*Phalacrocorax olivaceus* Humboldt	oli	Native	DP	–	–
	Anhingidae	*Anhinga anhinga* L.	anh	Native	DP	–	–
	Anatidae	*Dendrocygna autumnalis* L	aut	Native	OW	–	–
		Anas diazi Ridgway	dia	Native	OW	–	–
	Podicipedidae	*Podylimbus podiceps* L	pod	Native	OW	–	–
	Rallidae	*Fulica americana* Gmelin	fam	Native	OW	–	–
	Alcedinidae	*Ceryle alcyon* L	alc	Native	B	–	–
		C. torquata L	tor	Native	B	–	–
	Jacanidae	*Jacana spinosa* L	spi	Native	FV	–	–
	Pandionidae	*Pandion haliaetus* L	hal	Native	BT	–	–
Fish							
	Characidae	*Astyanax mexicanus* Filippi	Af	Native	None	–	–
	Cyprinidae	*Dionda dichroma* Hubbs y Miller	Dd	Endemic	Unknown	T	V
	Cyprinodontidae	*Cualac tessellatus* Miller	Ct	Endemic	Unknown	E	E
	Goodeidae	*Ataeniobius toweri* Meek	At	Endemic	Unknown	E	E
	Cichlidae	*Cichlasoma bartoni* Bean	Cb	Endemic	Unknown	E	V
		C. labridens Pellegrin	Cl[1]	Endemic	Unknown	T	E
		Cichlasoma sp.	Cl[1]	Endemic	Unknown	E	–
		C. cyanoguttatum Bird and Girard	Cc	Introduced	Unknown	–	–
		Oreochromis sp.	Ta	Exotic	None	–	–
	Poecilidae	*Gambusia panuco* Hubbs	Gp	Introduced	Unknown	–	–
		Poecilia mexicana Steindachner	Pm	Introduced	Unknown	–	–
		P. latipunctata Meek	Pl	Introduced	Unknown	E	CR

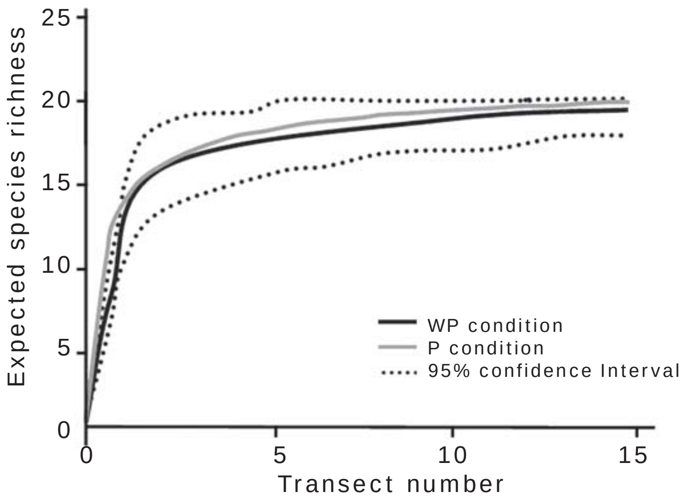

Fig. 2. Rarefaction curves for birds in the sectors of Media Luna in P (with people) and WP (without people) conditions. Comparisons were made for n = 15 transects and 1,601 individuals observed in WP condition, with 20 bird species in both conditions. There was no statistical difference; both conditions are in the confidence interval of 95% curves.

Fig. 2. Curvas de rarefacción para las aves de la Media Luna en condiciones P (con gente) y WP (sin gente). Las comparaciones fueron hechas para n = 15 transectos y 1.601 individuos observados en condición sin gente, con 20 especies en ambas condiciones. No se encontró diferencia estadística; ambas condiciones se encuentran dentro de las curvas del intervalo de confianza al 95%.

accounted for 55.35% of variance (see fig. 5B). Sectors 5 and 6 were the least susceptible to people presence and some intolerant species such as *Fulica americana* and *Pandion haliaetus* from the first group (in WP condition), and *Dendrocygna autumnalis* from the third group were redistributed in the second group in condition P.

The first two axis from FCA accounted for 66.7% of the variance in the fish data (fig. 6). The fish community showed three main groups. The first group was represented by *Cichlasoma bartoni* and *Oreochromis* sp. and was related to the most disturbed sectors (1, 11, 12 and 13). A second group corresponded to the most generalist species such as *Astyanax mexicanus*, *Cichlasoma labridens* and *C. cyanoguttatum*, and is related to sectors 2 and 10; these species did not show special requirements. *Dionda dichroma* was only observed in sector 10. The third group contained the best conserved sectors; *Ataeniobius toweri* only appeared related to sectors with well established sub–aquatic vegetation (sector 3, 4, 5, 6, 7, 8 and 9).

Discussion

Sector characteristics were reflected by species distribution and abundance of bioindicator groups. Vegetation and other structural habitat variables are important to determine bird abundance (Read

Table 3. Kruskal–Wallis results for specific richness and abundance distribution of birds and fish among sectors in the Media Luna. All results were significant except fish species richness: Bg. Bioindicator group; C. Condition; Dv. Dependent variable (Sr. Species richness; A. Abundance).

Tabla 3. Resultados de las pruebas de Kruskal–Wallis para la distribución de la riqueza específica y la abundancia de aves y peces entre los sectores de la Media Luna. Con excepción de la riqueza específica de peces, todos los resultados fueron significativos: Bg. Grupo bioindicador; C. Condición; Dv. Variable dependiente (Sr. Riqueza específica; A. Abundancia).

Bg	C	Dv	H	d.f.	*p*
Birds	WP	Sr	129.4	12	0.0001
Birds	WP	A	119.6	12	0.0001
Birds	P	Sr	129.4	12	0.0001
Birds	P	A	113.9	12	0.0001
Fish	–	Sr	20.80	12	0.0534
Fish	–	A	23.39	12	0.0022

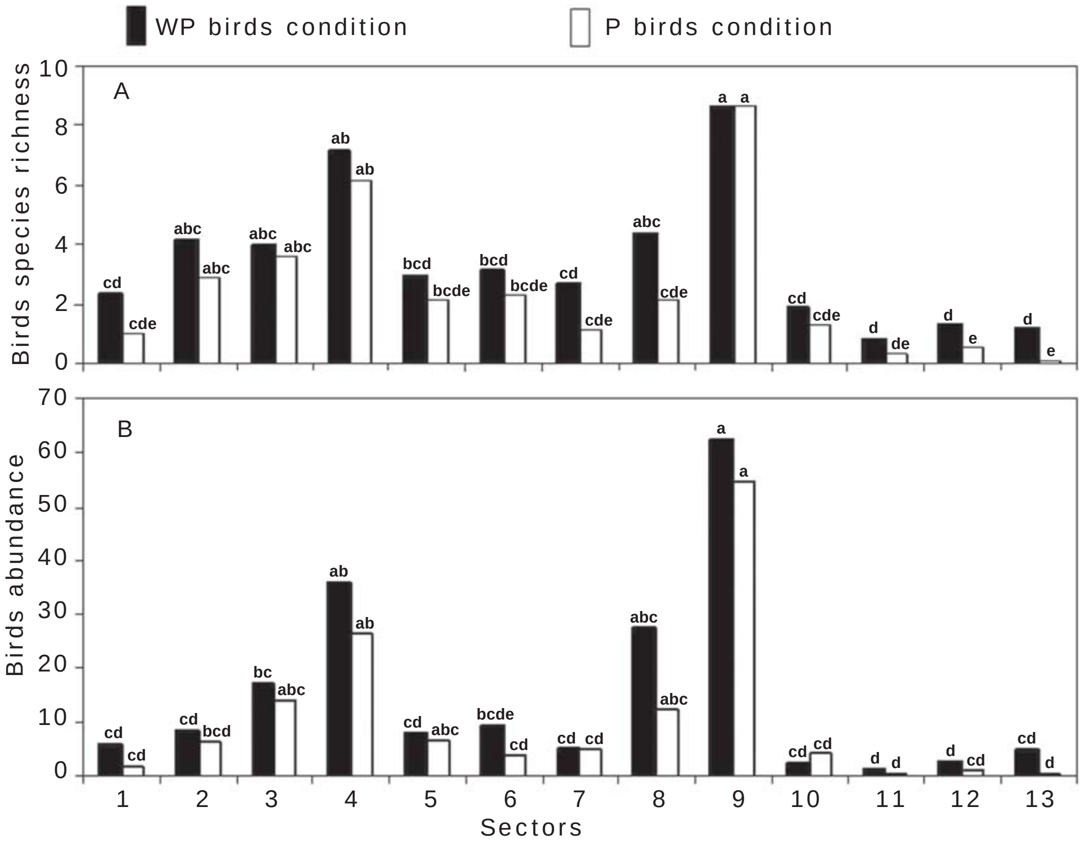

Fig. 3. Results of Dunn test for bird species in Media Luna sectors, in both WP and P conditions for: A. Species richness; B. Mean individual abundance. The letters over the bars indicates the statistical group for each condition; similar letters indicate statistical similarity between sectors. There were strong statistical differences between sectors 9, 4 and 8 in contrast with 10 to 13 for bird richness and abundance.

Fig. 3. Resultados de la prueba de Dunn para las especies de aves en los sectores de la Media Luna en las condiciones sin gente (WP) y con gente (P) para: A. Riqueza de especies; B. Abundancia media de individuos. Las letras sobre las barras indican el grupo estadístico para cada condición; las letras similares indican similitud estadística entre los sectores. Existen fuertes diferencias significativas entre los sectores 9, 4 y 8 en contraste con los sectores del 10 al 13 tanto para la riqueza como para la abundancia de aves.

et al., 2000). Although birds can move openly into Media Luna sectors, some sectors do not have the appropriate conditions for all species observed. Our results showed statistical differences in the spatial distribution of birds among sectors, with lowest abundance and richness values when there was visitor presence (fig. 3). We suggest that this presence creates environmental stress that accounts for the different responses to tolerance among birds throughout the Media Luna system.

FCA confirmed the observations that bird distribution changes between conditions of human presence. Some bird species benefit from anthropic modifications which tend to disguise some impact (Read et al., 2000). Species such as *P. olivaceus*, *A. anhinga,* most Ardeidae species, all Alcedinidae species, *P. haliaethus* and *M. americana* benefit from riparian woodlands. *C. albus*, *A. herodias* and *N. nycticorax* benefit from trees but are affected by border changes and *P. podiceps* which do not benefit are affected by riparian grassland destruction.

Bird groups or particular species which are affected by any kind of change are usually considered the indicator species for this particular change (Read et al., 2000; Paillison et al., 2002; Veraart et al., 2004). The best example of a close relation with habitat structure and high quality of aquatic vegetation was *J. spinosa*. This species lives on floating vegetation and is very territorial (Peterson & Chalif,

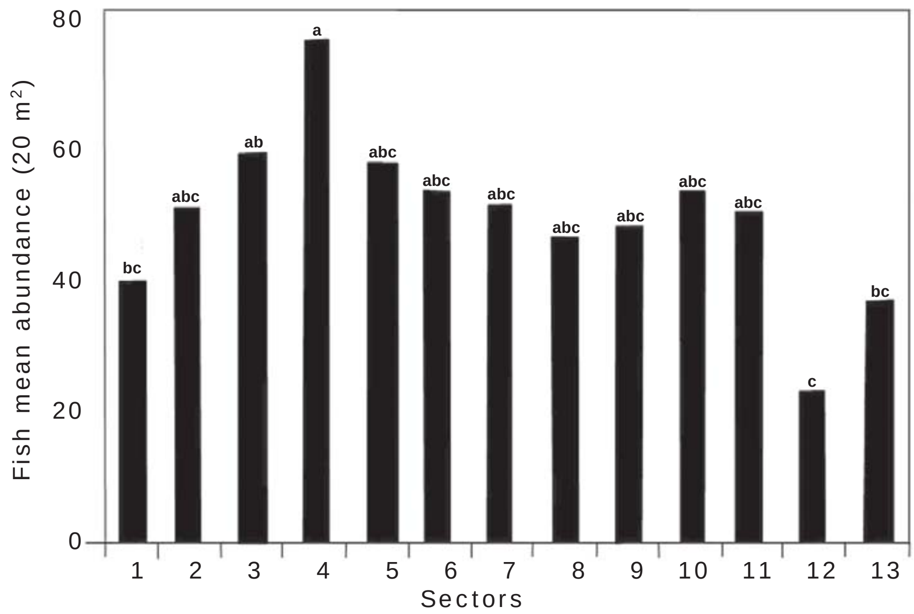

Fig. 4. Results of Dunn test for fish species abundance in Media Luna sectors. The letters above the bars indicate the statistical group; similar letters indicate statistical similarity between sectors. There are significant differences in the abundance between sectors number 4 and 1, 12 and 13.

Fig. 4. Resultados de la prueba de Dunn para la abundancia de peces en los sectores de la Media Luna. Las letras sobre las barras indican el grupo estadístico; las letras similares indican similitud estadística entre los sectores. Existen diferencias significativas en la abundancia entre los sectores 4 y los sectores 1, 12 y 13.

1989). It appears to be tolerant as it attempts only small escape movements from human presence. This behaviour is related to avoiding encroaching on another territory; its vocalizations, however, indicate stress. We consider this species to be the best environmental quality bird indicator.

The most intolerant species to direct human impact were *A. diazi*, *B. ibis, F. americana, P. haliaetus* and *D. autumnalis*. These five species were the best indicators of tourist disturbance caused by direct human presence in the Media Luna.

For fish, species richness and spatial distribution show a complex relation with the geographic location, size of the river or creek and the habitat characteristics in these system parts (Heino et al., 2005). Media Luna sectors have enough habitat conditions for most fish species and there are no significant differences in species richness between sectors (fig. 4). These results were confirmed by few relations between most fish species and habitat particularities as shown in the FCA results (fig. 6). This ordination method emphasizes opposite habitat structure preferences between two endemic species: *C. bartoni* related to bare ground and *A. toweri* related only to dense subaquatic vegetation. We considered these species as fish indicators for tourist impact and habitat changes in Media Luna.

Conservation policies may underestimate the value of small fragments. Each small fragment of unique and isolated native habitat can be important not only to maintain, but also to generate endemic biodiversity, and it must be carefully evaluated (Rubinoff & Powell, 2004). We emphasize the importance of small wetlands in semi–arid regions with fish endemism and the need for good management planning in order to avoid a critical situation.

The use of bioindicators helps us to analyse the impact of direct and indirect effects of tourism on biodiversity (e.g. Mancini et al., 2005). We observed altered conditions in Media Luna, such as abrupt riverside and areas > 1 m deep (non anthropized sectors have gentle slopes and gradual deep increases) which are now completely unusable for some riparian bird species, such as Ardeidae. Among fish groups, we observed that cichlids have parental care and their young are sure to be found anywhere, but the other young fish species need shallow waters (< 0.5 m) and dense vegetation coverage for survival. Only cichlids were observed breeding successfully in the most disturbed sectors; for *C. bartoni* and *Oreochromis* sp. these sectors were the best places.

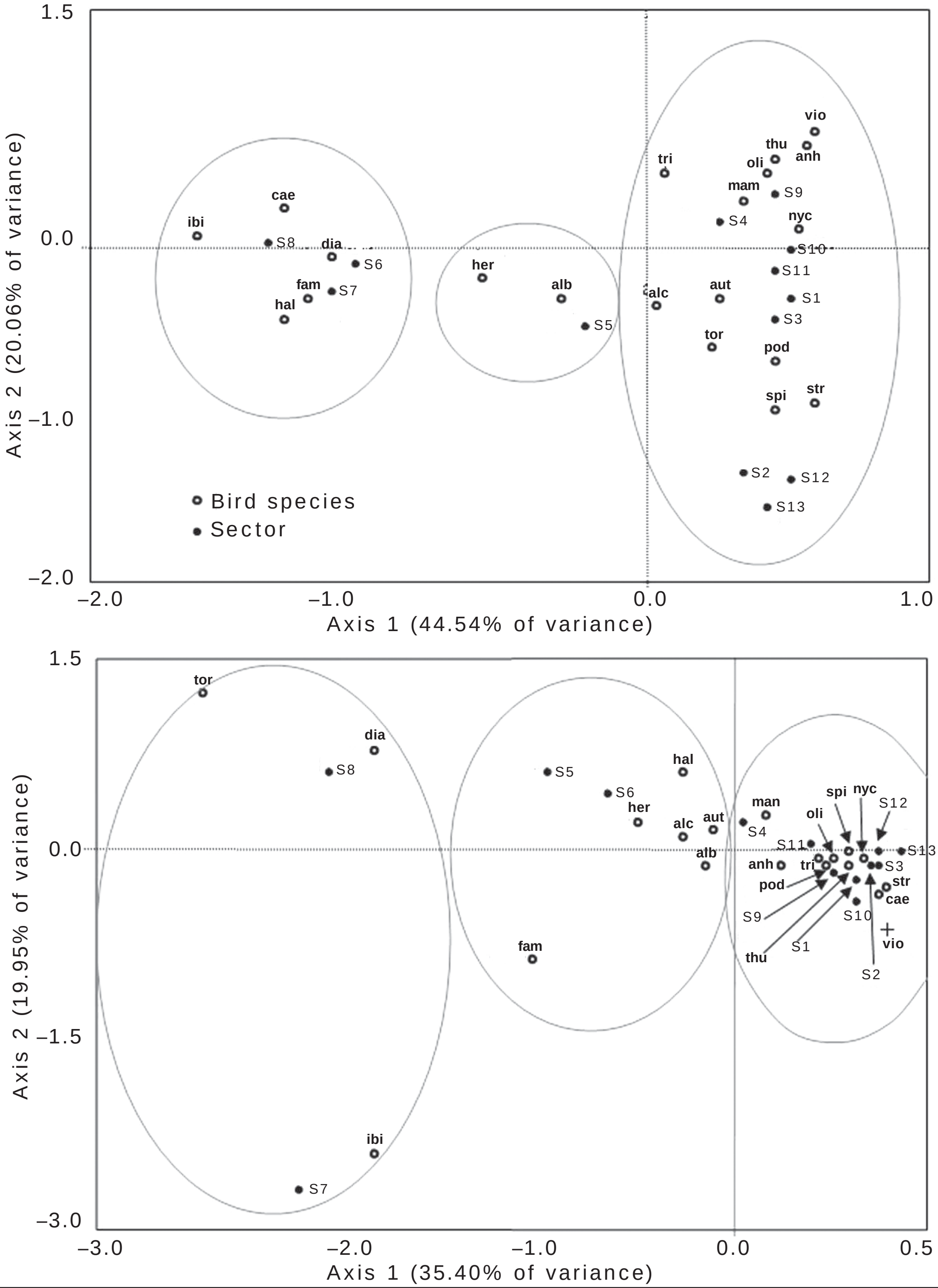

Fig. 5. FCA plot for birds in Media Luna system showing relationships between sectors and bird species for axis 1 and 2: A. For WP condition; B. For P condition. In the principal axis, species group according to direct anthropic tolerance. Some species change sector if the condition varies from WP to P, but most tolerant species do not move.

Fig. 5. Resultados de FCA para las aves del sistema de la Media Luna mostrando la relación entre los sectores y las especies de aves para los ejes 1 y 2: A. Para la condición sin gente (WP); B. Para la condición con gente (P). Algunas especies cambian de sector si la condición varía de WP a P, sin embargo las especies más tolerantes no cambian.

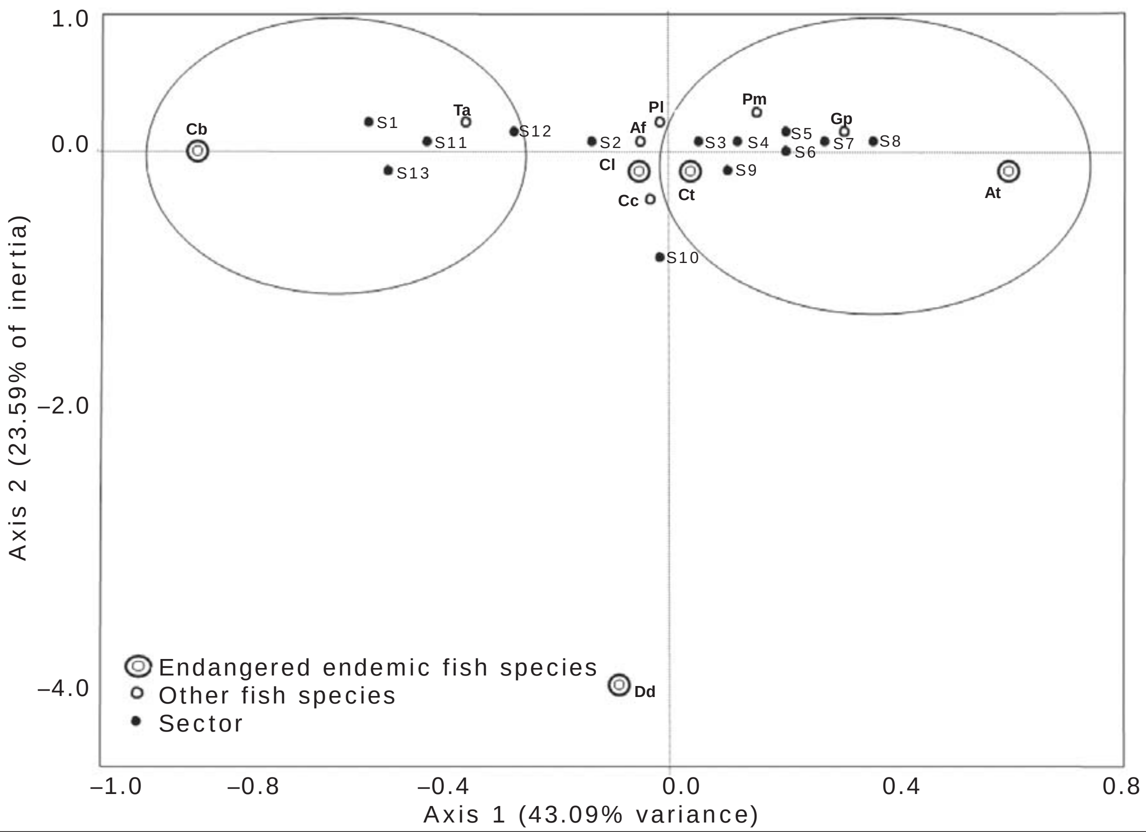

Fig. 6. FCA plot for fish in Media Luna system showing relationships between sectors and fish species for axis 1 and 2. Strong contrast is shown in axis 1 between two endangered endemic fish: *Ataeniobius toweri* (At) and *Cichlasoma bartoni* (Cb), the first lives in dense vegetation and the second prefers bare portions.

Fig. 6. Resultados de FCA para los peces del sistema de la Media Luna mostrando la relación entre los sectores y las especies de peces para los ejes 1 y 2. Se observan fuertes contrastes entre dos especies amenazadas y endémicas: Ataeniobius toweri *(At) y* Cichlasoma bartoni *(Cb), la primera habitante de zonas con vegetación densa y la segunda que mostró preferencia por sitios sin vegetación.*

Both indicator groups are important elements in this ecosystem, but management and conservation actions should focus mainly on the fish group, considering the arrival of visitors and their implication in habitat structure and quality (e.g. Root, 1998; Currie, 2003). We observed that the best riparian grassland conservation, with and without trees, was related to the maximum bird diversity and abundance, and the best subaquatic quality and abundance was related to the best fish density. Grassland and aquatic vegetation constitute barriers as few visitors cross them. As long as these barriers remain this system can be maintained. These habitat structures are the basis of conservation of the entire system. Restriction of sector 10 is especially important for conservation of *D. dichroma*, and tourist use should be kept moderate in altered channels in view of the conservation implications with *C. bartoni*. Finally, subaquatic coverage is especially important for *A. toweri*.

Media Luna spring shares species, environmental variables and problems with several other semiarid springs (Palacio–Núñez, 1997) and our present findings may provide helpful information for their management.

Acknowledgements

We thank J. Jesús Enríquez–Fernández who collaborated in the field research in all phases. This study was partially supported by grants (A–1870/04, A–1870/05) from the AECI (Agencia Española de Cooperación Internacional); Becas MAE No. 32342 and by a CONACyT pre–doctoral grant No. 187777.

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