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Diversity, Abundance and Nesting Phenology of the Wading Birds of Bahía Kino, Sonora, México

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Abstract.—The occurrence and nesting phenology of Ardeidae species and other wading birds were documented from 2009-2013 in the Bahía Kino bioregion of western Sonora, México. Two active colonies were surveyed: in a mangrove (*Avicennia germinans*; *Rhizophora mangle*) estuary and on a nearshore desert island. Thirteen species of nesting wading birds were recorded, 11 of which are year-round residents and two occurring only during the breeding season; two additional species were documented only in migration. The most abundant species was the Snowy Egret (*Egretta thula*), which had a peak of 234 nests in 2012. Of particular conservation interest is the Reddish Egret (*E. rufescens*), which had a peak of 149 nests in 2012. Potential prey of wading birds in the estuary was also sampled, with special focus on brachyuran crabs, which constitute the main prey items of the Yellow-crowned Night-Heron (*Nyctanassa violacea*). The rapid development of the region, and especially the establishment of large-scale mariculture operations along Estero Santa Cruz, has the potential to impact local wading bird populations, and thus an understanding of wading bird diversity, abundance and habitat use may prove critical to inform future management and conservation initiatives. *Received 10 September 2014, accepted 26 May 2015.*

Key words.—Ardeidae, Bahía Kino, Estero Santa Cruz, Humedales de la Laguna La Cruz, Isla Alcatraz, monitoring, wading birds, Yellow-crowned Night-Heron prey.

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Wading bird populations constitute an ecologically important component of the avifauna of the coastal wetlands of the Gulf of California. Located on the east coast of the Gulf, Bahía Kino is classified as the Central Gulf Coast Subdivision of the Sonoran Desert (Turner and Brown 1982; Rebman and Roberts 2012) and is notable for its high avian biodiversity attributable, in part, to the close juxtaposition of marine, desert, mangrove (*Avicennia germinans*; *Rhizophora mangle*) and island ecosystems. In addition, Bahía Kino's location in the Midriff Island region of the Gulf of California derives benefits from consistent, strong offshore upwelling with associated high marine primary productivity. These ecological dynamics support large local colonies of seabirds, such as Double-crested Cormorant (*Phalacrocorax auritus*; Pfister *et al.* 2005) and Brown Pelican (*Pelecanus occidentalis*; Galván 2007), as well as relatively less common seabirds, including Craveri's Murrelet (*Synthliboramphus craveri*; Hurley and Blinick 2011), and dense aggregations of wintering shorebirds (Fleischner and Gates 2009).

Historically, Bahía Kino had been a small, quiet fishing village. However, the human population has more than doubled in the last 25 years, from 3,017 inhabitants in 1990 to 6,050 in 2010 (L. R. Meltzer, pers. commun.), and the beachfront properties north of the old village have been heavily developed and impacted by tourism. Furthermore, in the past few decades, shrimp aquaculture development has expanded dramatically in the eastern and southern portions of Estero Santa Cruz, with at least 20 installations totaling 4,603 ha of ponds surrounding the estuary (Comité de Sanidad Acuicola del Estado de Sonora 2014). Thus, in the face of growing environmental risks and anthropogenic disturbances, and to complement the previously mentioned studies of seabirds and shorebirds, there is a need for studies on wading bird diversity and abundance, as well as identification of foraging and nesting requirements in the wetlands and on nearshore islands. Here, we collate and summarize the results of 5 years of wading bird monitoring and discuss the ecological context that supports the wading bird avifauna.

METHODS

Study Area

The study area was centered in Bahía Kino, Sonora (28° 49' N, 111° 56' W) (Fig. 1). Habitats included an estuary with associated mangrove stands, a nearshore island with desert scrub vegetation (mainly for nesting) and, to a lesser extent, the shallow coastal beaches along the Bay, as well as islands farther offshore.

Humedales de la Laguna La Cruz (Estero Santa Cruz; hereafter estero) was designated in 2013 as México's 139th Ramsar site (Ramsar Convention on Wetlands 2013). It is a 6,665-ha negative estuary located 0.5 km to the south of the town of Bahía Kino (28° 48' N, 111° 54' W) (Fig. 1D). The mouth of the estero is 1.1 km wide and opens to the west-southwest into the Bay and the Gulf of California. It contains a complex network of channels that average 1.1 m in depth and reach a maximum depth of 5 m at the mouth (Grijalva-Chon *et al.* 1996). The habitats in the estero include extensive tidally inundated mudflats and sand flats; mangrove thickets and mangrove fringe communities, including black mangrove (*Avicennia germinans*) and red mangrove (*Rhizophora mangle*); and small islands with Sonoran Desert vegetation, including cardón (*Pachycereus pringlei*), teddy-bear cholla (*Cylindropuntia bigelovii*) and desert wolfberry (*Lycium* spp.). There is also extensive saltmarsh habitat dominated by various shrubs and grasses (e.g., *Sporobolus*) and saltgrasses (*Distichalis* sp.). Several barren salt flats form a patchwork within the salt-marsh vegetation and are inundated only during high spring and storm tides in the summer months between May and September. "Heron Island" is located in a section of the estero that we monitored and is approximately 0.42 ha (Fig. 1E); it consists of a black mangrove thicket averaging 4 m tall (Fleishman and Blinick 2011).

Isla Alcatraz (also called Isla Pelícano, or Pelican Island) is a 59.5-ha volcanic island located 1.4 km offshore of the town of Bahía Kino (28° 48' N, 111° 59' W) (Fig. 1C). The highest peaks rise steeply to 135 m (Felger and Wilder 2012), which are flanked on the northeast by a gently sloping bajada with stands of desert scrub and cardón forest; this is the main nesting site of wading birds. A sandy beach stretches along the eastern shore, surrounded by rocky reefs that create a sheltered lagoon. At low tide an approximately 1.5-ha mudflat that provides foraging habitat for wading birds and shorebirds is exposed.

Field Methods

January surveys of the regional avifauna were reported by Fleischner and Riegner (1993) and have been updated annually through 2015. Although general monitoring of breeding, wintering and migratory waterbirds began in 2001, from 2009-2013 observations followed a consistent protocol and were systematically recorded year-round at least once a month throughout the entire study area. Surveys of the wading bird colony on Isla Alcatraz were conducted every 7-10 days for the entire duration of the nesting season from December through July. A minimum of bimonthly monitoring of the colony in Estero Santa Cruz was conducted September-June during each year of the 2009-2013 study period.

The Isla Alcatraz colony was initially split into four sections based on natural vegetative and topographic breaks to facilitate counting. Three stationary count locations were chosen based on good viewing of at least one section of the colony, achieving full colony coverage. Counts were made by scanning up and down, across each section, in sequence from southeast to northwest. Counts lasted 1-3 hr and were made from a distance of 100 m to minimize disturbance to the colony. For each species in each section of the colony, the total number of active nests was recorded.

For the Isla Alcatraz colony, the survey method remained more or less unchanged to maintain consistency, but some adjustments were made to reduce disturbance as the colony shifted spatially on the island. Two new sections were added, and counts were made from > 50 m from the edge of the shifted colony to minimize disturbance.

From 2009-2011, a medium to large colony of wading birds nested in a patch of black mangroves on the sand spit that extends along the northwest shore of Estero Santa Cruz (Figs. 1D, 1E). In an effort to minimize colony disturbance, we used the flight-line method (Erwin 1981; Paul and Paul 2004) to estimate species composition and nest abundance. Counts were conducted during low tides and when the majority of the colony was in the guard stage (i.e., when adults were incubating or brooding). Observations were made from atop a sand dune ~65 m from the edge of the colony.

Following Erwin (1981), counts began 2 hr after sunrise and lasted for 1 hr. All wading birds entering and leaving the colony were identified to species and recorded. Flight rate was calculated as $FR = (F_{in} + F_{out})$, where F_{in} is total flights into the colony and F_{out} is total flights out of the colony. Number of nests was estimated as $N = FR \times 1.5$ (Paul and Paul 2004). Flight rate is not equivalent to number of nests but provides an index of the population size and offers a general estimate of the number of pairs when other methods are impractical, though, admittedly, this is a rough estimate (Sprandel 2009; Kushlan 2011). Two such surveys were conducted in both the 2009 and 2010 breeding seasons, and three in 2011. During the 2012-2013 seasons, the colony moved to a small black mangrove island ("Heron Island;" Fig. 1E). Direct counts of nests along the island's perimeter were made from a distance of 50 m.

To estimate categories of potentially available prey, in January 2013 and 2015, Estero Santa Cruz was sampled in an area commonly used by foraging herons. During both high and low tides, teams of students dragged a 6-m, fine-mesh seine net in shallow water to trap macroinvertebrates and small vertebrates; the captured organisms were placed in small glass laboratory bowls, identified, photographed and then released. Other teams dug in the muddy and sandy substrate and sifted the sediment in search of invertebrates; again, the animals were temporarily held in bowls, identified and then released. To

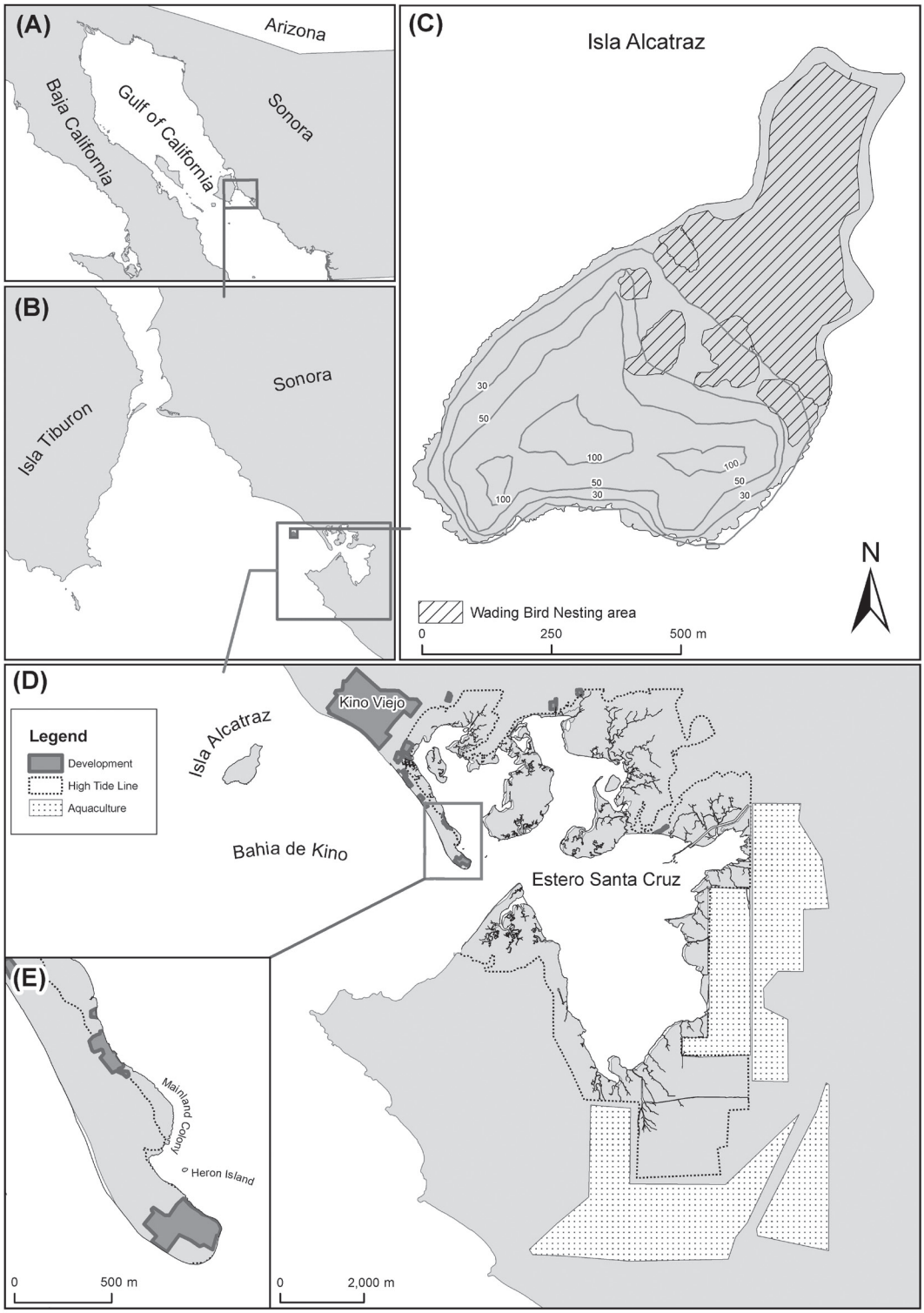

Figure 1. Map of the (A) region highlighting (B) Bahía Kino, (C) Isla Alcatraz, (D) Estero Santa Cruz and (E) the location of the mainland mangrove colony and Heron Island. In (C), hatched areas indicate the six sections that were surveyed.

estimate the abundance of large Mexican (or princely) fiddler crabs (*Uca princeps*), a 0.5-m² frame was placed repeatedly within an extensive crab colony along a line transect at the base of the mangrove fringe; burrow entrances were then counted within the frame. In addition, Yellow-crowned Night-Heron (scientific names are given in Table 1) diet has been studied in the estero since 1989 by examining regurgitated food pellets and other discarded indigestible parts of prey (mostly crab chelipeds) at roosts and subsequently identifying samples to species (using keys in Brusca 1980).

RESULTS

Eight species of herons (Table 1) and White Ibises occurred regularly in the estero in all four seasons (Table 1); five of these species were always present in suitable habitat throughout the year. The mangrove habitat was used by 100% of species (for feeding and nesting), while the nearshore island habitat was used by 73% of species (mostly only for nesting). Four species were also observed on sandy beaches, and two species were documented in the town of Bahía Kino.

Least Bitterns were occasionally heard vocalizing ("cooing" call from Gibbs *et al.* 2009) in the mangroves of Estero Santa Cruz during the spring and early summer. The earliest seasonal date we recorded them was 3 April 2014 when a pair was seen; their distinctive call was heard through the end of June 2009, 2011 and 2014. Although no nests have been found, the observation of Least Bitterns and their call being heard during the breeding season are indicative of nesting.

Seven species of herons, plus White Ibises, occurred in the colony on Isla Alcatraz (Table 2). Great Blue Herons are resident year-round in varying numbers, with the majority of individuals arriving in early December. Great Blue Herons are the first species to begin breeding, followed by Reddish Egrets in early March; the remaining herons (except Cattle Egrets) and White Ibises began breeding in early April (Fig. 2). Direct counts of nests on Isla Alcatraz showed large intraspecific fluctuations in abundance from year to year, and month of peak nesting activity within species also varied (Table 2). The most abundant species were Snowy Egrets, which had 234 active nests in 2012. One of the most consistent species was the Great Blue Heron, which had an average of 48.2 active nests/season (SD = 8.9; Table 2). Of particular conservation interest are Reddish Egrets, which nested in large numbers on

Table 1. Habitat and seasonal abundance estimates of herons (and other wading birds) in the Bahía Kino bioregion (based on field records 1989-2015). Habitat codes are: B = Beach/Nearshore (beach out to 0.5 km from shore); H = Human habitation (in town), including agricultural sites; I = Islands (nearshore); M = Mangrove estuary. The estimated abundance categories are as follows: c = common: always present in suitable habitat (often > 15 sightings/year); f = fairly common: regularly found in suitable habitat (11-15 sightings/year); u = uncommon: present in suitable habitat, but not regularly seen (5-10 sightings/year); r = rare: rarely seen even in suitable habitat (< 5 sightings/year); * = accidental: sight record in region, but out of typical range (usually 1 sighting/year). Winter = December-February; Spring = March-May; Summer = June-August; Fall = September-November.

Common Name	Scientific Name	Habitats	Winter	Spring	Summer	Fall
American Bittern	*Botaurus lentiginosus*	M	—	*	—	—
Least Bittern	*Ixobrychus exilis*	M	—	r	r	—
Great Blue Heron	*Ardea herodias*	BIM	c	c	c	c
Great Egret	*A. alba*	BIM	c	c	u	c
Snowy Egret	*Egretta thula*	BHIM	c	c	c	c
Little Blue Heron	*E. caerulea*	IM	f	c	f	c
Tricolored Heron	*E. tricolor*	IM	f	c	c	c
Reddish Egret	*E. rufescens*	BIM	c	c	c	c
Cattle Egret	*Bubulcus ibis*	HIM	r	r	f	u
Green Heron	*Butorides virescens*	IM	u	r	u	u
Black-crowned Night-Heron	*Nycticorax nycticorax*	IM	c	c	c	c
Yellow-crowned Night-Heron	*Nyctanassa violacea*	IM	c	c	c	c
White Ibis	*Eudocimus albus*	IM	f	c	c	c
White-faced Ibis	*Plegadis chihi*	M	—	u	—	u
Roseate Spoonbill	*Platalea ajaja*	IM	r	c	c	u

Table 2. Annual seasonal high count of active nests (month in parentheses) on Isla Alcatraz 2009-2013.

Species	2009	2010	2011	2012	2013	$\bar{x}$	SD
Great Blue Heron	39 (April)	52 (May)	59 (May)	52 (March)	39 (April)	48.2	8.9
Snowy Egret	10 (May)	2 (June)	77 (July)	234 (May)	201 (June)	104.8	107.6
Tricolored Heron	42 (June)	0	17 (July)	37 (May)	44 (June)	28.0	19.0
Reddish Egret	100 (May)	62 (May)	110 (May)	149 (May)	42 (June)	92.6	41.9
Cattle Egret	0	0	0	2 (May)	6 (June)	1.6	2.6
Black-crowned Night-Heron	77 (May)	86 (June)	46 (May)	60 (May)	24 (June)	58.6	24.7
Yellow-crowned Night-Heron	35 (May)	0	0	55 (April)	19 (June)	21.8	23.6
White Ibis	13 (May)	6 (March)	54 (May)	0	73 (June)	29.2	32.4

Isla Alcatraz; in 2012, 149 active nests ($\bar{x}$ = 92.6; SD = 41.9; Table 2) were observed.

In Estero Santa Cruz, flight-rates and estimates of number of nests were calculated for 12 species of wading birds for each survey undertaken from 2009-2011 (Table 3); in 2012 and 2013, direct counts were possible. The estimated number of nests for each species varied greatly across years; the most abundant species, Snowy Egrets, had an estimated 216 nests in 2010. The highest count for Reddish Egrets in this colony was 63 nests in 2010.

White Ibises are common year-round residents and breed in both the Isla Alcatraz and Estero Santa Cruz colonies. Roseate Spoonbills also nest in small numbers in the Estero Santa Cruz mixed-species colony (Fleishman and Blinick 2011). American Bitterns and White-faced Ibises were accidental and uncommon, respectively, in the estero during migration (Table 1).

In Estero Santa Cruz, the likely prey of the species surveyed here (Table 1) included both macroinvertebrates and small vertebrates found on the substrate and in the water column (Table 4). Regarding the diet of Yellow-crowned Night-Herons, the most frequently encountered prey remains (mostly chelipeds) were from large Mexican fiddler crabs (32%; Table 5). The density of large Mexican fiddler crab burrows measured 48.0 m^{-2} (n = 10 quadrats; SD = 18.09).

DISCUSSION

The 10 most common Ardeidae species (plus the White Ibis) in the Bahía Kino bioregion are the same species identified across the wetland zones of Magdalena Bay, Baja California Sur, México (Zárate-Ovando *et al.* 2006). Similarly, the most species-rich habitat in both bioregions is the mangrove zone, and we found that 100% of wading bird species in our study used Estero Santa Cruz, which is dominated by mangroves. Although there is a shallow lagoon and low-tide-ex-

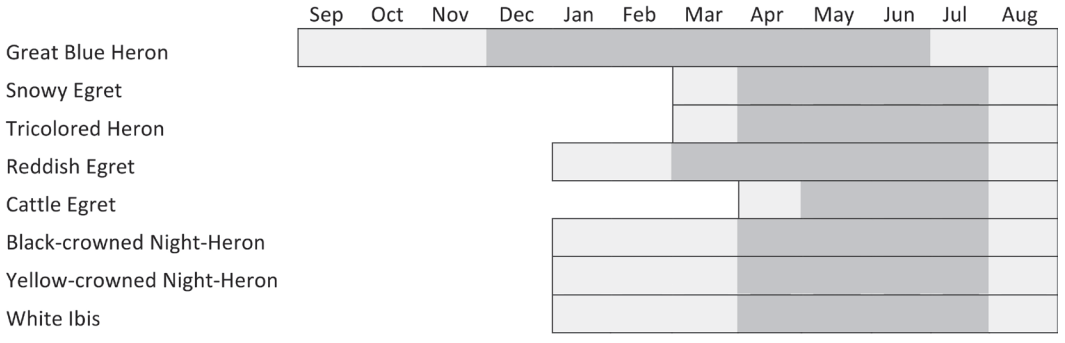

Figure 2. Monthly presence (light gray) and breeding (dark gray) of wading birds on Isla Alcatraz estimated from cumulative observations during 2009-2013. Breeding was considered to begin with commencement of nest construction and to end in July when observations ceased.

Table 3. Number of nests estimated from flight-rates (2009-2011) and direct counts (2012-2013) in Estero Santa Cruz during June 2009-2013. (In 2012 and 2013, the colony abandoned the original site and a subset relocated to Heron Island.)

Species	2009	2010	2011	2012	2013
Great Blue Heron	2	2	0	0	1
Great Egret	2	0	2	2	0
Snowy Egret	132	216	150	30	11
Little Blue Heron	3	3	11	0	0
Tricolored Heron	8	29	26	1	0
Reddish Egret	17	63	14	1	0
Cattle Egret	0	2	56	2	0
Green Heron	3	3	3	0	0
Black-crowned Night-Heron	5	3	0	0	0
Yellow-crowned Night-Heron	33	36	36	15	27
White Ibis	30	90	65	3	1
Roseate Spoonbill	11	11	2	12	10

posed mudflats along the eastern shore of Isla Alcatraz, most adult herons commute across the Bay on a daily basis to forage in the mangrove estuary. Indeed, the presence of mangrove habitat may be a key factor in supporting wading bird species richness in the Gulf of California as suggested by markedly fewer wading bird species documented in more northerly regions that lack these tropical/subtropical plant communities; only two species of herons were reported in La Salina, Bahía San Jorge (Mellink and Palacios 1993) and three species in Estero del Chayo, Isla Montague (Peresbarbosa and Mellink 2001).

As herons are opportunistic foragers, the small vertebrates and macroinvertebrates we sampled in the estero could conceivably constitute part of the prey base for most species. Yellow-crowned Night-Herons are specialists on crustaceans and feed on the abundant fiddler crabs in this bioregion. Interestingly, the density of large Mexican fiddler crab burrows in Estero Santa Cruz was almost identical to that found for sand fiddler crabs (*U. pugilator*) and mudflat fiddler crabs (*U. rapax*) combined (47.93 m^{-2}) in a study conducted in Tampa Bay, Florida, USA (Smith *et al.* 2009). Overall, considering that we monitored wading birds in about 40% of the total area of Estero Santa Cruz (though this represents a higher percentage when accounting only for suitable potential nesting habitat), the survey estimates presented here should be considered a minimum; accordingly, it would be of interest to survey additional areas of the estero with a focus along the mangrove tidal channels. We also

Table 4. Potential prey of herons sampled in Estero Santa Cruz, January 2013 and 2015.

Class	Family	Species	Common Name
Teleostei			
	Atherinidae	*Colpichthys regis*	false grunion
	Syngnathidae	*Cosmocampus arctus*	snubnose pipefish
	Gerreidae	*Ecinostomus* sp.	mojarra sp. (juvenile)
	Gobiidae	*Quietula guaymasiae*	Guaymas goby
	Paralichthyidae	*Paralichthys* sp.	flounder sp. (juvenile)
	Tetraodontidae	*Sphoeroides annulatus*	bullseye puffer (juvenile)
Crustacea			
	Penaeidae	*Penaeus* sp.	shrimp sp. (juvenile)
Polychaeta			
	Nereididae	*Nereis* sp.	free-living sandworm sp.
Cephalopoda			
	Loliginidae	*Lolliguncula panamensis*	Panama brief squid (juvenile)

Table 5. Crustacean (Infraorder Brachyura) prey of Yellow-crowned Night-Herons sampled periodically since 1989.

Family	Species	Common Name	% Occurrence
Grapsidae	*Goniopsis pulchra*	mangrove crab	15
Ocypodidae	*Uca crenulata*	crenulated fiddler crab	3
	U. princeps	large Mexican fiddler crab	32
Portunidae	*Callinectes arcuatus*	arched swimming crab	2
	Portunus xantusii	Xantus swimming crab	14
Panopeidae	*Eurytium affine*	no common name	12
Xanthidae	*Leptodius occidentalis*	black-fingered mud crab	22

hypothesize that relative species abundances will vary across the different habitats of the estero.

On Isla Alcatraz, Great Blue Herons are the first species to begin breeding (Fig. 2). Similarly, Great Blue Herons are the earliest nesters on Isla Montague in the northern Gulf of California, but, perhaps as a function of their more northerly distribution, breeding begins several months later in mid-March (Peresbarbosa and Mellink 2001). On Isla Alcatraz, these are also the only herons that nest on the slopes in the cardón cactus, and they remain largely segregated from the rest of the wading bird colony due to the height and location of their nests. This may partially explain this species' consistency from year to year, as there is a fixed number of nest sites in the massive cardóns and, due to this heron's relatively large size and associated advantage in territorial disputes, there is no interspecific competition for nest sites. The other species in the wading bird colony, however, experience interspecific competition with other nesting waterbirds, including Double-crested Cormorants and Brown Pelicans, as they share the same nesting habitat in the desert scrub. From 2009-2013, there was a significant shift in nesting location from the base of the slope to spreading out across the flat portion of the island to the edge of the vegetation zone. This may be attributed to the large increase in nesting Brown Pelicans, which may displace the herons into less desirable territories (E. W. Clark, pers. obs.).

From a management and conservation perspective, Reddish Egrets are of particular interest as they are federally designated as a "species of special concern" in México (Palacios *et al.* 2010) and identified with a Red List category of "near threatened" by the International Union for Conservation of Nature (2013). In their survey of 45 Reddish Egret rookeries across western México, Palacios *et al.* (2010) recognized Isla Alcatraz as supporting the "most significant breeding population for Sonora and the second largest colony for northwest México." Since those surveys, the Isla Alcatraz colony has increased in size. During our 2012 season, we documented that Isla Alcatraz remains the second largest Reddish Egret colony in northwest México (Wilson *et al.* 2014). Accordingly, such an important breeding population deserves special conservation attention, a main priority identified for this species (Kushlan and Hancock 2005).

The value of waterbird monitoring is that future population trends, especially in the face of environmental threats, can be identified against baseline data. This is especially important when confronting multi-scale environmental changes, including the potential impact of human disturbance on sensitive species as well as the effects of both climate and sea-level shifts. The results of our 5-year monitoring program described here establish the high productivity of this bioregion. Specifically, fringe mangrove thickets, island desert scrub vegetation and tidally influenced mudflats, sand bars and channels are habitat components critical to nesting and foraging wading birds. However, the ever-increasing human use of both Estero Santa Cruz and Isla Alcatraz pose significant concerns for the long-term maintenance of biodiversity in this region and, overall, "degradation of coastal wetlands is one of the Gulf's most serious threats" (Carvajal *et al.* 2010). Thus, it is imperative that the growth of mariculture operations is con-

trolled and that water quality is monitored at numerous points in the estero, especially at effluent input sites. In addition, it is important to educate the public, perhaps with official signage, that nesting colonies of wading birds should not be approached; this holds for Estero Santa Cruz as well as for Isla Alcatraz. Even though Isla Alcatraz is recognized as part of the Islas del Golfo de California Biosphere Reserve and is managed by the Comisión Nacional de Áreas Naturales Protegidas (Comisión Nacional de Áreas Naturales Protegidas 2000), there is a lack of funds for proper management and for patrolling by a much-needed seasonal park guard. The 2013 designation of Estero Santa Cruz as a Ramsar site is an encouraging step (Ramsar Convention on Wetlands 2013); however, there needs to be follow-through and concerted efforts to ensure the long-term sustainability of wading bird diversity in this ecologically valuable region of the Gulf of California.

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