DISTRIBUTION AND ABUNDANCE OF THE ENDANGERED KILLIFISH *FUNDULUS LIMA*, AND ITS INTERACTION WITH EXOTIC FISHES IN OASES OF CENTRAL BAJA CALIFORNIA, MEXICO

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ABSTRACT—The distribution and abundance of the endangered Baja California killifish, *Fundulus lima*, and its interaction with exotic fishes were studied in oases of the central part of Baja California peninsula, Mexico (Río San Ignacio and Río La Purísima basins), from October 2002 to July 2004. Five fish species were recorded: the native killifish and 4 exotics (*Cyprinus carpio, Poecilia reticulata, Xiphophorus hellerii*, and *Tilapia* cf. *zillii*). Two new populations of the killifish are reported for the Río San Ignacio as well as confirmation of occurrence in the upper Río La Purísima. Density of the killifish in the Río San Ignacio showed a significant inverse correlation with that of the exotic redbelly tilapia (*Tilapia* cf. *zillii*). Baja California killifish densities in both rivers decreased significantly after the hurricane-induced flood event of 23 September 2003, but exhibited notable recovery 10 months later. Relative abundance of killifish at the type locality, San Ignacio oasis, decreased significantly during an 8-year period after introduction of tilapia. The status of Baja California killifish should be changed from threatened to endangered to reflect continued reductions in distribution as result of proliferation of nonnative fishes, particularly redbelly tilapia. Management efforts to reduce abundance of exotic fishes are needed to ensure persistence of the endemic Baja California killifish.

RESUMEN—La distribución y abundancia de la sardinilla peninsular en peligro de extinción, *Fundulus lima*, y su interacción con peces exóticos, fueron estudiados en oasis de la parte central de la península de Baja California, México (cuencas río San Ignacio y río La Purísima), de octubre 2002 a julio 2004. Cinco especies ícticas fueron registradas, la nativa sardinilla peninsular y cuatro exóticas (*Cyprinus carpio, Poecilia reticulata, Xiphophorus hellerii* y *Tilapia* cf. *zillii*). Dos poblaciones nuevas de la sardinilla peninsular son reportadas para el río San Ignacio, y se confirma además su presencia en la cabecera del río La Purísima. La densidad de la sardinilla peninsular en sitios del río San Ignacio demostró una correlación inversa significativa con aquélla del cíclido exótico *Tilapia* cf. *zillii*. Las densidades de la sardinilla en ambos ríos disminuyeron significativamente después del evento de inundación causado por el huracán del 23 septiembre 2003, pero exhibieron una marcada recuperación diez meses después. La abundancia relativa de la sardinilla disminuyó radicalmente en la localidad tipo, el oasis de San Ignacio, en un lapso de 8 años después de la introducción de la tilapia. El estatus de conservación de la sardinilla peninsular debe ser cambiado de amenazado a en peligro de extinción, reflejando reducciones continuas en distribución como resultado de la proliferación de peces no nativos, particularmente de la tilapia. Esfuerzos de manejo para reducir la abundancia de peces exóticos son requeridos para asegurar la persistencia de la sardinilla peninsular endémica.

The Baja California killifish (*Fundulus lima*) is one of only 3 freshwater fishes endemic to the generally arid peninsula of Baja California, Mexico, with a distribution confined to oases of the Pacific drainage basins, from the Río San Ignacio southward to the Río Las Pocitas (Ruiz-Campos, 2000; Ruiz-Campos et al., 2002). These oases are considered relict, subtropical, meso-

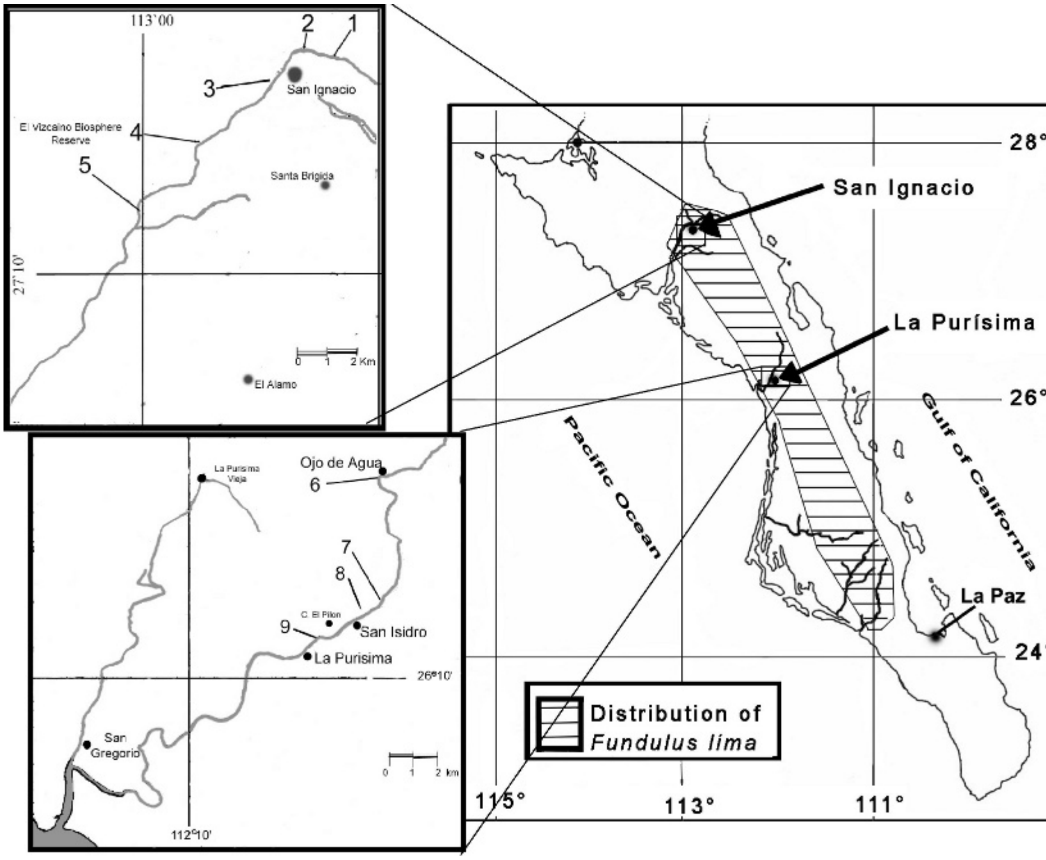

Fig. 1—Location of fish sampling sites (1–9) in the Río San Ignacio and Río La Purísima basins, Baja California Sur, Mexico. 1, Rancho El Tizón; 2, Lake Side; 3, Poza Larga; 4, Rancho Los Corralitos; 5, Rancho San Sabas; 6, Ojo de Agua; 7, Presa Carambuche; 8, Carambuche; and 9, La Purísima.

philic ecosystems that resulted from the radical ecological transformation of central Baja California during the Holocene (ca. the last 8,000 years), from a generally mesic to a xeric environment (sensu Axelrod, 1948; Grismer and McGuire, 1993; Camarena-Rosales et al., 2001).

During the last decade, populations of the Baja California killifish have been declining over a large part of its range, apparently due to competitive interactions with introduced exotic fishes, especially a form of redbelly tilapia, *Tilapia* cf. *zillii* (Ruiz-Campos et al., 2002). Although this killifish is currently categorized as threatened (SEMARNAT, 2002), recent surveys (2002 to 2004) have shown its virtual extirpation at sites representing more than 50% of its range (e.g., San Javier, San Luis, and San Pedro de La Presa drainage basins) and its conservation status should be changed to endangered (GRC, unpubl. data).

Between 1991 and 1995, sampling for Baja California killifish at the type locality (San Ignacio oasis) showed it to be the most abundant fish present, coexisting with 3 exotics: common carp, *Cyprinus carpio*; green swordtail, *Xiphophorus hellerii*; and guppy, *Poecilia reticulata* (Ruiz-Campos et al., 2002). However, the 1996 introduction of redbelly tilapia into this oasis has caused a dramatic population decline of Baja California killifish (Ruiz-Campos et al., 2002). In this paper, we discuss the distribution and abundance of this endangered killifish, as well as its interaction with exotic fishes in oases of 2 drainage basins of the central Baja California peninsula.

Methods—The Río San Ignacio is located south of the Sierra San Francisco mountain range, heads at

TABLE 1—Capture-per-unity-effort (CPUE) values for fishes by sampling sites and type of gear in the Río San Ignacio and Río La Purísima river basins. Numbers after site names correspond to sites marked in Fig. 1. Sampling was conducted from 2002 to 2004. Gear is denoted by MT (minnows traps; fish/trap/h), GN (gill net; fish/h), SN (seine net; fish/m^2), and CN (cast net; fish/throw). Species are denoted by BCK (Baja California killifish), GS (green swordtail), GU (guppy), CO (common carp), and RT (redbelly tilapia). n = total number of fishes captured per sampling event.

Basin / Site (site number) / Gear, number, date	Species					n
	BCK	GS	GU	CO	RT	
Río San Ignacio						
El Tizón (1)						
MT, 10, 26 October 2002	0.03	0.03	0.00		0.29	60
MT, 10, 06 February 2003	0.03	0.04	0.00		1.04	189
MT, 10, 29 March 2004	0.01	1.73	0.07		1.80	614
MT, 10, 5 July 2004	0.00	0.06	0.11		0.32	83
Mean CPUE, *SD*	0.02, 0.02	0.47, 0.84	0.05, 0.05		0.86, 0.71	
Lake Side (2)						
MT, 10, 6 February 2003	0.02	0.06	0.06	0.00	1.79	328
MT, 10, 29 March 2004	0.00	0.01	0.00	0.00	0.00	2
GN, 01, 29 March 2004	0.00	0.00	0.00	0.14	0.88	17
Mean CPUE, *SD*	0.01, 0.01	0.02, 0.02	0.02, 0.03	0.05, 0.06	0.89, 0.60	
Poza Larga (3)						
CN, 01, 26 October 2002	24.83	9.66	0.00	10.83	0.00	91
MT, 10, 6 February 2003	0.33	0.30	0.69	0.00	0.00	224
GN, 01, 6 February 2003	0.24	0.00	0.00	0.00	0.00	4
MT, 10, 22 September 2003	5.40	0.22	0.51	0.00	0.00	1,042
GN, 01, 22 September 2003	5.6	0.30	0.00	0.00	0.00	100
MT, 10, 29 March 2004	0.02	0.30	0.00	0.00	0.00	54
GN, 01, 29 March 2004	2.98	0.00	0.00	0.23	0.06	56
MT, 10, 5 July 2004	2.42	0.03	0.01	0.02	0.39	488
GN, 01, 5 July 2004	1.77	0.00	0.00	0.51	0.19	42
Mean CPUE, *SD*	4.84, 7.33	1.2, 3.18	0.13, 0.27	1.29, 3.58	0.07, 0.14	
Los Corralitos (4)						
SN, 10, 26 October 2002	5.90			0.00	0.0	213
MT, 10, 6 February 2003	0.04			0.00	0.02	10
GN, 01, 6 February 2003	0.24			0.00	0.19	7
MT, 10, 22 September 2003	1.90			0.00	0.40	391
GN, 01, 22 September 2003	0.00			0.05	0.05	2
MT, 10, 29 March 2004	0.07			0.00	0.00	12
GN, 01, 29 March 2004	0.66			0.10	0.05	14
MT, 10, 5 July 2004	0.51			0.00	0.02	90
GN, 01, 5 July 2004	0.00			0.23	0.09	5
Mean CPUE, *SD*	1.04, 1.92			0.04, 0.08	0.09, 0.13	
San Sabas (5)						
CN, 01, 6 February 2003	6.70	0.00	0.00	0.00	0.00	40
MT, 10, 22 September 2003	4.60	0.00	1.60	0.00	0.00	1,054
MT, 10, 29 March 2004	1.20	0.00	0.00	0.01	0.01	207
GN, 01, 29 March 2004	1.01	0.00	0.00	0.05	0.05	19
MT, 10, 5 July 2004	2.49	0.09	0.01	0.00	0.07	452
GN, 01, 5 July 2004	0.00	0.00	0.00	0.00	0.23	4
Mean CPUE, *SD*	2.67, 2.53	0.02, 0.04	0.27, 0.65	0.01, 0.02	0.06, 0.09	
Río La Purísima						
Ojo de Agua (6)						
MT, 10, 8 February 2003	0.24				0.04	48
GN, 01, 8 February 2003	0.00				0.46	78

Table 1—Continued.

Basin / Site (site number) / Gear, number, date	BCK	GS	GU	CO	RT	*n*
MT, 10, 31 January 2004	0.00				0.00	0
GN, 01, 31 January 2004	0.50				0.56	180
MT, 10, 2 July 2004	1.36				0.19	264
GN, 01, 2 July 2004	0.00				0.15	26
Mean CPUE, *SD*	0.36, 0.39				0.23, 0.18	
Presa Carambuche (7)						
GN, 01, 28 October 2002	0.00				0.00	0
MT, 10, 28 October 2002	0.87				1.05	326
MT, 10, 8 February 2003	0.74				0.08	139
MT, 10, 31 January 2004	0.17				0.00	29
MT, 10, 2 July 2004	0.71				0.24	162
Mean CPUE, *SD*	0.50, 0.33				0.27, 0.31	
Carambuche (8)						
MT, 10, 8 February 2003	0.03		0.00		0.10	22
MT, 10, 31 January 2004	0.00		0.00		0.00	0
MT, 10, 2 July 2004	0.02		0.02		0.04	14
Mean CPUE, *SD*	0.02, 0.01		<0.01		0.05, 0.04	
La Purísima (9)						
MT, 10, 8 February 2003	1.00		0.00		0.50	255
MT, 10, 31 January 2004	0.06		0.00		0.02	14
MT, 10, 2 July 2004	0.58		0.01		1.72	393
Mean CPUE, *SD*	0.55, 0.32		<0.01		0.75, 0.65	

a spring on the Babisuri Plain, and intermittently flows westward through the small towns of Santa Lucía, Cueva Colorada, Piñuela, and Guamuchil before reaching San Ignacio oasis (Fig. 1). There, it is impounded by a dam that also serves as a bridge to enter the town from Mexican Highway 1. The river then flows intermittently southwestward, passing the ranches Los Estribos, Los Corralitos, and San Sabas, before completely disappearing in a wide sandy plain about 20 km northeast of the large, hypersaline, coastal lagoon of San Ignacio. The fluvial valley is bordered by basaltic terraces and hills of sedimentary rocks. General climate is extremely arid, with sparse winter rains (<100 mm) and mean annual temperature ranging from 18 to 24°C (Arriaga et al., 2000).

Another major regional drainage, the Río La Purísima (Fig. 1), originates on the western slope of the Sierra La Giganta mountain range and is the largest perennial stream in Baja California Sur. It flows above ground for nearly 32 km, through the villages of La Mochila, La Pintada, Huerta Vieja, Carambuche, San Isidro, La Purísima, El Saucito, Los Corrales, and San Gregorio, before entering the coastal San Gregorio estuary. Similarly, general climate is arid with winter rains delivering average annual precipitation up to 200 mm (Arriaga et al., 2000).

The conspicuous riparian vegetation of the Río San Ignacio is represented by native Mexican fan palm (*Washingtonia robusta*), southern cattail (*Typha domingensis*), spiny rush (*Juncus acutus*), vinorama (*Acacia brandegeana*), western honey mesquite (*Prosopis glandulosa*), and exotic date palm (*Phoenix dactylifera*), giant reed (*Arundo donax*), and tamarisk (*Tamarix*) (Arriaga et al., 1997; GRC, pers. observ.). Along the Río La Purísima, dominant riparian plants are date palm, common reed or ''carrizo'' (*Phragmites australis*), southern cattail, mule fat or ''batamote'' (*Baccharis salicifolia*), vinorama, western honey mesquite, Bonpland willow (*Salix bonplandiana*), and the conspicuous exotic woody vine or ''bejuco'' *Cryptostegia grandiflora* (GRC, pers. observ.). Aquatic vegetation in both basins is represented by the genera *Ceratophyllum, Enteromorpha, Chara, Potamogeton*, and *Nuphar*.

A reconnaissance survey of the study areas (14 to 16 April 2002) resulted in the selection of 9 sampling sites and standardization of sampling techniques (Fig. 1). These sites were later sampled during the period October 2002 to July 2004. At each site, samples were made using capture techniques that were passive (Hubert, 1983), active (Hayes, 1983), or both. Passive capture devices consisted of 10 minnow traps (45 cm long × 23 cm, 6.4-mm mesh netting, and 2.2-cm openings at both ends) and one experimental gill net composed of 4 panels 4.5 m long × 1.80 m high, with bar meshes of 1.3, 3.8, 7.6, and 10.2 cm, respectively. Traps were baited with commercially available corn chips and marshmallows and placed in different areas of each study site. Deployment times for traps and the gill net ranged from 12 to 22 h per sampling event (mean = 17 h). The active capture devices were a cast net (4-m diameter with 2.54-cm bar mesh) and a minnow seine (7.8 m long × 1.9 m high, with 3.5-

mm bar mesh). We also measured temperature, dissolved oxygen, salinity, conductivity, pH, and total dissolved solids in different areas of each study site by using a Hydrolab Scout 2 multi-analyzer (Hydrolab Co., Austin, Texas).

At each locality, captured fishes were counted separately for each fishing gear (trap, bar-mesh size panel of the gill net, cast with cast net, or minnow-seine haul). Only Baja California killifish were kept alive for measuring length (standard length to nearest 0.1 mm) and weight (to nearest 0.01 g) in the field. A subsample of these individuals was then placed on dry ice for transportation to the laboratory, and those remaining were released. All exotic fishes were placed on dry ice for transportation to the laboratory.

Baja California killifish were preserved in 70% ethanol, while exotic fishes were first fixed in 10% formaldehyde, and then preserved in 50% isopropanol. All specimens were deposited in the Fish Collection of the Facultad de Ciencias of the Universidad Autónoma de Baja California (UABC) at Ensenada. Abundance of each species by locality was expressed in terms of catch-per-unit-effort (CPUE: fish/capture device/unit of time or area). For each river basin, degree of correlation between CPUE of Baja California killifish and each biotic (exotic fishes) or abiotic (physicochemical) variable was determined using Spearman's non-parametric correlation (Sokal and Rohlf, 1981). All statistical tests were computed using Statistica 6.0 software (Statsoft Inc., Tulsa, Oklahoma).

RESULTS—*Physicochemical Variables*—In the Río San Ignacio, the salinity increased from upstream to downstream, with the lowest value (<0.1 ppt) in October 2002 (El Tizón) and the highest (4.3 ppt) in July 2004 (San Sabas). In the Río La Purísima, salinity also increased from upstream (Ojo de Agua) to downstream (La Purísima), but with lesser range of variation; the lowest values (<0.1 ppt) were recorded before the Marty hurricane-induced flood event (23 September 2003) and the highest values (0.4 to 1.0 ppt) after it. In the Río San Ignacio, pH varied between 7.02 (El Tizón, October 2002) and 10.34 (Los Corralitos, July 2004), while in Río La Purísima, it varied from 7.67 (Ojo de Agua, October 2002) to 10.13 (Presa Carambuche, July 2004).

Distribution and Abundance of Fishes—Five fish species were captured during the study, both native species (Baja California killifish) and exotic species (common carp, green swordtail, guppy, and redbelly tilapia). The distribution and abundance of these taxa are described below by site and date of sampling (Table 1).

Río San Ignacio Sites—Rancho El Tizón (27°17′53.2″N, 112°53′12.3″W; elevation 128 m), an open-water oasis, situated 200 m downstream from the spring source, had a muddy bottom and maximum depth of 2 m. Baja California killifish was the least abundant taxon found, with mean trap CPUE of 0.02 (1.4%), and redbelly tilapia the most abundant taxon, with a mean trap CPUE of 0.86 (61.4%). Mean biomass of Baja California killifish over all sampling intervals was 12.93 g and represented 1.1% of the total biomass captured. Guppy was rare and green swordtail was seasonally abundant.

The Lake Side (27°17′56.0″N, 112°53′39.0″W; elevation 125 m) is part of the reservoir Presa San Ignacio. All 5 taxa collected in this study were taken here, and Baja California killifish was rare (1%), collected in only 1 of 2 sampling times. Biomass of Baja California killifish was 2.6% of all fishes in February 2003. Redbelly tilapia was the most abundant fish over the study period (89.9%), and the other 3 species were intermittent.

Poza Larga (27°16′26.1″N, 112°54′46.5″W; elevation 108 m) is a large pond about 4 km downstream of the Río San Ignacio spring source. This pond varied seasonally in size from ca. 250 m long × 30 m wide × 1.5 m deep (September 2003, just prior to the flood event) to more than 1 km × 60 m × 2.5 m (March 2004). All fish species were captured there, with the Baja California killifish being the most abundant over the study period and for all gears combined (64.3%), except for February 2003, when the guppy dominated in traps (52.3%). In March 2004, nearly 6 months after the flood event, the mean trap CPUE for Baja California killifish decreased from 5.40 (88.1%) to 0.02 (6.3%), but it was increased to 2.42 (84.3%) for July 2004. Noteworthy was the continued presence of both juvenile and adult redbelly tilapia at this site after the flood event. Biomass of Baja California killifish in traps was 84.2% of the total fish biomass.

Rancho Los Corralitos (27°13″01.9″N, 112°59′16.9″W; elevation 73 m) was a large pond (300 m long × 50 m wide × 1.6 m maximum depth) with sandy bottom and abundant submerged vegetation. Banks and flood plain were covered by salt grass (*Distichlis spicata*) and spiny rush. Baja California killifish, common carp, and redbelly tilapia were captured at this site, with the killifish the most abundant (88.9%) over all gears and sampling dates. Common carp was present in the gill nets after February 2003 sampling event, with rates of capture that increased through the sampling intervals (0.05 to 0.23 fish/h). Biomass of Baja California killifish in traps was 76.4% of the total fish biomass captured.

Rancho San Sabas (27°11′51.8″N, 113°00′09.3″W; elevation 27 m) was one of the last oasis localities with perennial pools in this drainage before reaching the salt pannes of the coastal San Ignacio Lagoon. These bedrock pools with sand patches show strong seasonal fluctuations in size and depth. A thick layer of floating, filamentous algae (*Enteromorpha*) covered most of the pools in September 2003. All 5 fish species were captured here, and Baja California killifish was dominant (88.1%) for all gears and dates of sampling. Green swordtail, common carp, and redbelly tilapia were scarce and occurred after the September 2003 flood event. Biomass of Baja California killifish in traps represented 97.1% of the total fishes biomass captured.

Río La Purísima Sites—Ojo de Agua (26°19′24.2″N, 111°59′09.7″W; elevation 195 m) was a series of interconnected ponds (20 to 60 m wide, 200 m long, and maximum depth of 2 m) with rocky-sandy bottom and bordered by date palm and giant reed. Baja California killifish and redbelly tilapia were captured here, with the highest CPUE for Baja California killifish (61.0%) along the study period. After the September 2003 flood event, the mean trap CPUE for Baja California killifish decreased to 0.0 (January 2004), but increased to 1.36 fish/h (87.7%) in July 2004. Biomass of Baja California killifish in traps was 86.2% of the total fishes biomass.

Presa Carambuche (26°14′19.8″N, 112°00′03.6″W; elevation 160 m) was located about 3 km upstream from the town of Carambuche and consisted of a series of small shallow pools with rock and pebble bottoms and submerged (*Ceratophyllum, Chara*) and rooted-floating (*Potamogeton, Nuphar*) vegetation. Only Baja California killifish and redbelly tilapia occurred here. Baja California killifish was the most abundant fish in 3 of 4 sampling times, with mean CPUEs ranging from 0.17 (100%) to 0.74 (90.2%). The abundance of Baja California killifish also decreased after the flood event. Biomass of Baja California killifish represented 63.2% of the total fish biomass captured in traps during the sampling period.

Carambuche (26°12′51.7″N, 112°01′28.7″W; elevation 100 m) was an oasis situated opposite the town of the same name. Here the river bottom is bedrock with sand patches. Three fish species were captured (Baja California killifish, guppy, and redbelly tilapia), with dominance by the latter (64.9%). Baja California killifish represented 59.0% of the total fish biomass captured in traps.

La Purísima (26°11′58.4″N, 112°03′56.8″W; elevation 87 m) was located in front of El Pilón hill and consisted of a series of small pools (used for extraction of water for crops) with rock bottoms and bordered by southern cattails. Three fish species were captured (Baja California killifish, guppy, and redbelly tilapia), with Baja California killifish the most abundant fish in 2 of 3 sampling times (February 2003 and January 2004), and redbelly tilapia dominating in July 2004 (74.5%). In January 2004, nearly 4 months after the flood event, Baja California killifish was scarce in traps (0.06 fish/h) but increased to 0.58 (25.1%) during July 2004. Biomass of the Baja California killifish comprised 40.7% to the total fish biomass in traps.

In the Río San Ignacio basin sites, the CPUE of Baja California killifish and redbelly tilapia at the different sites showed a significant inverse correlation ($rs = -0.441$, $n = 30$, $P < 0.05$). Similar correlation analysis for CPUE data from the Río La Purísima basin sites was not significant ($rs = 0.409$, $n = 14$, $P > 0.05$).

Prior to the flood event of 23 September 2003, the CPUEs for the killifish and the tilapia were inversely correlated in the Río San Ignacio ($rs = -0.615$, $n = 16$, $P < 0.01$), but not in the Río La Purísima ($rs = 0.58$, $n = 7$, $P > 0.05$). However, following the flood event, the CPUEs of both species were positively correlated in the Río La Purísima ($rs = 0.685$, $n = 10$, $P < 0.05$), but not in the Río San Ignacio ($rs = -0.257$, $n = 15$, $P > 0.05$).

The CPUEs for green swordtail and guppy were positively correlated only in the Río San Ignacio ($rs = 0.552$, $n = 14$, $P < 0.05$). Other correlations of CPUE between species were not significant. In both river drainages, no significant correlations were detected between the CPUEs of Baja California killifish and each of the measured variables of water quality.

Discussion—During this study, 2 new localities for Baja California killifish in the Río San Ignacio were discovered (Los Corralitos and San Sabas), and its presence in the upper Río La Purísima was confirmed (Follett, 1960; Ruiz-Campos et al., 2002).

The abundance and biomass of Baja California killifish showed contrasting levels within and between the 2 basins studied. The CPUE was relatively higher in populations of the Río San Ignacio, particularly at sites where redbelly tilapia was not abundant (e.g., Poza Larga and San Sabas). Density of the killifish at the different sites of the Río San Ignacio exhibited significant negative correlation with that of the tilapia, especially prior to the flood event (23 September 2003), indicating a possible negative competitive effect by tilapia.

Previous seasonal samplings (1992 to 1993) at a site in the Río San Ignacio (site 1, El Tizón) prior to the introduction of the tilapia in 1996 showed the killifish to be dominant, with levels of relative abundance from 70 to 97% of the fish community (Alaníz-García, 1995). However, 10 years later, the fish community was dominated by redbelly tilapia, with relative abundance ranging from 84 to 94%, while killifish only reached abundance levels of 3 to 8%. These chronologically contrasting abundances would seem to represent a clear example of competitive exclusion for habitat resources or predation (Zaret and Rand, 1971; Douglas et al., 1994).

In both river basins, density and biomass of fishes captured in traps diminished significantly during the samplings of January and March 2004. This was presumably due to high mortality resulting from the extreme hurricane-induced flood event of 23 September 2003, considered by many local residents as the strongest flood of approximately the last 50 years. Nearly 10 months after the flood, the populations of Baja California killifish showed higher rates of recovery than those of the exotic fishes. This differential repopulation might be a consequence of higher survival by the killifish during excessively strong flows. We have noted that when disturbed, Baja California killifish will frequently hide in bank-side caves and under rocks (GRC, pers. observ.). Higher capacity for repopulation by native fishes following floods also has been noted in southwestern USA streams with normally regulated flows (Propst and Gido, 2004).

At Poza Larga, density and biomass of the Baja California killifish was highest among fishes captured in September 2003, just before the flood event, possibly due to a cumulative effect of the removal of exotic species during previous samplings (October 2002 and February 2003). These periodic removals perhaps reduced competitive pressure for space or food by the exotics. In this large pond with a highly fluctuating water level, CPUE (fish/trap/h) for the killifish increased substantially from 0.333 (February 2003) to 5.4 (21–22 September 2003), but later dramatically decreased to 0.018 (March 2004), probably due to the flood event. In July 2004, almost 10 months after the flood, its CPUE again increased to 2.42 fish/trap/h (45% of the total fishes captured in September 2003). This increase in density might be explained by colonization of individuals after the flood, as well as the low abundance of redbelly tilapia. Evidence of downstream dispersal of exotic tilapia by the flood was seen in March and July 2004, when juveniles and adults were captured in Poza Larga (site 3) and San Sabas (site 5). At both sites, no redbelly tilapia had been caught prior to the flood event.

Population levels of the endemic Baja California killifish are judged to be critically low at some sites in the 2 river basins. This is particularly true at the type locality (San Ignacio oasis at El Tizón and Lake Side), where Baja California killifish has been virtually displaced by redbelly tilapia. Continued dispersal of invasive tilapia to downstream sites where Baja California killifish is more abundant threatens those populations, because dispersal has been promoted by recent flood events.

Population decline of Baja California killifish, apparently due to competition with recently introduced exotic fishes, might be difficult to reverse, as has been demonstrated with several other native fishes in western North America (Moyle et al., 1986; Minckley and Deacon, 1991; Douglas et al., 1994). Dedicated programs of control or eradication of the exotic fishes are needed throughout the range of endemic Baja California killifish to ensure its persistence.

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