Relative Abundance and Distribution of Fishes and Crayfish at Ash Meadows National Wildlife Refuge, Nye County, Nevada, 2010–11

Open-File Report 2012–1141

U.S. Department of the Interior
U.S. Geological Survey

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By G. Gary Scoppettone, Danielle M. Johnson, Mark E. Hereford, Peter Rissler, Mark Fabes, Antonio Salgado, and Sean Shea

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Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
cubic meter per second (m^3/s)	70.07	acre-foot per day (acre-ft/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32.$$

Relative Abundance and Distribution of Fishes and Crayfish at Ash Meadows National Wildlife Refuge, Nye County, Nevada, 2010–11

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Introduction

Ash Meadows National Wildlife Refuge (AMNWR) was established by the U.S. Fish and Wildlife Service (with the assistance of The Nature Conservancy) in 1984 to protect one of the highest concentrations of endemic flora and fauna in North America (Pister, 1985; Sada, 1990). Prior to federal acquisition, Ash Meadows had been anthropogenically altered, and non-native species had been introduced to the detriment of native species; reports and published literature document the negative effects to the Ash Meadows flora and fauna (Deacon and others, 1964; U.S. Department of the Interior, 1971; Landye, 1973; Pister, 1974; Soltz and Naiman, 1978; Taylor, 1980; Williams and others, 1985; Williams and Sada, 1985; Baugh and others, 1986; Hershler and Sada, 1987; Knight and Clemmer, 1987; Sada, 1990; Deacon and Williams, 1991; Scoppettone and others, 2005; Kennedy and others, 2006). Such activities led to the extinction of the endemic Ash Meadows poolfish (*Empetrichthyes merriami*) (Miller, 1961; Soltz and Naiman, 1978), and subsequently the federal government listed three local endemic fish as endangered pursuant to the Endangered Species Act (U.S. Fish and Wildlife Service, 1989)—Warm springs pupfish (*Cyprinodon nevadensis pectoralis)*, Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), and Ash Meadows speckled dace (*Rhinichthys osculus nevadensis*).

Public ownership of a large portion of Ash Meadows provided the opportunity to restore the landscape to some semblance of its historical condition. Elimination of invasive aquatic species may be more difficult than landscape restoration, and their persistence can cause additional native fish decline or extirpation (Taylor and others, 1984; Moyle and others, 1986; Miller and others, 1989; Minckley and Deacon, 1991; Olden and Poff, 2005). Chemical treatment to remove invasive fishes is often unsuccessful (Meffe, 1983; Rinne and Turner, 1991; Meronek and others, 1996). In Ash Meadows, there has been some success in chemical eradication of localized populations of largemouth bass (*Micropterus salmoides*) and black bullhead (*Ameiurus melas*) (St. George, 1998, 1999; Weissenfluh, 2008b), as well as convict cichlid (*Archocentrus nigrofasciatus*) and sailfin molly (*Poecilia latipinna*) (Weissenfluh, 2008a). However, there has been less success in removing western mosquitofish (*Gambusia affinis*) from Ash Meadows's larger spring systems, and sailfin molly maintains strongholds in several spring systems (Scoppettone and others, 2011b). Perhaps the more destructive invasive species are two invertebrates: red swamp crayfish (*Procambarus clarkii*) and red-rim melania (*Melanoides tuberculata*). Following the appearance of red swamp crayfish within the Warm Springs Complex, Warm Springs pupfish was believed to be extirpated from one spring system (St. George, 2000) and near extirpation in two others (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2008, 2011). Crayfish also were demonstrated to greatly suppress the Bradford Springs population of Ash Meadows speckled dace population (McShane and others, 2004). Red-rim melania is known to displace native snail populations (Mitchell and others, 2007), and has been implicated as an agent of extinction of native Ash Meadows spring-snails (Donald Sada, Desert Research Institute, oral commun., 2011). Both invasive invertebrates are difficult to control or eradicate (Mitchell and others, 2007; Freeman and others, 2010).

Habitat restoration that favors native species can help control non-native species (McShane and others, 2004; Scoppettone and others, 2005; Kennedy and others, 2006). Restoration of Carson Slough and its tributaries present an opportunity to promote habitat types that favor native species over non-natives. Historically, the majority of Ash Meadows spring systems were tributaries to Carson Slough. In 2007 and 2008, a survey of Ash Meadows spring systems was conducted to generate baseline information on the distribution of fishes throughout AMNWR (Scoppettone and others, 2011b). In this study, we conducted a follow-up survey with emphasis on upper Carson Slough. This permitted us to gauge the early effects of spring system restoration on fish populations and to generate further baseline data relevant to future restoration efforts.

Background

Dudley and Larson (1976) described the Ash Meadows spring systems as emerging in three groups: northern, central, and southern spring systems. Their grouping is based on spring connectivity: Fairbanks, Soda, Rogers, Longstreet, Five, and Cold Springs make up Northern Springs; School, North Indian, South Indian, Marsh, North Scruggs, South Scruggs, and Crystal Springs make up the Central Springs; and Kings Pool, Point of Rocks, Jack Rabbit, Big, Forest, Tubbs, and Bradford Springs make up the Southern Springs. Our grouping of spring systems is similar to that of Dudley and Larson (1976), but is taxonomically influenced—we include Crystal Spring with the Southern Springs, and we refer to the Central Springs as the Warm Springs Complex. Our grouping allows us to better distinguish Warm Springs and Ash Meadows pupfish habitats.

Northern Springs

Historically, the Northern Springs flowed into a common channel (Carson Slough) as shown in the Mount Diablo Meridian (Department of Interior General Land office, February 16, 1887). Prior to spring system restoration, the outflows of the Northern Springs were all earthen ditches conveying water for irrigation. Over time, water conveyance channels had become clogged with emergent vegetation causing channels to overflow, creating marsh lands within several hundred meters of spring discharge points. Restoration of the Northern Springs is targeted toward conveying spring discharge within a well-defined channel mimicking the historical course (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). Our 2011 survey was conducted during phase 2 of pre- and post-restoration of Fairbanks Spring system. In phase 1 completed in March 2010, a stream channel was constructed from Fairbanks spring-pool to 4 km downstream and its discharge formed a shallow marsh. In phase 2 completed in November 2010, Fairbanks Spring was connected, with a well-defined channel, to Longstreet and Rogers Springs. To avoid confusion in comparing seasonal fish distribution created by changes to the Northern Spring systems, we named the reach of stream receiving water from Longstreet and Rogers Springs and southward to join Fairbanks Springs and extending to Peterson Reservoir as “Carson Slough.” In phase 1, this reach received water only from Longstreet and Rogers Springs, drained from a common marsh. In phase 2, Carson Slough also received water from Fairbanks Spring at about the slough’s midpoint. In addition to changing stream courses, the Fairbanks Spring system received 98 Ash Meadows speckled dace on April 14–15, 2010, and another 20 dace on August 19, 2010 (Cristi Baldino, Ash Meadows National Wildlife Refuge, written commun., 2011).

Soda Spring also was restored following the 2007–08 survey. Prior to restoration, the outflow was marsh habitat discharging into Fairbanks Spring, and after restoration, a well-defined channel approximately 300 m in length discharged into a shallow marsh south of the Soda spring-pool. A total of 21 speckled dace were introduced between April 3 and 18, 2011 (Cristi Baldino, Ash Meadows National Wildlife Refuge, written commun., 2011).

Restoration of Longstreet, Rogers, and Cold Springs is in the design stage. As part of restoration, sailfin mollies were eliminated from the Longstreet Spring system prior to the spring survey. This was part of a Nevada Department of Wildlife rotenone project conducted from February 15–16, 2011 (Kevin Guadalupe, Great Basin Institute, written commun., 2012). Longstreet Spring was the only site in the Northern Spring area known to harbor sailfin molly (Scoppettone and others, 2011b).

Warm Springs Complex

The Warm Springs Complex consists of several warm (30–33.5^{o}C), low discharge springs (<0.028 m^3/s) sufficiently isolated to harbor one of the six subspecies of Amargosa pupfish, Warm Springs Amargosa pupfish (Miller, 1948). One small population in Mexican Spring was lost in 1973 when the spring dried (Yoakum and others, 1976). Because Warm Springs pupfish exist in such small and low-flow habitat, they are more susceptible to non-native invaders, such as crayfish and mosquitofish.

During the current study, the Indian Spring system was undergoing restoration and was not sampled. Other changes since the 2007–08 survey were refuge acquisition of a private land along North Scruggs Spring, allowing us to sample that entire system, and rehabilitation of School Spring, including elimination of mosquitofish and crayfish from that system (Weissenfluh, 2008c, 2010).

Southern Springs

Crystal Spring is Ash Meadows largest spring by discharge (0.18 m^3/s). Much of the flow is conveyed in concrete channels constructed before federal acquisition. A diagram of the Crystal Spring channel system appears in Scoppettone and others (1995). The channels are in a state of decay, and water has broken through at several locations. During this study, water was being diverted to Crystal Reservoir, and Crystal Marsh and Horseshoe Marsh, also referred to as Lower Crystal Reservoir and Horseshoe Reservoir, respectively.

No restoration was initiated in the Southern Springs area since the 2007–08 survey by Scoppettone and others (2011b). However, there was a substantial change in vegetation along the Jackrabbit Spring system with coyote willow (*Salix exigua*) proliferating along the stream reach restored in 2006, and common reed (*Phragmites* sp.) spreading several hundred meters downstream of the restoration site.

Materials and Methods

We followed Scoppettone and others (2011b) and used Geographic Information Systems (GIS) using the National Agricultural Imagery Program (NAIP) to trace stream channels and to determine locations of sampling stations. In this study, comprehensive surveys of Ash Meadows spring systems were conducted in the fall 2010 and spring 2011. We also surveyed the larger Northern Springs in the winter 2011. There were 741 and 744 established sampling stations for the fall and spring surveys, respectively, and 156 for the winter survey. (fig. 1). The lowermost reach of the Fairbanks Spring outflow was realigned to flow into Carson Slough between fall 2010 and winter 2011 (fig. 1). Coordinates for each station were created using North American Datum (NAD) 83 decimal degrees longitude/latitude and downloaded into Garmin Global Positioning System (GPS) units. These units typically are accurate within a 2 m radius of a specific station. GIS also was used to illustrate seasonal distribution and relative abundance of fishes in each spring system. Data collected during each sampling period were used to develop species-specific GIS maps, which display range and densities.

We used standard Gee (1/8-in. mesh) and modified minnow traps and followed the same sampling protocol described by Scoppettone and others (2011b). Most traps were set in the afternoon and checked the following morning. Shorter sets, placed in the morning and checked 3 –h later, were used in areas with high fish densities, high crayfish densities, spring pools, and areas with water temperatures greater than 29^{o}C (to prevent fish mortality). Floats were used in spring-pools to set a trap at mid-water and a trap near the surface, as well as four benthic sets to sample the entire water column. Fish were identified to species and 10–20 individuals from each trap were measured to fork length (FL). Water temperature, using pocket thermometers, and depth measurements were taken at each station.

Relative abundance and distribution are illustrated using two methods: (1) total fish captured in each system and major habitat type (springhead, spring-pool, outflow, marsh, and reservoir) is shown by season in tabular form; and (2) trap-specific distribution and abundance using combined seasonal data are presented using GIS-generated maps.

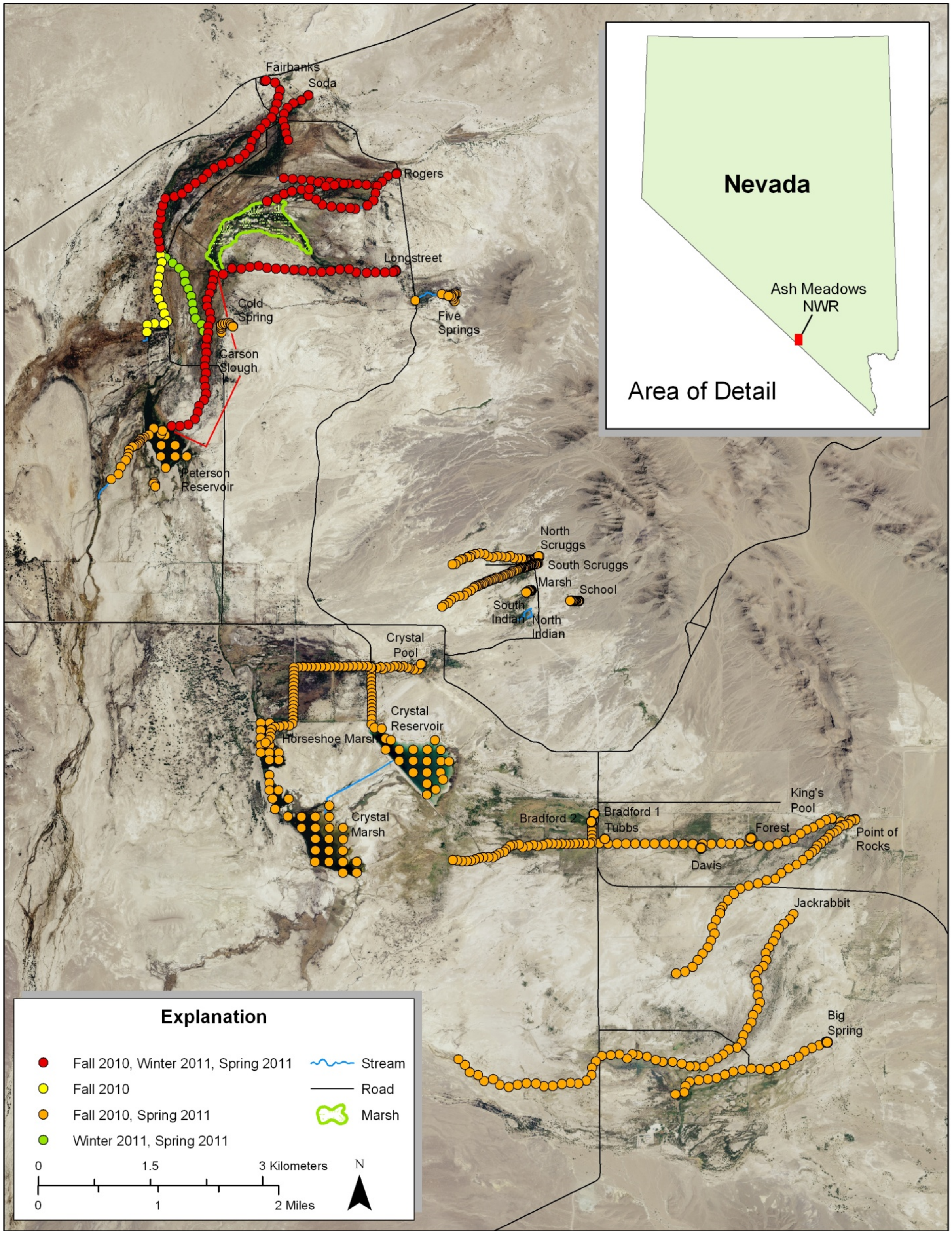

Figure 1. Aerial photograph of Ash Meadows National Wildlife Refuge showing sampling stations in fall 2010 (741), winter 2011 (156), and spring 2011 (744), Nye County, Nevada.

Results

Northern Springs

Pupfish were numerous and widespread in the restored habitats of Fairbanks and Soda Springs, and Carson Slough. In Fairbanks Spring system, pupfish were captured in greatest frequency and over a broader area in fall 2010 and spring 2011 than in winter 2011 (table 1, figs. 2 and 4). The greatest number of pupfish was captured from Carson Slough, close to Peterson Reservoir, in winter (fig. 3). The greatest number of speckled dace was captured in winter from Fairbanks outflow (n=236) and from Carson Slough (n=13) (table 1). Speckled dace distribution was broadest in spring 2011 (figs. 5–7), with two dace captured in Longstreet stream and another two in Peterson stream. Water velocity at four stations in Fairbanks stream and five stations in Carson Slough was too rapid to set minnow traps; we suspect that we would have captured dace at these stations as well. There were no consistent trends in pupfish length between spring-pools and stream outflows among seasons (table A1). Among the Northern Springs, pupfish in Five Springs generally were the smallest (17–51 mm). The larger crayfish generally occurred in the spring systems with greater discharge (Fairbanks, Rogers, and Longstreet Springs). American bullfrog (*Rana catesbeiana*) also was captured in Fairbanks, Soda, Rogers and Longstreet Spring systems (table 1).

In the Northern Springs area, sailfin molly was only present in the Longstreet Spring system, with few captures in the spring-pool and outflow stream in fall 2010 and winter 2011 (table 1, figs. A1–A2). Following the February 2011 chemical treatment aimed at eliminating sailfin molly from the Longstreet Spring system, no sailfin mollies were captured in spring 2011 (fig. A3). Mosquitofish were more widespread than sailfin molly (figs. A4–A6), but captures generally were low for the Fairbanks and Longstreet Spring systems in winter and spring. Cold Spring was the only Northern Spring system in which no mosquitofish was captured. Captures for mosquitofish were highest in the Rogers Spring system, which also had the highest captures of crayfish for the three seasons sampled.

Table 1. Seasonal catches of fishes, bullfrog, and crayfish at the Northern Springs of the Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

[Winter 2011—only Fairbanks, Soda, Rogers and Longstreet Springs were sampled. Spring locations are shown in figure 1. Species: CYMI, Ash Meadows Amargosa pupfish; CYPE, Warm Springs Amargosa pupfish; GAAF, Mosquitofish; LECY, Green Sunfish; MISA, Largemouth Bass; POLA, Sailfin Molly; PRCL, Red Swamp Crayfish; RACA, Bullfrog; RHON, Ash Meadows speckled dace]

System	Season	Species								
		CYMI	**CYPE**	**RHON**	**GAAF**	**POLA**	**LECY**	**MISA**	**RACA**	**PRCL**
Fairbanks spring-pool	Fall 2010	426	-	-	-	-	-	-	-	62
	Winter 2011	272	-	-	-	-	-	-	-	-
	Spring 2011	417	-	-	-	-	-	-	-	31
Fairbanks stream	Fall 2010	1,264	-	120	149	-	-	-	-	41
	Winter 2011	880	-	236	3	-	-	-	1	72
	Spring 2011	2,491	-	166	5	-	-	-	1	56
Soda spring-pool	Fall 2010	3	-	-	10	-	-	-	-	3
	Winter 2011	-	-	-	-	-	-	-	-	10
	Spring 2011	12	-	-	2	-	-	-	-	24
Soda stream	Fall 2010	251	-	-	-	-	-	-	2	41
	Winter 2011	417	-	-	5	-	-	-	-	58
	Spring 2011	363	-	-	3	-	-	-	-	58
Roger spring-pool	Fall 2010	125	-	-	66	-	-	-	6	31
	Winter 2011	213	-	-	22	-	-	-	2	8
	Spring 2011	227	-	-	21	-	-	-	10	2
Roger stream	Fall 2010	14	-	-	205	-	-	-	-	150
	Winter 2011	58	-	-	190	-	-	-	1	195
	Spring 2011	32	-	-	97	-	-	-	-	176
Longstreet spring-pool	Fall 2010	319	-	-	5	5	-	-	-	16
	Winter 2011	599	-	-	16	13	-	-	4	29
	Spring 2011	79	-	-	1	-	-	-	-	24
Longstreet stream	Fall 2010	27	-	-	30	1	-	-	-	51
	Winter 2011	19	-	-	20	4	-	-	-	22
	Spring 2011	17	-	1	-	-	-	-	-	39
Carson Slough	Fall 2010	157	-	-	115	-	-	-	-	6
	Winter 2011	1,449	-	13	2	-	-	-	-	11
	Spring 2011	312	-	3	4	-	-	-	-	28
Five Springs spring-pool	Fall 2010	24	-	-	4	-	-	-	-	8
	Spring 2011	12	-	-	-	-	-	-	-	3
Five Springs stream	Fall 2010	6	-	-	43	-	-	-	-	34
	Spring 2011	10	-	-	36	-	-	-	-	-
Peterson reservoir	Fall 2010	29	-	-	19	-	-	-	-	1
	Spring 2011	8	-	-	-	-	-	-	-	-
Peterson stream	Fall 2010	No water due to low reservoir level								
	Spring 2011	124	-	2	1	-	-	-	-	1
Cold spring	Fall 2010	-	-	-	-	-	-	-	-	21
	Spring 2011	-	-	-	-	-	-	-	-	26
Cold stream	Fall 2010	1	-	-	-	-	-	-	-	51
	Spring 2011	1	-	-	-	-	-	-	-	37
Cold pool	Fall 2010	-	-	-	-	-	-	-	-	5
	Spring 2011	-	-	-	-	-	-	-	-	18

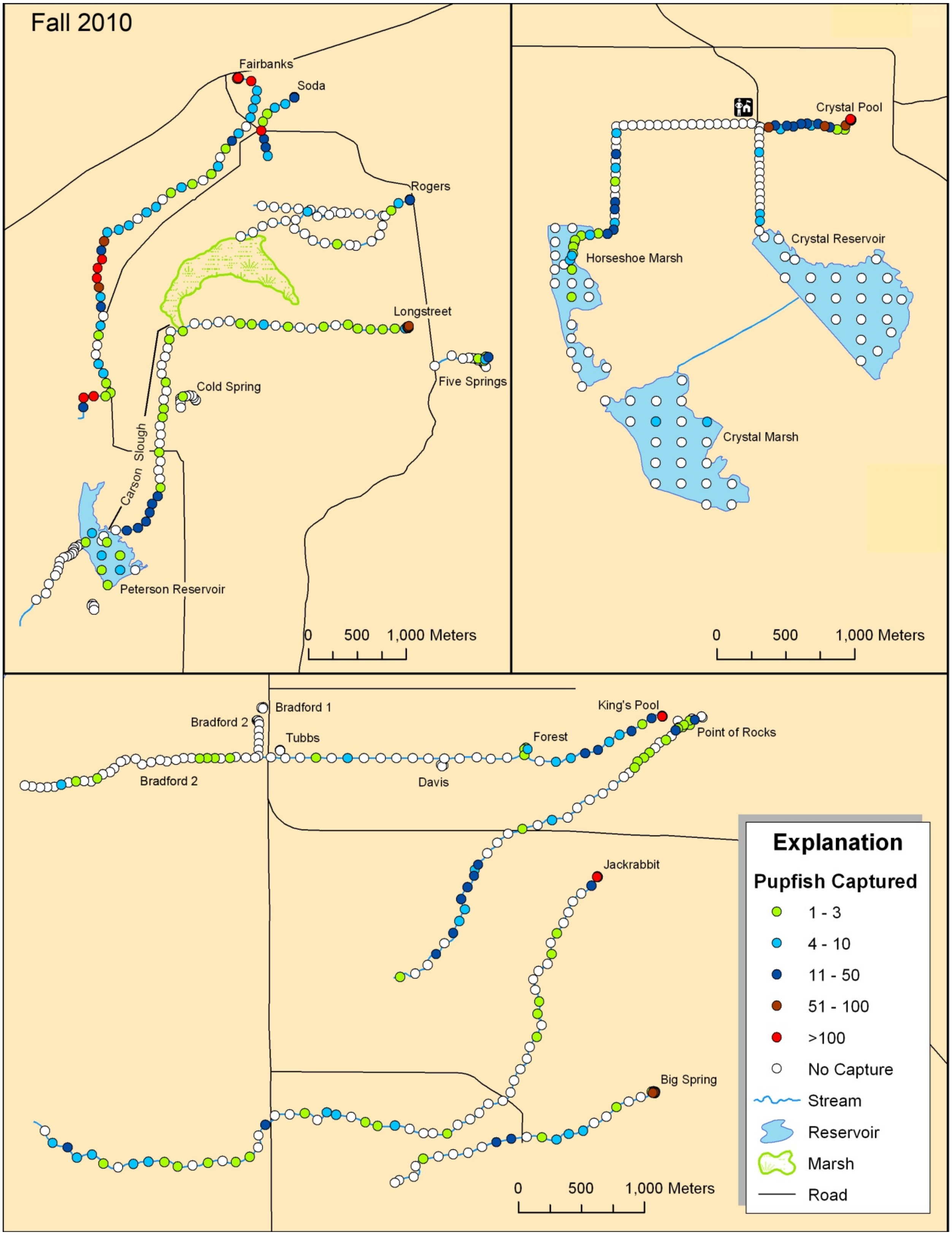

Figure 2. Relative abundance and distribution of Ash Meadows Amargosa pupfish throughout Ash Meadows National Wildlife Refuge, Nevada, fall 2010.

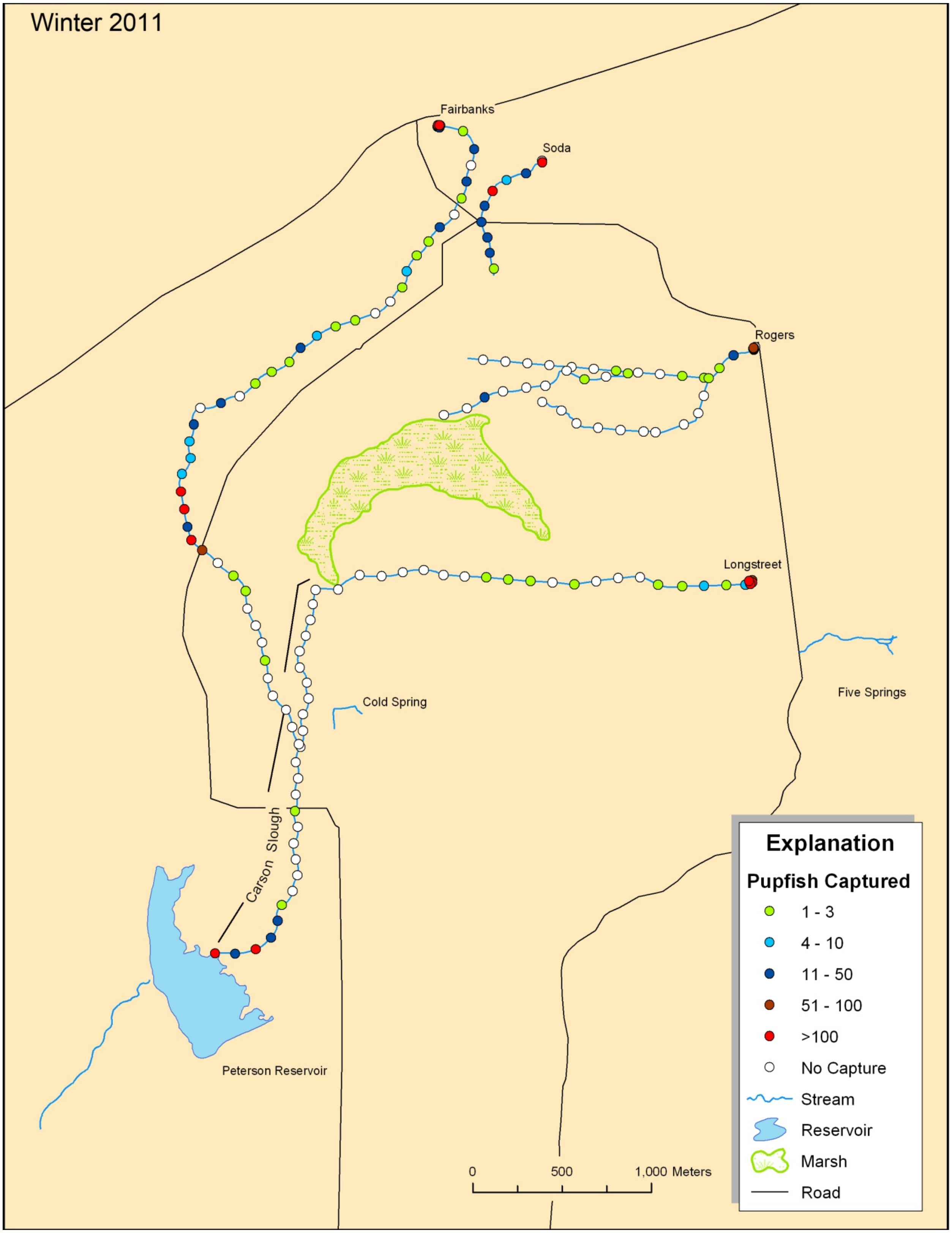

Figure 3. Relative abundance and distribution of Ash Meadows Amargosa pupfish in Fairbanks, Soda, Rogers, and Longstreet Springs Ash Meadows, National Wildlife Refuge, Nevada, winter 2011.

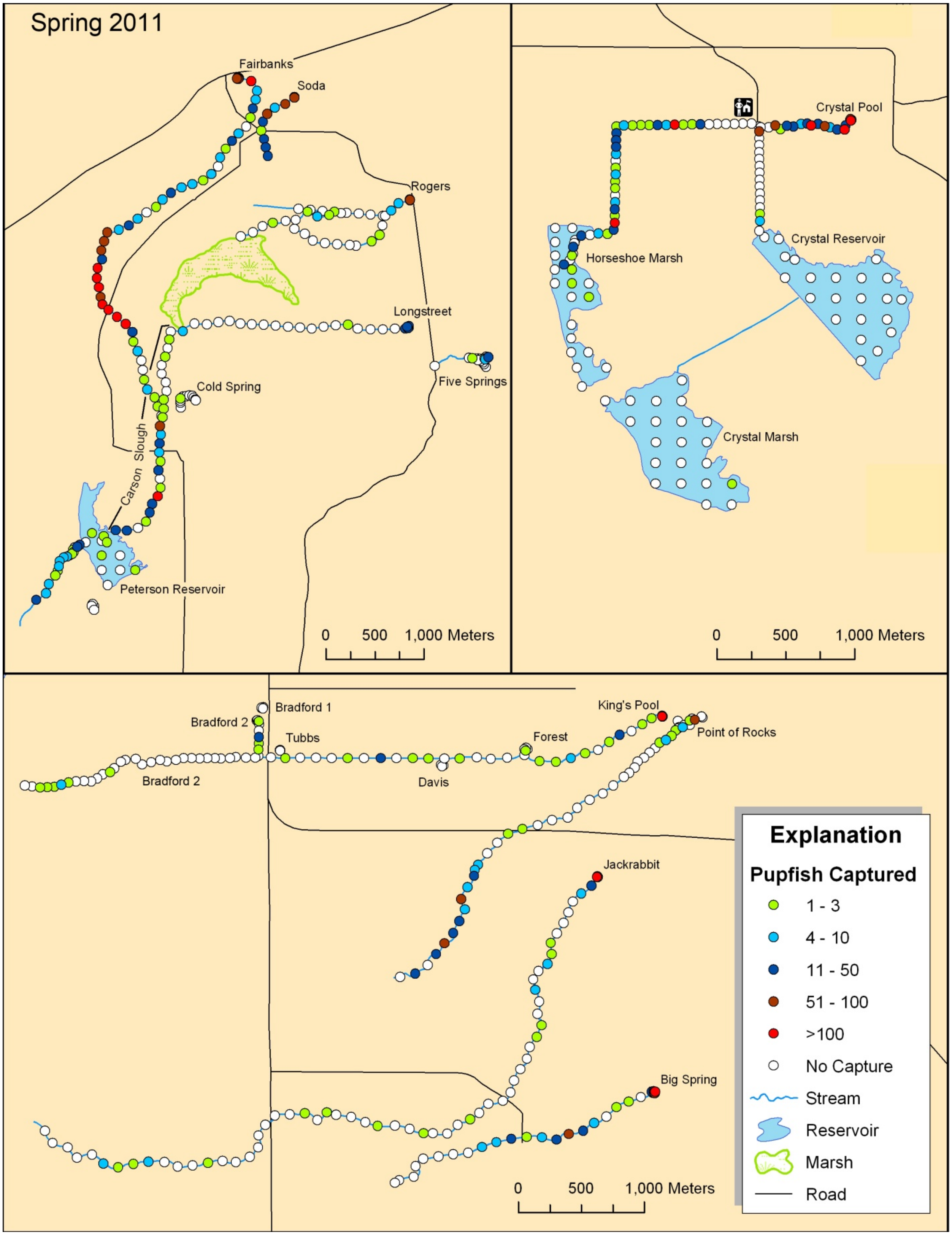

Figure 4. Relative abundance and distribution of Ash Meadows Amargosa pupfish throughout Ash Meadows National Wildlife Refuge, Nevada, spring 2011.

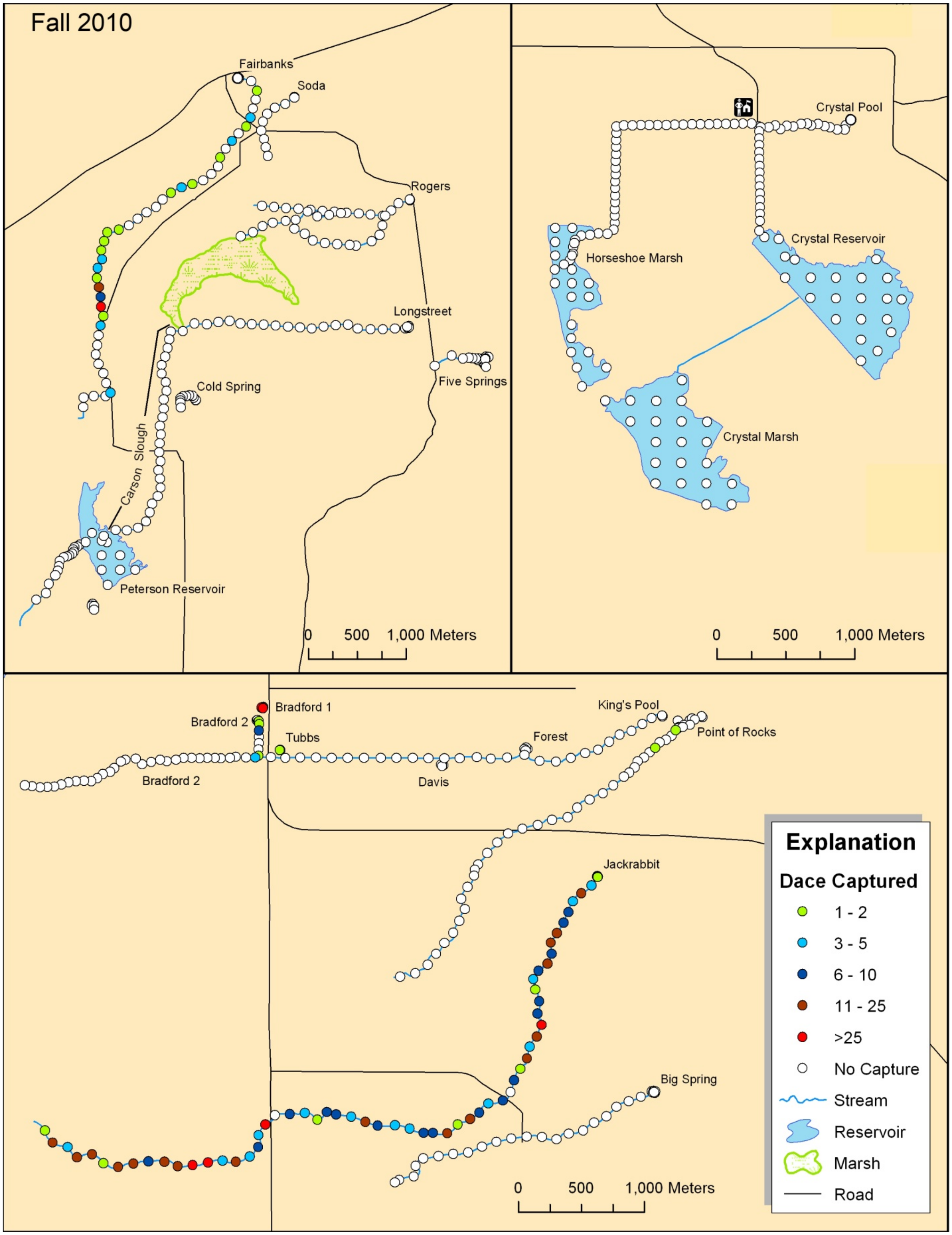

Figure 5. Relative abundance and distribution of Ash Meadows speckled dace throughout Ash Meadows National Wildlife Refuge, Nevada, fall 2010.

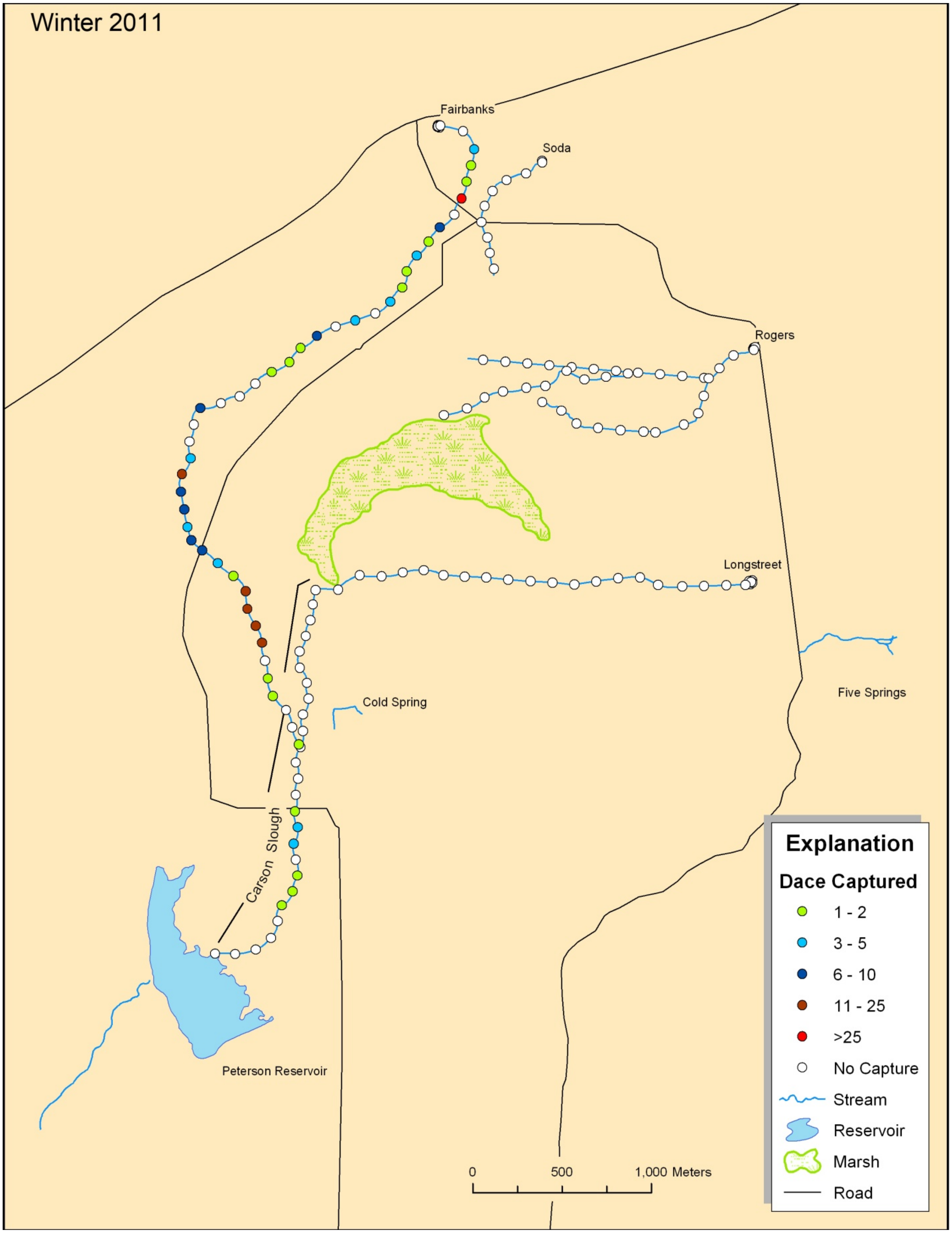

Figure 6. Relative abundance and distribution of Ash Meadows speckled dace in Fairbanks, Soda, Rogers, and Longstreet Springs Ash Meadows National Wildlife Refuge, Nevada, winter 2011.

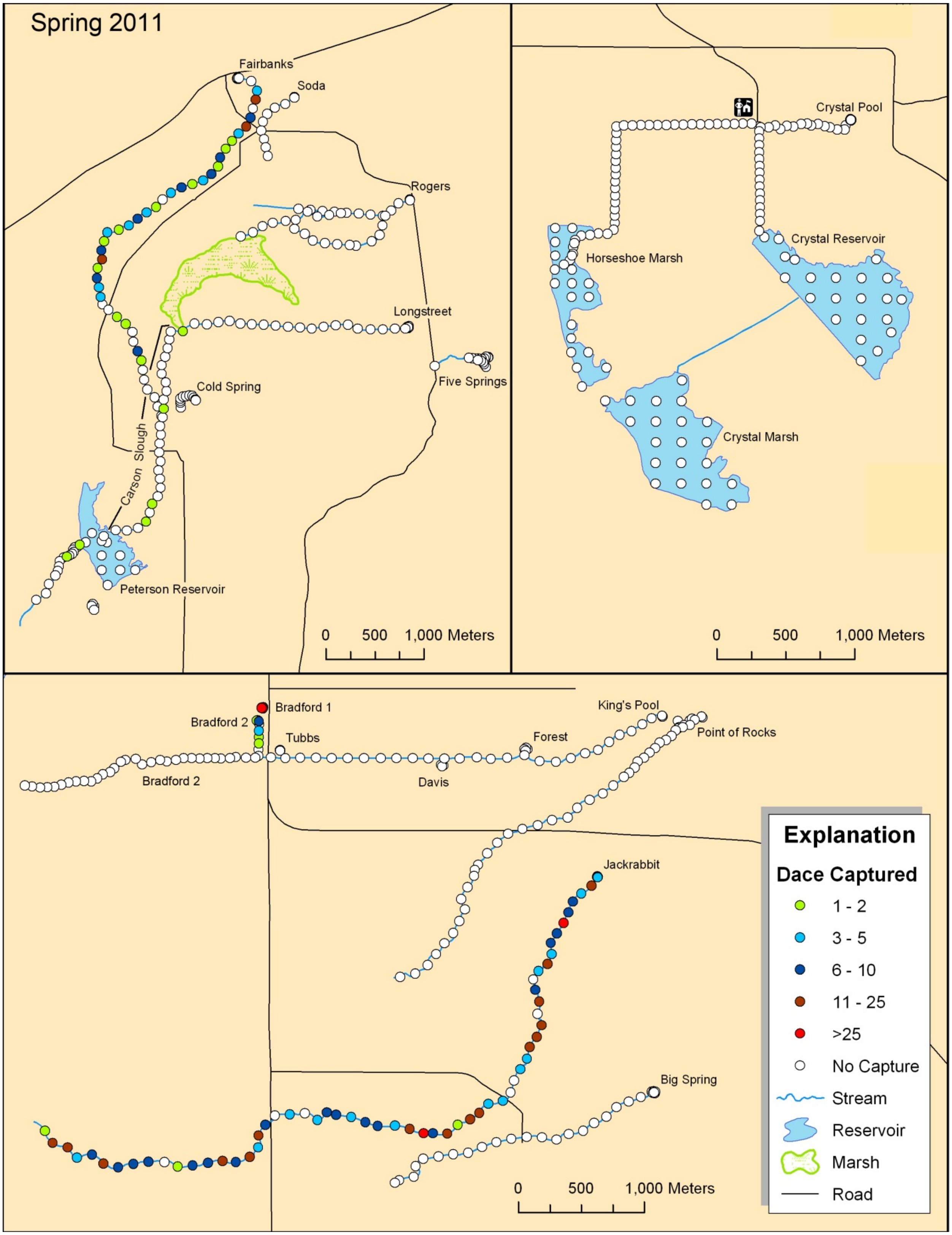

Figure 7. Relative abundance and distribution of Ash Meadows speckled dace throughout Ash Meadows National Wildlife Refuge, Nevada, spring 2011.

Warm Springs Complex

Pupfish captures for both North Scruggs and South Scruggs Springs were highest in the fall (95 and 120, respectively; table 2) when juvenile pupfish were abundant in their respective marshes at the downstream end of each of the two springs. In North Scruggs Spring, no pupfish were captured in the upper-most 50 m of stream in fall or spring; they were distributed over a wider area in the fall (fig. 8). South Scruggs Spring was the only spring-system in the Warm Springs Complex harboring mosquitofish and crayfish (table 2). Mosquitofish were captured within a 400 m stream reach in fall and 300 m stream reach in spring (fig. A10). Crayfish were more widespread than pupfish or mosquitofish (fig. A11), and in the fall, there were more crayfish captures than pupfish or mosquitofish captures (table 2).

School and Marsh Springs are truncated systems with more constant water temperatures and pupfish captures were highest in the spring (329 and 123, respectively; table 2). Pupfish was the only species captured from both Marsh and School Springs. The majority of pupfish captures were from the spring outflows (rather than spring-pools) for both systems (table 2). School Spring has undergone extensive restoration since our 2007–08 surveys (Weissenfluh, 2010), and fish were captured throughout the system and not just limited to the spring-pool (fig. 8).

Table 2. Seasonal catches of fishes, bullfrogs, and crayfish in the Warm Springs Complex of the Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

[Spring locations are shown in figure 1. Species: CYMI, Ash Meadows Amargosa pupfish; CYPE, Warm Springs Amargosa pupfish; GAAF, Mosquitofish; LECY, Green Sunfish; MISA, Largemouth Bass; POLA, Sailfin Molly; PRCL, Red Swamp Crayfish; RACA, Bullfrog; RHON, Ash Meadows speckled dace]

System	Season	Species								
		CYMI	CYPE	RHON	GAAF	POLA	LECY	MISA	RACA	PRCL
North Scruggs spring-pool	Fall 2010	-	-	-	-	-	-	-	-	-
	Spring 2011	-	-	-	-	-	-	-	-	-
North Scruggs stream	Fall 2010	-	95	-	-	-	-	-	-	-
	Spring 2011	-	58	-	-	-	-	-	-	-
South Scruggs spring-pool	Fall 2010	-	1	-	-	-	-	-	-	2
	Spring 2011	-	-	-	-	-	-	-	-	2
South Scruggs stream	Fall 2010	-	120	-	13	-	-	-	-	131
	Spring 2011	-	93	-	19	-	-	-	-	69
Marsh spring-pool	Fall 2010	-	-	-	-	-	-	-	-	-
	Spring 2011	-	-	-	-	-	-	-	-	-
Marsh Stream	Fall 2010	-	64	-	-	-	-	-	-	-
	Spring 2011	-	123	-	-	-	-	-	-	-
North and South Indian spring-pools and streams	Not surveyed due to ongoing restoration									
School spring-pool	Fall 2010	-	13	-	-	-	-	-	-	-
	Spring 2011	-	2	-	-	-	-	-	-	-
School stream	Fall 2010	-	252	-	-	-	-	-	-	-
	Spring 2011	-	329	-	-	-	-	-	-	-

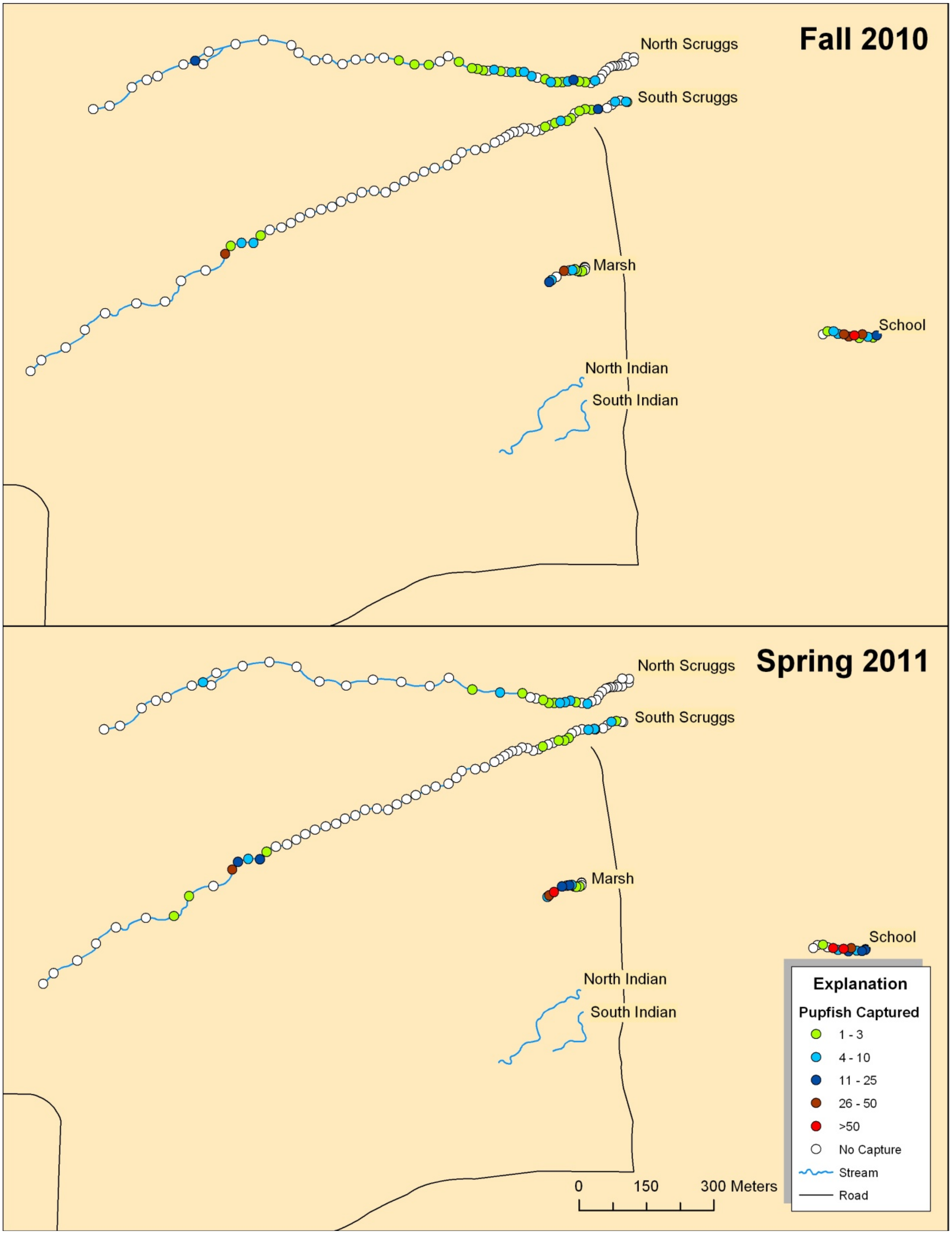

Figure 8. Relative abundance and distribution of pupfish in North Scruggs, South Scruggs, Marsh, and School Springs, Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

Southern Springs

Distribution of pupfish was broader in the Crystal Spring system in spring 2011 than in fall 2010; however, captures in the spring-pool were much greater in the fall than in the spring (table 3, fig. 2). Mosquitofish (figs. A4 and A6) and crayfish (figs. A7 and A9) also were captured in greater numbers and over a broader area in spring 2011. Sailfin molly (figs. A1 and A3) were captured less frequently and at substantially fewer stations than other species, but had slightly greater capture and broader distribution in spring 2011.

Pupfish captures from the spring-pool in Kings Pool Spring were similar in fall 2010 (n=647) and spring 2011 (n=635) (table 3). Captures in the outflow stream were substantially less than the spring-pool, and there was a greater disparity in captures between fall 2010 (n=137) and spring 2011 (n=78). Most stream captures were upstream of Forest Spring (fig. 2). The mean size of pupfish captured in the stream (34 mm) was greater than pupfish captured from the spring-pool (32 mm) (table A3).

The greatest capture of pupfish in the Point of Rocks Springs system was in spring 2011 with the greatest density in the upper and lower end of the system. Only three speckled dace were captured and this was during the fall sampling period. Few mollies were captured and these were relegated to the upper reaches (figs. A1 and A3). Mosquitofish were abundant with the highest captures and greatest distribution in fall 2010 (table 3; figs. A4 and A6). Crayfish also were abundant and widespread in the fall 2010 and spring 2011, but crayfish had a wider distribution in spring 2011 (figs. A7 and A9). Crayfish captures tended to be highest in the upper springbrook but below the spring-pool in an area where pupfish captures tended to be less (figs. 2–3; figs. A7 and A9).

The only fishes captured from Bradford 1 Spring were speckled dace and mosquitofish. Bradford 1 Spring supported a substantial number of speckled dace for its limited habitat, but many were juveniles (<50 mm FL; table A3). Four aquatic species were captured in Bradford 2 Spring (pupfish, speckled dace, mosquitofish, and crayfish), but only mosquitofish were captured with great frequency (table 3). More mosquitofish were captured than crayfish, but crayfish were captured at more sampling sites, occurring throughout the springbrook downstream of the source pools (figs. A4, A6, A7, and A9). Mosquitofish also was the predominant species captured in Forest Spring, followed by crayfish. One speckled dace in fall 2010 was the only fish captured in Tubbs Spring, which is heavily infested with crayfish. Only crayfish were captured from Davis Spring.

The greatest number of pupfish captured in Big Spring was in spring 2011 for the spring-pool and outflow stream (table 3, fig. 2). Mosquitofish was the most frequently captured non-native fish, and capture success and distribution was greatest in fall 2010. Mollies were sparse in both fall 2010 and spring 2011 (fig. A3). The greatest number of crayfish was captured in the spring-pool and stream in spring 2011, but broadest distribution was in fall 2010 (fig. A11).

The greatest capture of pupfish in the Jackrabbit Spring system was in the spring-pool, and the greatest capture for speckled dace was in the stream. Pupfish and speckled dace captures were highest in fall 2010 (table 3, fig. 2). Both species had their broadest distribution in fall 2010. Along with their greater number in the stream, speckled dace had broader distribution than pupfish, and in fall 2010, speckled dace was captured in all but two sample locations. Mosquitofish and crayfish were abundant and widespread throughout the system, with the greatest capture and distribution in fall 2010. Mollies were limited in both distribution and number with the greatest number captured in spring 2011 in the spring-pool.

Table 3. Seasonal catches of fishes, bullfrogs, and crayfish at the Southern Springs of the Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

[No sampling of these springs in winter 2011. Spring locations are shown in figure 1. Species: CYMI, Ash Meadows Amargosa pupfish; CYPE, Warm Springs Amargosa pupfish; GAAF, Mosquitofish; LECY, Green Sunfish; MISA, Largemouth Bass; POLA, Sailfin Molly; PRCL, Red Swamp Crayfish; RACA, Bullfrog; RHON, Ash Meadows speckled dace]

System	Season	Species								
		CYMI	CYPE	RHON	GAAF	POLA	LECY	MISA	RACA	PRCL
Crystal spring-pool	Fall 2010	455	-	-	217	-	-	-	-	29
	Spring 2011	78	-	-	16	-	-	-	-	-
Crystal stream	Fall 2010	619	-	-	364	68	-	-	-	561
	Spring 2011	1,499	-	-	404	100	-	-	-	273
Crystal reservoir	Fall 2010	-	-	-	-	-	37	-	-	-
	Spring 2011	-	-	-	-	-	1	3	-	-
Crystal marsh	Fall 2010	13	-	-	1	-	52	-	-	-
	Spring 2011	1	-	-	22	-	39	-	-	-
Horseshoe marsh	Fall 2010	11	-	-	35	14	1	1	-	86
	Spring 2011	9	-	-	83	-	1	-	-	100
Kings Pool spring-pool	Fall 2010	647	-	-	6	10	-	-	-	-
	Spring 2011	635	-	-	21	-	-	-	-	-
Kings Pool stream	Fall 2010	137	-	-	123	19	-	-	-	59
	Spring 2011	78	-	-	33	20	-	-	-	60
Point of Rocks stream	Fall 2010	252	-	3	85	9	-	-	-	113
	Spring 2011	368	-	-	62	11	-	-	-	123
Bradford 1 spring-pool	Fall 2010	-	-	145	9	-	-	-	-	58
	Spring 2011	-	-	161	16	-	-	-	-	32
Bradford 1 stream	There is no longer an outflow channel due to restoration									
Bradford 2 spring-pool	Fall 2010	-	-	-	466	-	-	-	1	20
	Spring 2011	-	-	5	294	-	-	-	-	54
Bradford 2 stream	Fall 2010	12	-	16	174	15	-	-	-	131
	Spring 2011	34	-	13	177	10	-	-	-	89
Forest spring-pool	Fall 2010	9	-	-	235	7	-	-	-	75
	Spring 2011	3	-	-	53	-	-	-	-	40
Tubbs spring-pool	Fall 2010	-	-	1	-	-	-	-	-	67
	Spring 2011	-	-	-	-	-	-	-	-	28
Davis spring-pool	Fall 2010	-	-	-	-	-	-	-	-	11
	Spring 2011	-	-	-	-	-	-	-	-	-
Jackrabbit spring-pool	Fall 2010	474	-	3	42	3	-	-	-	14
	Spring 2011	468	-	10	22	54	-	-	-	11
Jackrabbit stream	Fall 2010	118	-	623	224	4	-	-	-	261
	Spring 2011	68	-	538	28	6	-	-	-	123
Big Spring spring-pool	Fall 2010	221	-	-	106	21	-	-	-	23
	Spring 2011	310	-	-	26	13	-	-	-	35
Big Spring stream	Fall 2010	54	-	-	195	18	-	-	1	94
	Spring 2011	201	-	-	85	11	-	-	1	131

Discussion

Results of this study illustrate the status of native fish species better than the status of non-native fish species. Mosquitofish are surface dwellers (Scoppettone, 1993), and presumably do not typically encounter minnow traps lying on the stream bottom. Pupfish and speckled dace are more benthically oriented (Scoppettone and others, 2005) and consequently are more like to encounter traps. Sailfin molly demonstrate greater trap avoidance than mosquitofish, pupfish, or speckled dace, and thus our trapping data likely underestimated the abundance of sailfin molly, although its distribution is accurately portrayed.

There was no consistent seasonal trend in capture success among species—several factors likely contributed to this condition. Population numbers in Crystal and Big Springs were probably influenced by invasive predators (largemouth bass in Big Spring and green sunfish (*Lepomis cyanellus)* and perhaps largemouth bass in Crystal Spring). These predators probably impacted both spring systems during or between surveys. AMNWR staff removed 46 green sunfish from these systems since October 5, 2010, with none having been caught after 2 were removed on June 21, 2011 (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). Fish population numbers at the Jackrabbit Spring system are being influenced by the spread of coyote willow. Predictably, the effect on pupfish is negative because pupfish feed on algae, which in turn requires sunlight (Kennedy and others, 2006). The effect on speckled dace needs further evaluation. Restoration efforts at Fairbanks and Soda Springs occurred during the survey, and profoundly influenced numbers and distribution of fishes and crayfish. Restoration of Fairbanks' and Soda springs' channels altered their previous connectivity relationships with the Longstreet, Rogers, and Cold Springs systems, thus influencing abundance and distribution of fishes in those systems as well.

Northern Springs

The abundance and widespread distribution of Ash Meadows Amargosa pupfish in the newly restored Fairbanks and Soda Springs demonstrate that open-water habitat is conducive to this species (Kennedy and others, 2006; Scoppettone and others, 2011a). The future relative abundance and distribution of pupfish probably will be influenced by how open the channel remains to sunlight. Thus where pupfish are concerned, it is important to encourage open-water habitats whenever possible, which is important for restoration considerations, including re-vegetation options.

The shift in the Soda Spring fish community is particularly noteworthy. Only mosquitofish were captured in the 2007–08 survey, with no pupfish recorded. During this survey, hundreds of pupfish were captured and 21 speckled dace from Jackrabbit Spring were introduced into the system in March 2011. Although none were captured during the spring 2011 sampling period, AMNWR personnel captured nine in July 2011 (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). Speckled dace occupy a wide range of habitat types (Moyle, 2002), including low-discharge spring systems, such as Soda Spring. However, there are frequent impacts from invasive crayfish and mosquitofish in shallow low-discharge systems. Soda Spring presents an opportunity to test whether speckled dace can persist in a low volume spring system in the presence of these invasive species.

Repatriation of speckled dace to the Fairbanks Spring system appears to have succeeded. More dace were captured in the minnow traps during each of the three seasons sampled than the 118 dace introduced to the system. Reintroduction of speckled dace occurred within several months of phase 1 post-restoration, when mosquitofish and crayfish numbers were low. A relatively low number of these predatory invasive species probably enhanced survival of speckled dace eggs and larvae (Leavy and others, 2004). Restoration of Longstreet and Rogers Springs is anticipated to allow speckled dace expansion in the Northern Springs area.

No sailfin molly was captured from the Longstreet Spring system during the spring 2011 sampling, suggesting that the February 2011 treatment was successful. The species appears to no longer be a threat to spread in the Northern Springs area.

Warm Springs Complex

Warm Springs pupfish have endured substantial habitat alteration and past invasion by non-native species (Miller and Deacon, 1973). When Scruggs Springs was discovered to harbor pupfish in 1967, both springs were already highly altered and non-native mosquitofish had invaded as well. Miller and Deacon (1973) showed Indian Spring as just one spring discharging into a reservoir; it too harbored pupfish and mosquitofish. When Scoppettone and others (1995) sampled the Warm Springs Complex, only Indian Spring was inhabited by mosquitofish and crayfish. By 2001, mosquitofish and crayfish also were reported from South Scruggs and School Springs, and the number of Warm Spring pupfish appeared to be decreasing (St. George, 2001).

There was a marked difference between the number of pupfish captured in North Scruggs by Scoppettone and others (2011b) in spring 2008 (n=81) and in this study (n=58), even though more stations were sampled in this study due to acquisition of a private land. Reasons for the substantial difference are unknown; however, the property acquisition presents an opportunity to improve habitat with the intent of expanding the range and number of pupfish. South Scruggs Spring harbored both mosquitofish and crayfish during both surveys; there was a greater number of pupfish captured in South Scruggs Spring than in North Scruggs Spring in fall 2010. Most of these were juveniles captured in shallow marsh habitat near the outflow terminus. South Scruggs Spring also had substantially greater flow than North Scruggs Spring. Once non-native mosquitofish and crayfish are eradicated from the South Scruggs Spring system, the Warm Springs pupfish population is expected to increase even more.

The outflow of Marsh Spring had changed between this survey and the 2007–08 survey. The terminal marsh was more thickly vegetated resulting in less open water. Total number of pupfish captured was only 64 in fall 2010 and 123 in spring 2011. The greatest pupfish capture success was in School Spring with 252 in fall 2010 and 329 in spring 2011. Capture success was highest in spring 2011 for both Marsh and School Springs, but was highest in fall 2010 for North and South Scruggs Springs. We attribute this difference to the annual proliferation of pupfish that occurs in the shallow marshes of the North and South Scruggs Spring system. Populations in marshes begin to proliferate in spring and reach their maximum number by fall. Many of the pupfish captured from the shallow marsh are juveniles (table A2) that apparently do not survive the winter. Presumably because of their more stable temperature, School and Marsh Springs do not support the relatively “boom and bust” populations seen at the North and South Scruggs Spring system.

Southern Springs

Since AMNWR was established, the Southern Springs have been plagued with largemouth bass and green sunfish invasions at various times (Threloff, 1990b; St. George, 1995, 1998, 1999, 2001; Ambruzs and others, 2006). Crystal Reservoir harbored largemouth bass when AMNWR was acquired and they have intermittently invaded Crystal spring-pool and the outflow stream; these invasions are followed by decreases in the pupfish population. Since the 2007–08 survey, green sunfish also invaded Crystal Spring outflow and were present in the system during our fall 2010 and spring 2011 sampling period (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). Amargosa pupfish typically are in greatest numbers in open-water habitat with ample algae production, and in fewer numbers in heavily shaded habitat (Kennedy and others, 2006; Scoppettone and others, 2011a). The canopy over Kings Pool stream has increased since the outflow was restored in 1997 and we suspect pupfish numbers have declined, but we have no direct comparisons. The number of pupfish captured in fall 2010 and spring 2011 were somewhat less than the number captured in the 2007–08 survey, but so were invasive mosquitofish and crayfish—species reported to increase with canopy cover. Pupfish captures in Jackrabbit stream also were less than the 2007–08 survey and this may be due to increased riparian growth and resulting cover, although again the captures of invasive mosquitofish and crayfish also were less.

AMNWR staff captured two speckled dace at Tubbs Spring in October 2006 and another in July 2007 (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). One speckled dace was captured in Tubbs Spring in fall 2010. These captures are the first dace captures at this spring since 1996 (St. George, 1997). The spring was chemically treated in 1998 (Jon Sjöberg, Nevada Department of Wildlife, written commun., 2011) resulting in the eradication of mosquitofish and sailfin molly. No fish were captured from Tubbs Spring in the 2007–08 survey. A pipe runs from Tubbs Spring to the Kings Pool outflow (Threloff, 1990a), and we suspect that the dace accessed Tubbs Spring through the pipe. Speckled dace was re-introduced into Forest Spring and Point of Rocks Spring in 2003. We suspect that crayfish, mosquitofish, and sailfin molly have prevented the introduced fish from establishing strong reproductive populations. Only three dace were captured in Point of Rocks Spring in fall 2010 and none in spring 2011. There were no speckled dace captures from Forest Spring although AMNWR staff did capture one in October 2006 and two in August 2007 (Darrick Weissenfluh, Ash Meadows National Wildlife Refuge, oral commun., 2011). When crayfish and mosquitofish were aggressively and systematically removed from Bradford 1 and 2 Springs, the speckled dace population responded with a substantial increase. Bradford 1 Spring supported a fairly robust population of speckled dace for its restricted area, but most captured dace were juveniles and few reached adulthood (>50 mm FL) (G.G. Scoppettone, U.S. Geological Survey, personal observation, 2011). This suggests that Bradford 1 habitat is capable of supporting relatively few adult dace. The stronghold for speckled dace in the Southern Springs area is the Jackrabbit Spring system, although Bradford 1 and 2 Springs support reproductive populations as well.

Conclusions

1. Restoration of Fairbanks Spring has led to an increase in the Ash Meadows pupfish population, and speckled dace were successfully repatriated into the Northern Springs.
2. Post-restoration of Fairbanks Spring, mosquitofish and crayfish were relatively few in number and limited in distribution.
3. Capture of Ash Meadows pupfish in Soda Spring changed from no captures in the 2007–08 survey (pre-restoration) to hundreds in this study (post-restoration), with most fish occupying the shallow open marsh near the spring discharge terminus.
4. Sailfin molly appeared to have been successfully eradicated from the Longstreet Spring system—none were captured during our spring 2011 sampling soon after the spring system was chemically treated. Mosquitofish were not eradicated from the system.
5. Although connected by marsh habitat with Longstreet Spring, Rogers Spring did not harbor sailfin molly.
6. Cold Spring was the only Northern Spring system without mosquitofish captures. Ash Meadows pupfish were rare but invasive crayfish were common at this site.
7. Eradication of mosquitofish and red swamp crayfish from South Scruggs Spring, the only spring in the Warm Springs Complex harboring them, would lead to an increase in pupfish and decrease in the risk of spread of these invasive species. This would be a valuable management prescription for this site.
8. Restoration of North Scruggs and Marsh Springs may lead to increase in resident pupfish populations.
9. Pupfish were found concentrated in North and South Scruggs spring systems in the upper reaches where water temperatures remain constantly warm, and near downstream most perennial water where the water is shallow and subject to ample sunlight.
10. Marsh and School Springs had relatively short outflow stream prior to discharging into a marsh, and most pupfish in these systems appear to be subject to fairly constant thermal environs.
11. Invasive centrarchids in Crystal and Big Springs were suspected to have a negative influence on pupfish numbers during this study, making comparisons of Ash Meadows pupfish population among seasons and years difficult.
12. Bradford 1 Spring supported a fairly sizable speckled dace population, but only few are expected to reach adulthood. Bradford 2 Spring continues to support a reproductive population of speckled dace, although the population does not appear to be robust.
13. One speckled dace was captured from Tubbs Spring. This fish was suspected to have entered Tubbs Spring through a pipe that extends to Kings Pool outflow.
14. Davis Spring remained fishless, but crayfish are still present.
15. Native fish populations are down in Jackrabbit Spring, and expansion of coyote willow along the banks of this spring is the suspected cause. Jackrabbit Spring remains the stronghold for Ash Meadows speckled dace.

17. The Point of Rock spring system is another low water volume spring system with pupfish concentrated near the thermal discharge, and near the stream terminus where the water was shallow and subject to ample sunlight. Water temperature fluctuates dramatically throughout the year. As with the North and South Scruggs Spring systems, the middle reaches are heavily vegetated and receive little sunlight.
18. Speckled dace introduced into Point of Rocks and Forest Springs did not appear to be successful. None were captured from Forest Spring and only three from Point of Rocks Spring during the fall 2010 survey.
19. The pupfish population in Kings Pool Spring spring-pool remains fairly robust, but numbers in the stream outflow are down substantially from the 2007–08 survey, presumably due to greater shading of the stream channel.

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References Cited

Ambruzs, S., Salgado, J.A., Scoppettone, G.G., and Goodchild, S., 2006, Survey of Ash Meadows speckled dace and pupfish in Jackrabbit Spring: U.S. Geological Survey Biological Resources Discipline, Reno Field Station and U.S. Fish and Wildlife Service, Southern Nevada Field Office, 8 p.

Baugh, T., Williams, J.E., Buck, D.A., and Deacon, J.E., 1986, New distributional records for *Cyprinodon nevadensis mionectes*, an endangered pupfish from Ash Meadows, Nevada: The Southwestern Naturalist, v. 31, p. 544-546.

Deacon, J.E., Hubbs, C., and Zahuranec, B.J., 1964, Some effects of introduced fishes on the native fish fauna of southern Nevada: Copeia, p. 384-388.

Deacon, J.E., and Williams, C.D., 1991, Ash Meadows and the legacy of the Devils Hole pupfish, *in* Minckley, W.L., and Deacon, J.E. (eds.), Battle against extinction—Native fish management in the American West: Tucson, The University of Arizona Press, p. 69-87.

Dudley, W.W., Jr., and Larson, J.D., 1976, Effect of irrigation pumping on desert pupfish habitats in Ash Meadows, Nye County, Nevada: U.S. Geological Survey Professional Paper 927, 153 p.

Freeman, M.A., Turnbull, J.F., Yeomans, W.E., and Bean, C.W., 2010, Prospects for management strategies of invasive crayfish populations with an emphasis on biological control: Aquatic Conservation: Marine and Freshwater Ecosystems, v. 20, p. 211-233.

Hershler, R., and Sada, D.W., 1987, Springsnails (Gastropoda:Hydrobiidae) of Ash Meadows, Amargosa Basin, California-Nevada: Proceedings of the Biological Society of Washington, v. 100, p. 776-843.

Kennedy, T.A., Finlay, J.C., and Hobbie, S.E., 2006, Eradication of invasive *Tamarix ramosissima* along a desert stream increase native fish density: Ecological Applications, v. 15, p. 2072-2083.

Knight, T.A., and Clemmer, G.H., 1987, Status of populations of the endemic plants of Ash Meadows, Nye County, Nevada: a report to U.S. Fish and Wildlife Service, Great Basin Complex, Reno Nevada, Project Agreement No. 86-2-1., Nevada Division of Forestry Department of Conservation and Natural Resources and Nevada Natural Heritage Program, Carson City, Nev.

Landye, J.J., 1973, Status of the inland aquatic and semi-aquatic mollusks of the American Southwest: Lower Colorado River Basin Research Laboratory, 60 p.

Leavy, T.R., McShane, R.R., Swaim, K.M., and Scoppettone G.G., 2004, (Part II) Status of Ash Meadows speckled dace in Bradford Springs, *in* Information on native fishes and invasive fishes and crayfish at Ash Meadows National Wildlife Refuge: U.S. Geological Survey, Biological Resources Division, Western Fisheries Research Center, Reno Field Station, p. 1-11.

McShane, R.R., Swaim, K.M., and Scoppettone, G.G., 2004, (Part I) Implication of habitat restoration for managing exotic crayfish at Ash Meadows, *in* Information on native fishes and invasive fishes and crayfish at Ash Meadows National Wildlife Refuge: U.S. Geological Survey, Biological Resources Division, Western Fisheries Research Center, Reno Field Station, p. 1-26.

Meffe, G.K., 1983, Attempted chemical renovation of an Arizona spring-brook for management of the endangered Sonoran topminnow: North American Journal of Fisheries Management, v. 3, p. 315-321.

Meronek, T.G., Bouchard, P.M., Buckner, E.R., Burri, T.M., Demmerly, K.K., Hatheli, D.C., Klumb, R.A., Schmidt, S.H., and Coble, D.W., 1996, A review of fish control projects: North American Journal of Fisheries Management, v. 16, p. 63-74.

Miller, R.R., 1948, The cyprinodont fishes of the Death Valley System of eastern California and Southwestern Nevada: Miscellaneous Publications Museum of Zoology, University of Michigan, v. 68, 155 p.

Miller, R.R., 1961, Man and the changing fauna of the American Southwest: Papers of the Michigan Academy of Science, Arts, and Letters, v. 46, p. 365-404.

Miller, R.R. and Deacon, J.E., 1973, New localities of the rare Warm Spring pupfish, *Cyprinodon nevadensis pectoralis*, from Ash Meadows: Copeia, p. 137-140.

Miller, R.R., Williams, J.D., and Williams, J.E., 1989, Extinction of North American fishes during the past century, Fisheries (Bethesda), v. 14, p. 22-38.

Minckley, W.L., and Deacon, J.E., 1991, Battle against extinction: native fish management in the American West: Tucson, The University of Arizona Press.

Mitchell, A.J., Hobbs, M.S., and Brandt, T.M., 2007, The effect of chemical treatment on red-rim melania *Melanoides tuberculata,* and exotic aquatic snail that serves as a vector of trematodes to fish and other species in the USA: North American Journal of Fisheries Management, v. 27, p. 1287-1293.

Moyle, P.B., 2002, Inland fishes of California: Berkeley, University of California Press.

Moyle, P.B., Li, H.W., and Barton, B.A., 1986, The Frankenstein effect: impact of introduced fishes on native fishes in North America, *in* Stround, R.H. (ed.), Fish culture in fisheries management: American Fisheries Society, Fish Culture Section and Fisheries Management Section, Bethesda, Maryland, p. 415-426.

Olden, J.D., and Poff, N.L., 2005, Long-term trends of native and non-native fish faunas in the American Southwest: Animal Biodiversity and Conservation, v. 28, p. 75-89.

Pister, E.P., 1974, Desert fishes and their habitats: Transactions of the American Fisheries Society, v. 103, p. 531-540.
Pister, E.P., 1985, Desert pupfishes: reflections on reality, desirability, and conscience: Fisheries, v. 10, p. 10-15.
Rinne, J.N., and Turner, P.R., 1991, Reclamation and alteration as management techniques, and a review of methodology in stream renovation, *in* Minckley, W.L., and Deacon, J. E. (eds.), Battle against extinction: native fish management in the American West: Tucson, University of Arizona Press.
Sada, D.W., 1990, Recovery plan for the endangered and threatened species of Ash Meadows, Nevada: Reno, Nev., U.S. Fish and Wildlife Service.
Scoppettone, G.G., 1993, Interactions between native nonnative fishes of the upper Muddy River, Nevada: Transactions of the American Fisheries Society, v. 122, p. 599-608.
Scoppettone, G.G., Rissler, P.H., Byers, S., Shea, S., Nielsen, B., and Sjöberg, J., 1995, Information on the status and ecology of Ash Meadows Fishes and *Ambrysus*: National Biological Service, Reno Field Station, 111 p.
Scoppettone, G.G., Hereford, M.E., Rissler, P.H., Johnson, D.M., and Salgado, J.A., 2011a, Relative abundance and distribution of fishes within an established Area of Critical Environmental Concern of the Amargosa River Canyon and Willow Creek, Inyo and San Bernardino Counties, California: U.S. Geological Survey Open-File Report 2011-1161, 32 p.
Scoppettone, G.G., Rissler, P., Johnson, D., and Hereford, M., 2011b, Relative abundance and distribution of fishes and crayfish at Ash Meadows National Wildlife Refuge, Nye County, Nevada, 2007-08: U.S. Geological Survey Open-File Report 2011-1017, 56 p.
Scoppettone, G.G., Rissler, P., Gourley, C., and Martinez, C., 2005, Habitat restoration as a means of controlling non-native fish in a Mojave Desert Oasis: Restoration Ecology, v. 13, p. 247-256.
Soltz, K.L., and Naiman, R.J., 1978, The natural history of native fishes in the Death Valley system: Natural History Museum of Los Angeles County, California, Science Series, v. 30, 76 p.
St. George, D., 1995, Ash Meadows National Wildlife Refuge annual endangered fish survey Fall 1994: Ash Meadows National Wildlife Refuge, Nevada, 6 p.
St. George, D., 1998, Ash Meadows National Wildlife Refuge 1997 native fish survey: Ash Meadows National Wildlife Refuge, Nevada, 8 p.
St. George, D., 1999, Ash Meadows National Wildlife Refuge nonnative fishes eradication report 1998: Ash Meadows National Wildlife Refuge, Nevada, 4 p.
St. George, D., 2000, Ash Meadows National Wildlife Refuge 1999 native fish survey: Ash Meadows National Wildlife Refuge, 10 p.
St. George, D., 2001, Ash Meadows National Wildlife Refuge 2001 native fish survey: Ash Meadows National Wildlife Refuge, 8 p.
Taylor, D., 1980, Endangered and threatened freshwater mollusks of Amargosa drainage, California—Nevada: Proposal to Office of Endangered Species, U.S. Fish and Wildlife Service—Tiburon Center for Environmental Studies, San Francisco State University.
Taylor, J.N., Courtenay, W.R., Jr., and McCann, J.A., 1984, Known impacts of exotic fishes in the continental United States, *in* Courtenay, W.R., Jr., and Stauffer, J.R., Jr., (eds.), Distribution, biology, and management of exotic fishes: Baltimore, Maryland, Johns Hopkins University Press.

Threloff, D., 1990a, The distribution and abundance of the fishes of Ash Meadows: a preliminary inventory: Ash Meadows National Wildlife Refuge, 23 p.

Threloff, D., 1990b, Ash Meadows Biannual Fish Count Summary: Ash Meadow National Wildlife Refuge, 11 p.

U.S. Department of the Interior, 1971, Status of desert pupfish, A progress report on the status of the desert pupfish, 14 p.

U.S. Fish and Wildlife Service, 1989, 50 CFR part 17, Endangered and threatened wildlife and plants: animal notice of review. Federal Register 54, 554-579.

Weissenfluh, D., 2008a, Ash Meadows NWR aquatic exotic control activities summary accomplish report (FY2008), U.S. Fish and Wildlife Service, 9 p.

Weissenfluh, D., 2008b, Davis Spring Aquatic Nuisance Species Eradication Accomplishment Report, U.S. Fish and Wildlife Service, 5 p.

Weissenfluh, D., 2008c, School Springs Refugium Restoration Accomplishment Report, U. S. Fish and Wildlife Service, 9 p.

Weissenfluh, D., 2010, Conservation of *Cyprinodon nevadensis pectoralis* and three endemic aquatic invertebrates in an artificial desert spring refuge located in Ash Meadows National Wildlife Refuge, Nevada, M.S. Thesis, Department of Biological Sciences, Texas Tech University, Lubbock, Tex.

Williams, J.E., Bowman, D.B., Brooks, J.E., Echelle, A.A., Edwards, R.J., Hendrickson, D.A., and Landye, J.J., 1985, Endangered aquatic ecosystems in North American deserts with a list of vanishing fishes of the region: Journal of Arizona-Nevada Academy of Sciences, v. 20, 60 p.

Williams, J.E., and Sada, D.W., 1985, Status of two endangered fishes, *Cyrpinodon nevadensis mionectes* and *Rhinichthys osculus nevadensis*, from two springs in Ash Meadows, Nevada: The Southwestern Naturalist, v. 30, p. 475-484.

Yoakum, J.D., Lockard, D., Osborn, C., Deacon, J., Allan, C., and Kobetich, G., 1976, Warm Springs pupfish recovery plan: U.S. Fish and Wildlife Service.

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Appendix A.

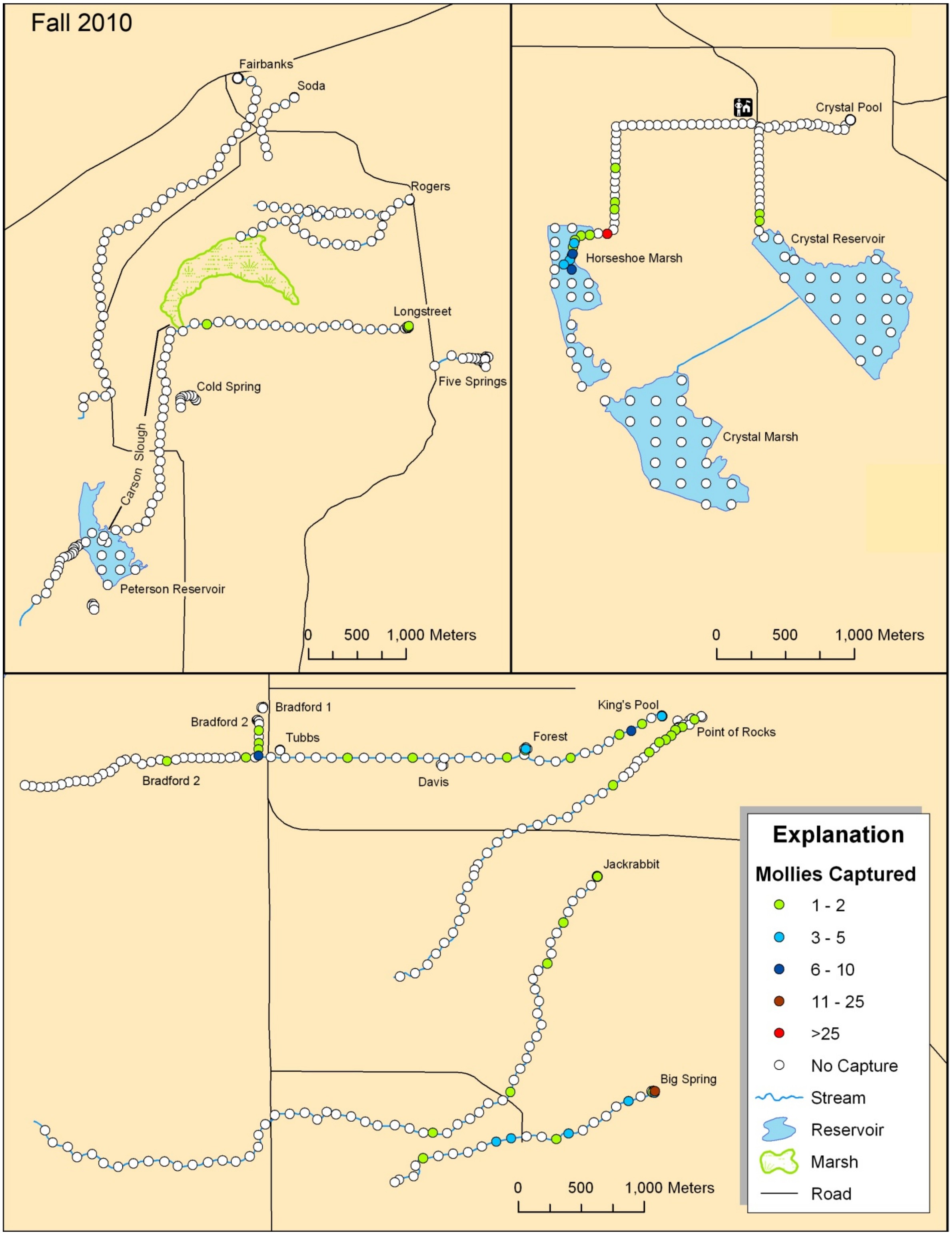

Figure A1. Relative abundance and distribution of sailfin molly throughout Ash Meadows National Wildlife Refuge, Nevada, fall 2010.

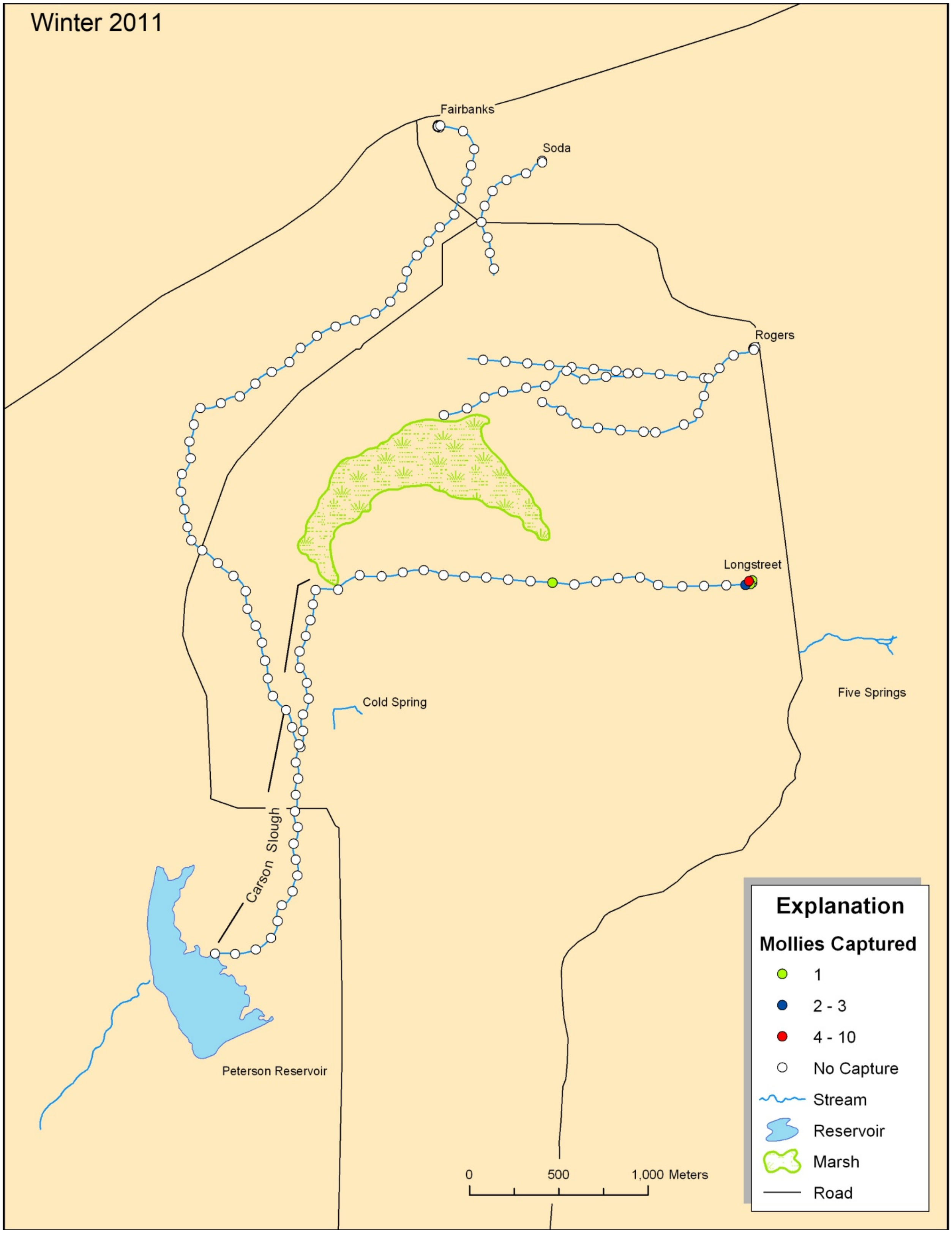

Figure A2. Relative abundance and distribution of sailfin molly in Fairbanks, Soda, Rogers, and Longstreet springs Ash Meadows, National Wildlife Refuge, Nevada, winter 2011.

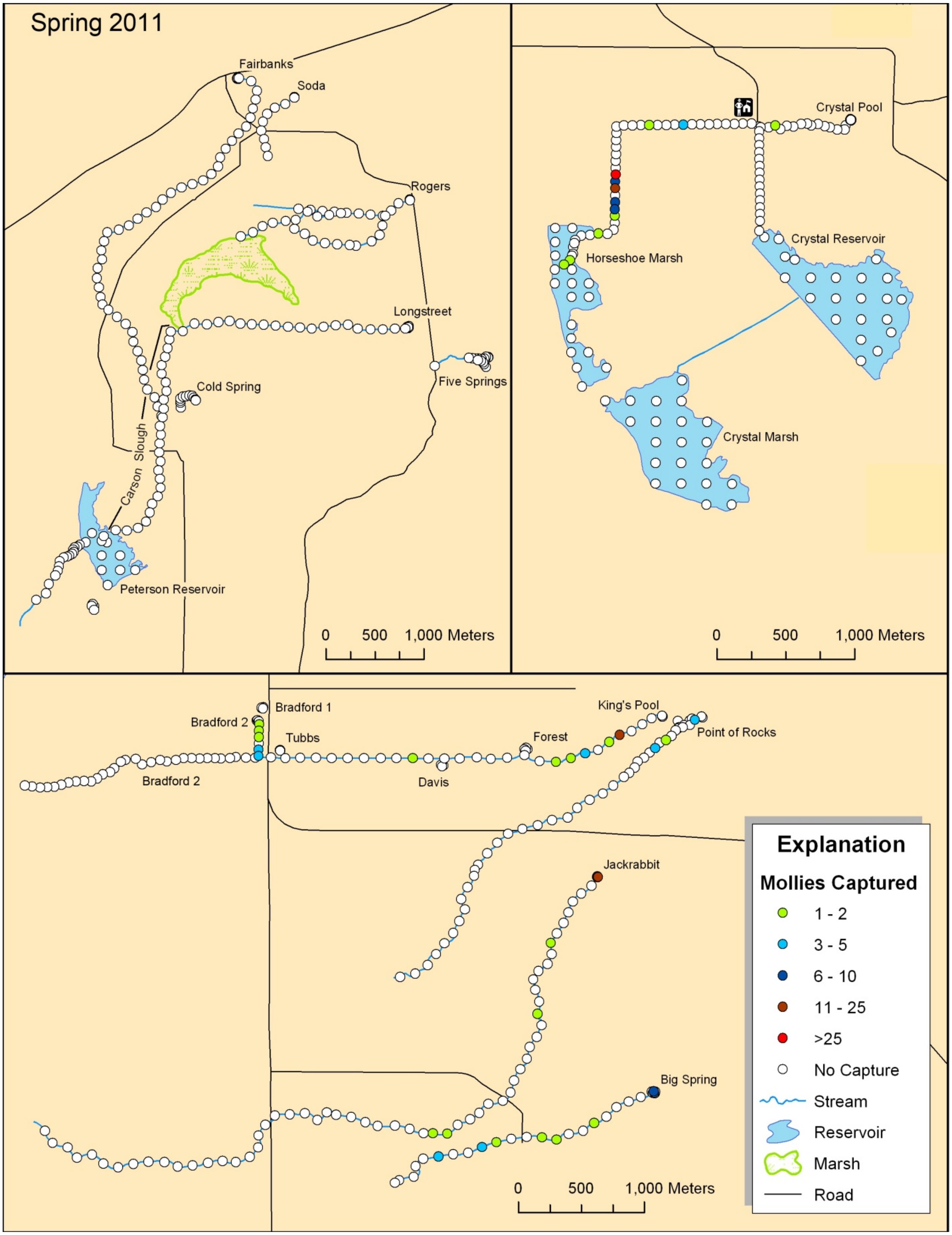

Figure A3. Relative abundance and distribution of sailfin molly throughout Ash Meadows National Wildlife Refuge, Nevada, spring 2011.

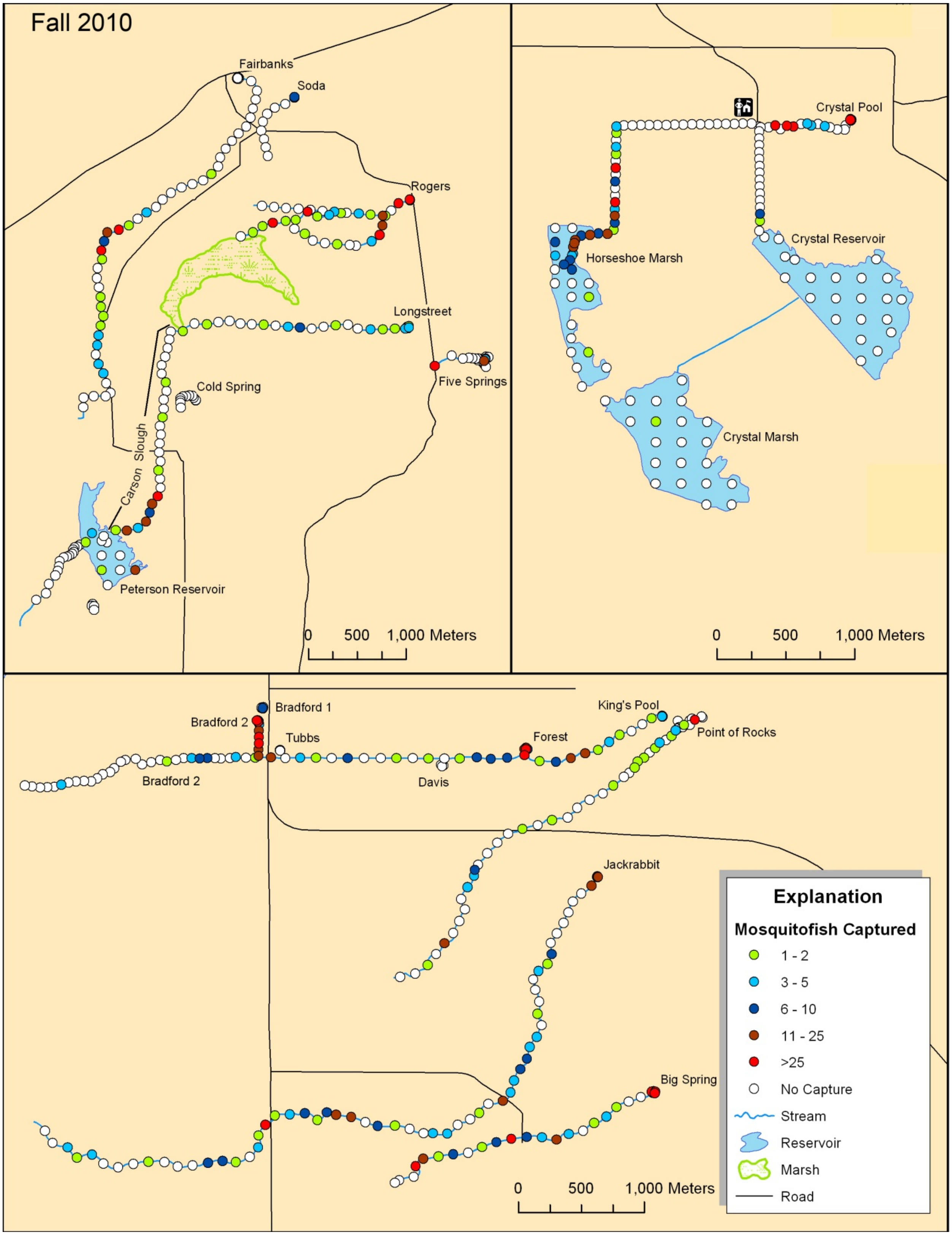

Figure A4. Relative abundance and distribution of mosquitofish throughout Ash Meadows National Wildlife Refuge, Nevada, fall 2010.

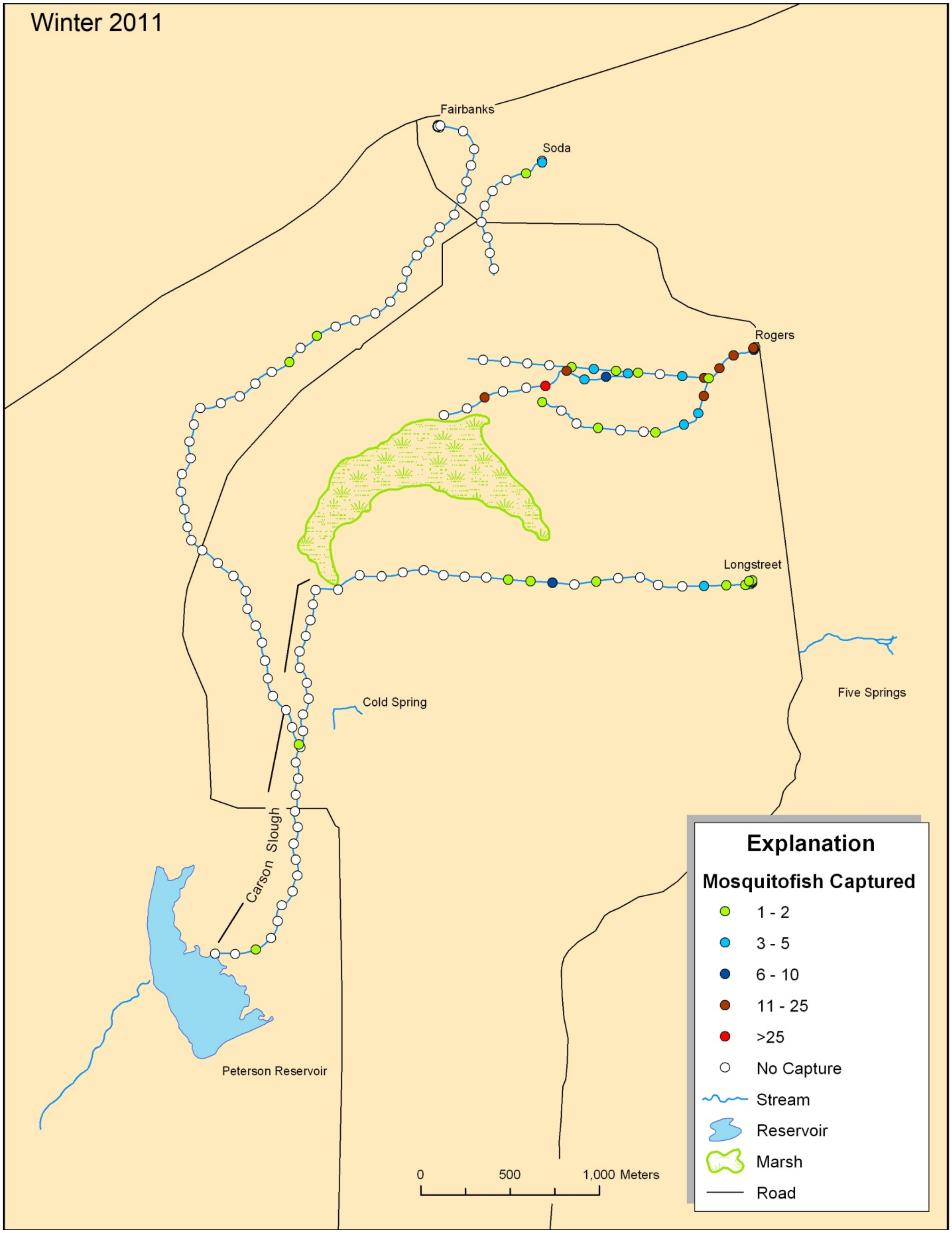

Figure A5. Relative abundance and distribution of mosquitofish in Fairbanks, Soda, Rogers, and Longstreet Springs, Ash Meadows, National Wildlife Refuge, Nevada, winter 2011.

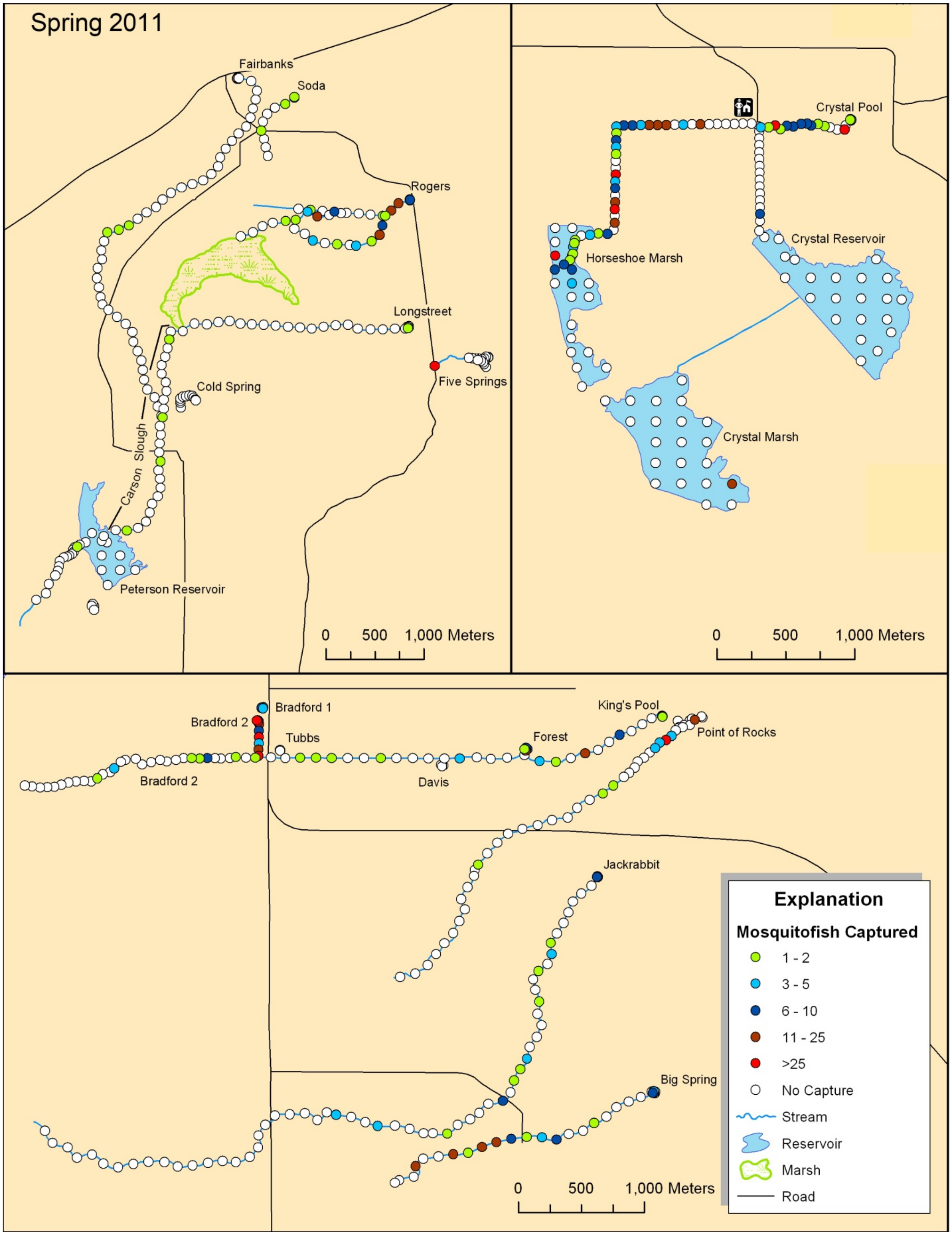

Figure A6. Relative abundance and distribution of mosquitofish throughout Ash Meadows National Wildlife Refuge, Nevada, spring 2011.

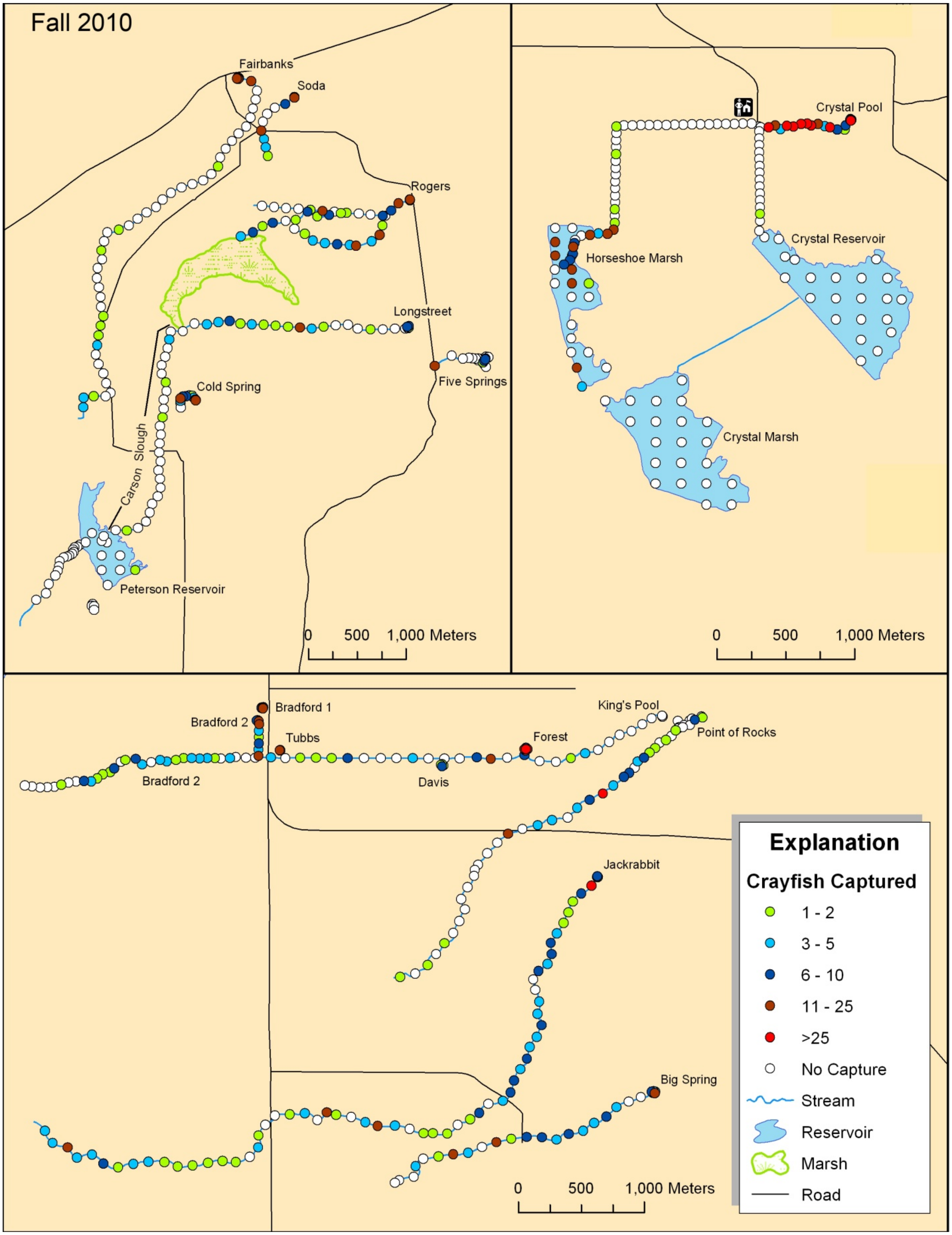

Figure A7. Relative abundance and distribution of crayfish throughout Ash Meadows National Wildlife Refuge, Nevada, fall 2010.

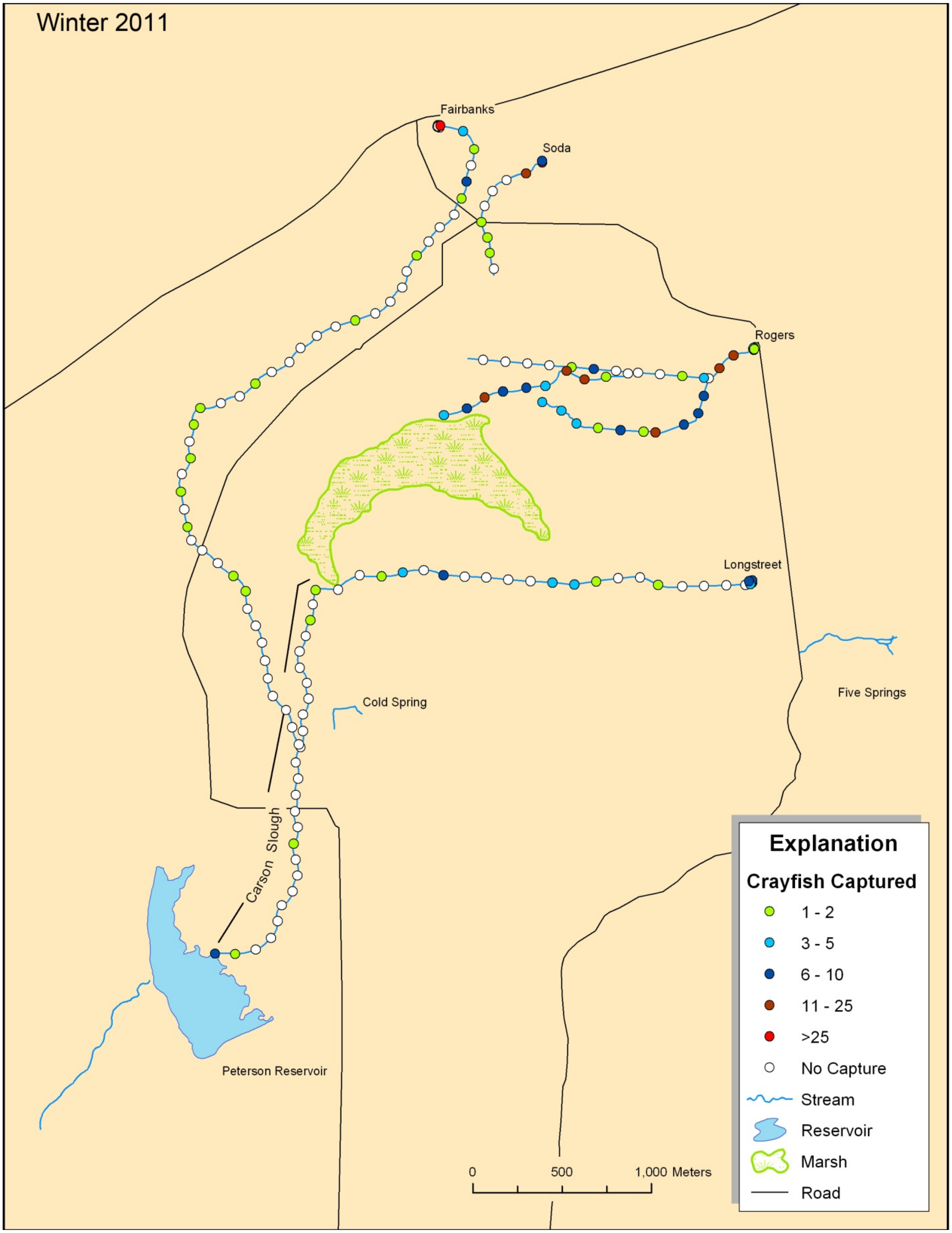

Figure A8. Relative abundance and distribution of crayfish in Fairbanks, Soda, Rogers, and Longstreet Springs, Ash Meadows, National Wildlife Refuge, Nevada, winter 2011.

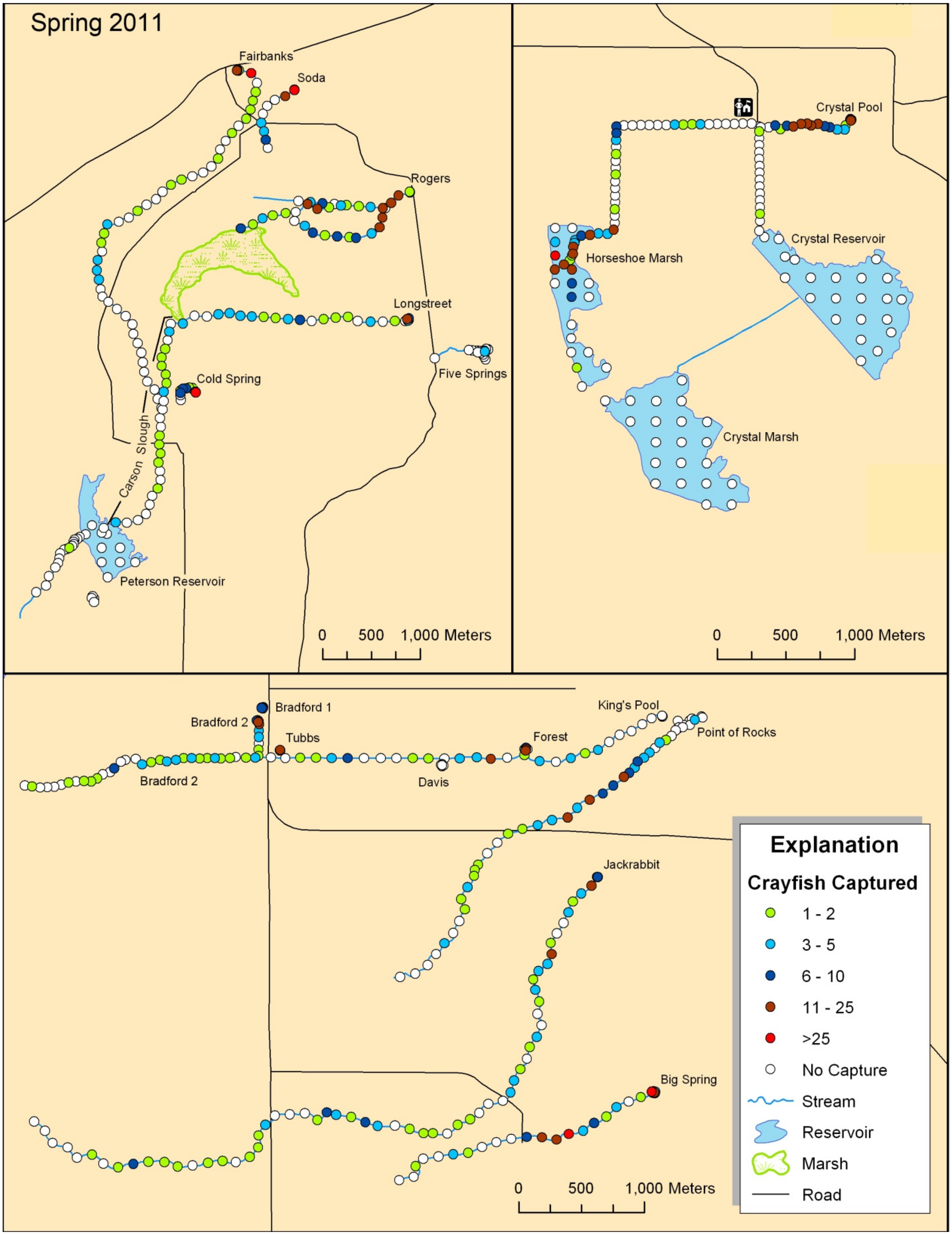

Figure A9. Relative abundance and distribution of crayfish throughout Ash Meadows National Wildlife Refuge, Nevada, spring 2011.

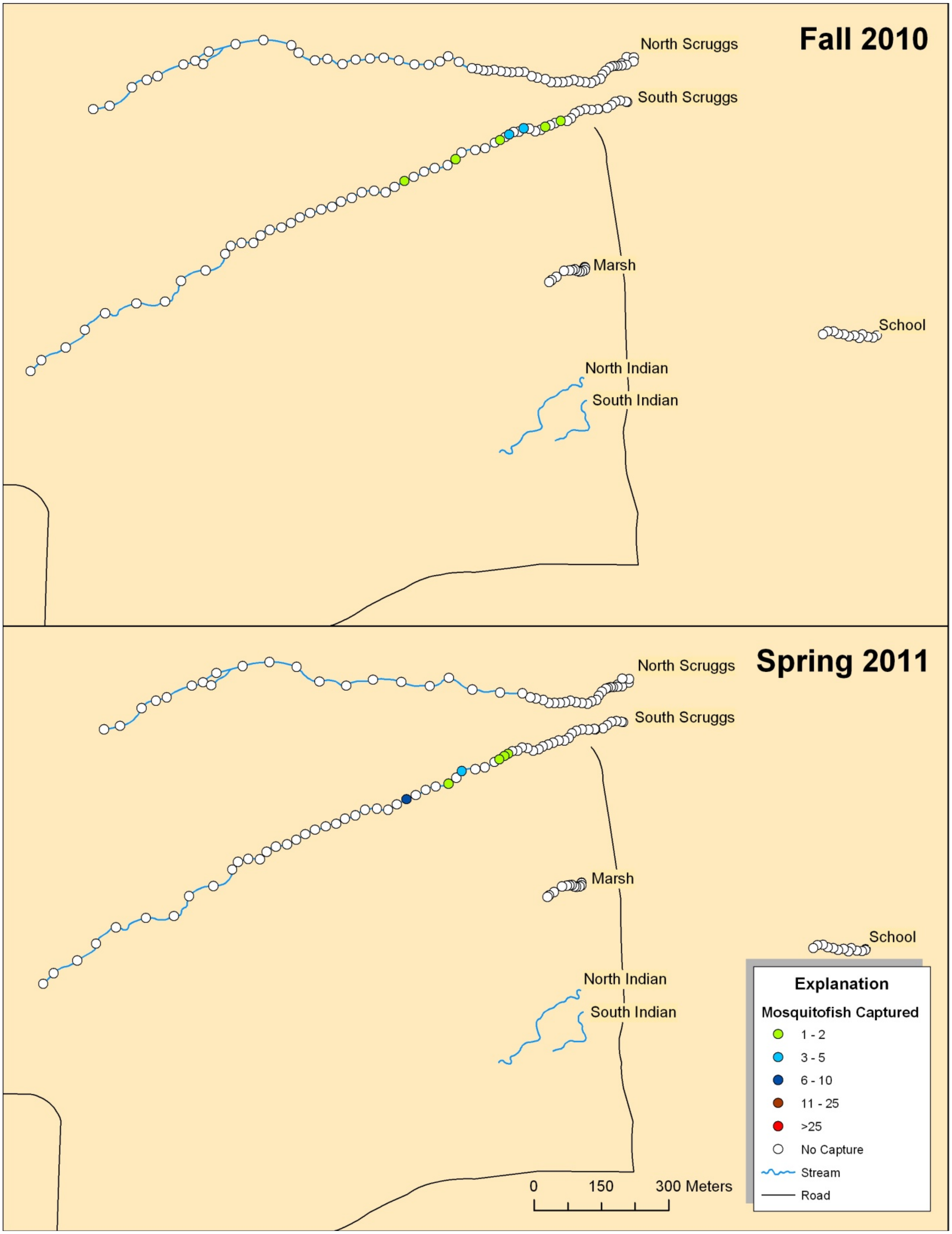

Figure A10. Relative abundance and distribution of mosquitofish in North Scruggs, South Scruggs, Marsh, and School Springs, Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

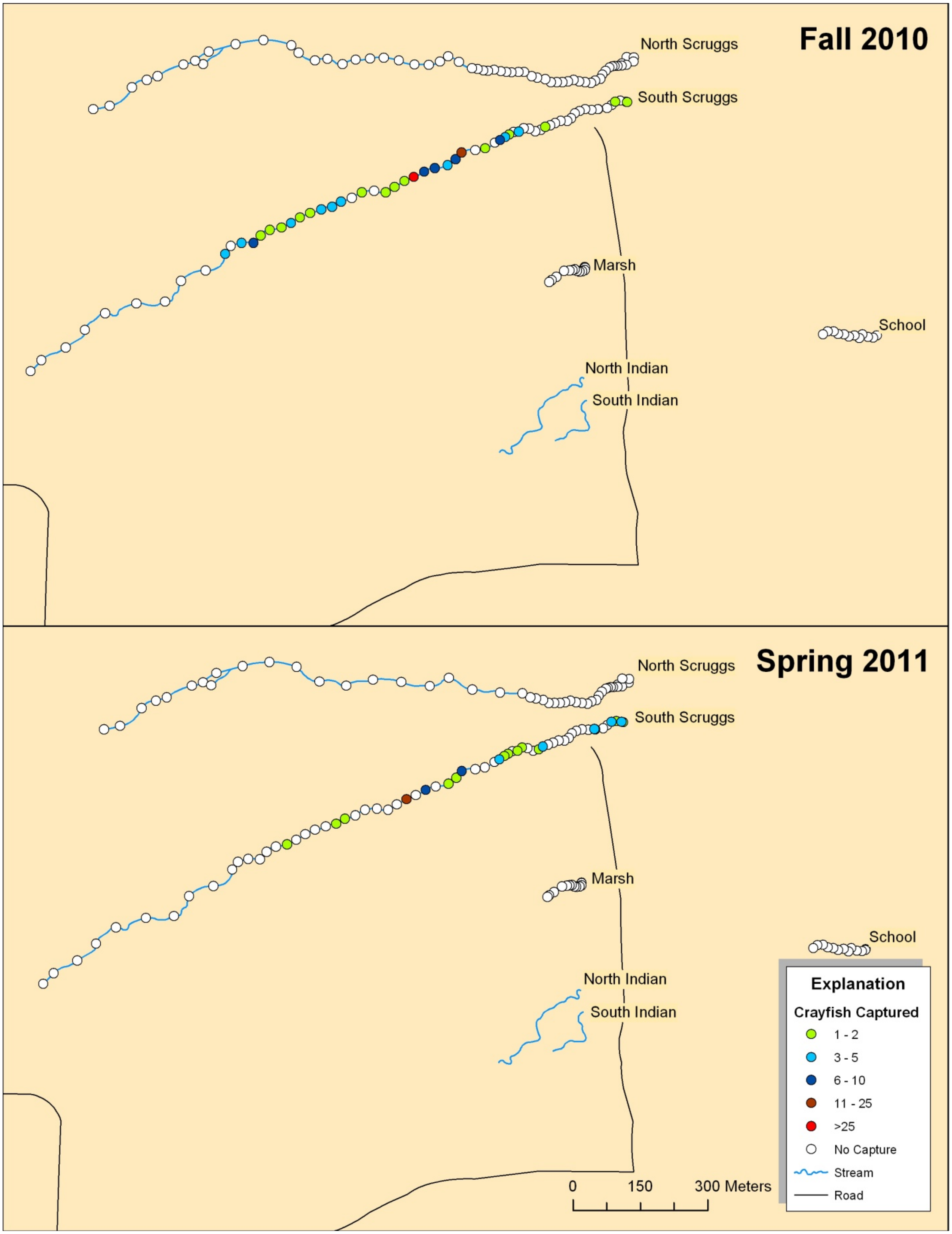

Figure A11. Relative abundance and distribution of crayfish in North Scruggs, South Scruggs, Marsh, and School Springs, Ash Meadows National Wildlife Refuge, Nevada, fall 2010 and spring 2011.

Table A1. Number and size of individuals of species captured seasonally at the Northern Springs of Ash Meadows National Wildlife Refuge, Nevada.

[Spring locations are shown in figure 1. FL, fork length. Species: CYMI - Ash Meadows pupfish, CYPE - Warm Springs pupfish, GAAF - Mosquitofish, LECY - Green Sunfish, MISA - Largemouth Bass, POLA - Sailfin Molly, PRCL - Red Swamp Crayfish, RACA – Bullfrog, RHON - Ash Meadows speckled dace]

Fall 2010

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average± Standard Deviation
Fairbanks spring-pool	CYMI	426	71	83	16 - 45	31 ± 6
	PRCL	62	10.3	60	18 - 68	53 ± 10
Fairbanks stream	CYMI	1264	28.1	261	18 - 50	33 ± 6
	RHON	120	2.7	68	24 - 83	58 ± 12
	GAAF	149	3.3	65	23 - 48	33 ± 5
	RACA	1	-	-	-	-
	PRCL	41	0.9	37	28 - 75	53 ± 14
Soda spring-pool	CYMI	3	3	3	29 - 32	30 ± 2
	GAAF	10	10	9	20 - 35	28 ± 5
	PRCL	3	3	3	35 - 50	43 ± 8
Soda stream	CYMI	251	27.9	66	15 - 47	28 ± 7
	GAAF	0	-	-	-	-
	RACA	2	0.2	2	80 - 95	88 ± 11
	PRCL	41	4.6	37	19 - 76	43 ± 16
Roger spring-pool	CYMI	125	20.8	78	16 - 78	30 ± 9
	GAAF	66	11	47	20 - 41	27 ± 5
	RACA	6	1	6	72 - 95	83 ± 8
	PRCL	31	5.2	31	30 - 66	48 ± 10
Roger stream	CYMI	14	0.5	14	26 - 55	37 ± 7
	GAAF	205	6.8	94	15 - 50	32 ± 6
	PRCL	150	5	122	20 - 72	49 ± 10
Longstreet spring-pool	CYMI	319	53.2	20	18 - 50	33 ± 9
	GAAF	5	0.8	5	25 - 44	35 ± 9
	POLA	5	0.8	2	26 - 33	30 ± 5
	PRCL	16	2.7	16	32 - 73	55 ± 12
Longstreet stream	CYMI	27	1.4	27	15 - 45	31 ± 8
	RHON	0	-	-	-	-
	GAAF	30	1.5	30	25 - 53	37 ± 7
	POLA	1	0.1	1	21 - 21	21 ± 0
	PRCL	51	2.6	41	28 - 70	50 ± 10
Carson Slough	CYMI	157	6	67	17 - 41	25 ± 6
	RHON	0	-	-	-	-
	GAAF	115	4.4	56	22 - 48	29 ± 4
	PRCL	6	0.2	6	40 - 68	54 ± 9
Five Springs spring-pool	CYMI	24	4.8	21	22 - 34	27 ± 3
	GAAF	4	0.8	4	17 - 22	20 ± 2
	PRCL	8	1.6	8	17 - 47	37 ± 10
Five Springs stream	CYMI	6	0.4	5	24 - 33	28 ± 3
	GAAF	43	3.1	20	17 - 51	30 ± 8
	PRCL	34	2.4	20	18 - 67	45 ± 16
Peterson reservoir	CYMI	29	2.9	29	20 - 35	26 ± 3
	GAAF	19	1.9	18	24 - 34	28 ± 3
	PRCL	1	0.1	1	70 - 70	70 ± 0
Peterson stream	CYMI	No water due to low reservoir level				
	RHON					
	GAAF					
	PRCL					
Cold spring-pool	PRCL	21	21	21	30 - 85	53 ± 12
Cold stream	CYMI	1	0.1	1	39 - 39	39 ± 0
	PRCL	51	6.4	47	30 - 68	50 ± 10
Cold pool	PRCL	5	-	-	-	-

Table A1. Number and size of individuals of species captured seasonally at the Northern Springs of Ash Meadows National Wildlife Refuge, Nevada.—Continued

Winter 2011

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average± Standard Deviation
Fairbanks spring-pool	**CYMI**	272	45.3	101	21 - 42	31 ± 5
	PRCL	0	-	-	-	-
Fairbanks stream	**CYMI**	880	19.6	181	25 - 51	38 ± 6
	RHON	236	5.2	174	31 - 83	60 ± 8
	GAAF	3	0.1	3	25 - 45	37 ± 10
	PRCL	72	1.6	37	38 - 75	54 ± 8
Soda spring-pool	**CYMI**	0	-	-	-	-
	GAAF	0	-	-	-	-
	PRCL	10	10	10	25 - 68	45 ± 14
Soda stream	**CYMI**	417	46.3	76	20 - 44	31 ± 5
	GAAF	5	0.6	5	27 - 41	33 ± 6
	PRCL	58	6.4	24	24 - 60	48 ± 9
Roger spring-pool	**CYMI**	213	35.5	114	18 - 41	28 ± 5
	GAAF	22	3.7	22	20 - 40	28 ± 5
	RACA	2	0.3	2	65 - 85	75 ± 14
	PRCL	8	1.3	8	31 - 60	46 ± 10
Roger stream	**CYMI**	58	1.8	39	28 - 51	35 ± 4
	GAAF	190	5.9	113	20 - 50	32 ± 7
	RACA	1	0	1	52	52
	PRCL	195	6.1	155	20 - 78	51 ± 11
Longstreet spring-pool	**CYMI**	599	99.8	100	21 - 50	35 ± 6
	GAAF	16	2.7	16	23 - 43	33 ± 6
	POLA	13	2.2	13	27 - 40	34 ± 4
	RACA	4	0.7	-	-	-
	PRCL	29	4.8	29	27 - 68	52 ± 11
Longstreet stream	**CYMI**	19	1	19	23 - 45	35 ± 7
	RHON	0	-	-	-	-
	GAAF	20	1	20	22 - 44	32 ± 7
	POLA	4	0.2	4	27 - 44	34 ± 8
	PRCL	22	1.1	22	27 - 69	54 ± 11
Carson Slough	**CYMI**	1449	58	53	21 - 46	29 ± 5
	RHON	13	0.5	13	48 - 70	60 ± 7
	GAAF	2	0.1	2	32 - 39	36 ± 5
	PRCL	11	0.4	11	35 - 77	55 ± 14
Five Springs spring-pool	**CYMI**	Not sampled in Winter 2011				
	GAAF					
	PRCL					
Five Springs stream	**CYMI**					
	GAAF					
	PRCL					
Peterson Reservoir	**CYMI**					
	GAAF					
	PRCL					
Peterson Stream	**CYMI**					
	RHON					
	GAAF					
	PRCL					
Cold spring-pool	**PRCL**					
Cold stream	**CYMI**					
	PRCL					
Cold pool	**PRCL**					

Table A1. Number and size of individuals of species captured seasonally at the Northern Springs of Ash Meadows National Wildlife Refuge, Nevada.—Continued

Spring 2011

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average ± Standard Deviation
Fairbanks spring-pool	**CYMI**	417	69.5	114	21 - 50	33 ± 5
	PRCL	31	5.2	29	22 - 62	46 ± 8
Fairbanks stream	**CYMI**	2491	55.4	288	21 - 58	35 ± 6
	RHON	166	3.7	146	24 - 77	51 ± 14
	GAAF	5	0.1	5	27 - 40	31 ± 5
	RACA	1	-	-	-	-
	PRCL	56	1.2	39	30 - 84	56 ± 12
Soda spring-pool	**CYMI**	12	12	10	21 - 34	26 ± 5
	GAAF	2	2	2	23 - 26	25 ± 2
	PRCL	24	24	10	50 - 62	56 ± 4
Soda stream	**CYMI**	363	40.3	79	22 - 47	31 ± 4
	GAAF	3	0.3	2	40 - 42	41 ± 1
	PRCL	58	6.4	36	32 - 68	50 ± 8
Roger spring-pool	**CYMI**	227	37.8	80	18 - 40	29 ± 5
	GAAF	21	3.5	21	19 - 32	23 ± 3
	RACA	10	1.7	0	-	-
	PRCL	2	0.3	2	42 - 50	46 ± 6
Roger spring	**CYMI**	32	1.1	32	23 - 52	36 ± 5
	GAAF	97	3.2	77	21 - 53	32 ± 6
	PRCL	176	5.9	139	21 - 79	56 ± 11
Longstreet spring-pool	**CYMI**	79	13.2	79	19 - 47	32 ± 7
	GAAF	1	0.2	1	47 - 47	47 ± 0
	POLA	0	-	-	-	-
	PRCL	24	4	24	29 - 75	45 ± 14
Longstreet stream	**CYMI**	17	0.9	17	23 - 42	34 ± 6
	RHON	1	0.1	1	53 - 53	53 ± 0
	GAAF	0	-	-	-	-
	POLA	0	-	-	-	-
	PRCL	39	2	39	24 - 72	51 ± 12
Carson Slough	**CYMI**	312	12	111	20 - 51	34 ± 7
	RHON	3	0.1	3	57 - 73	67 ± 9
	GAAF	4	0.2	2	28 - 30	29 ± 1
	PRCL	28	1.1	28	31 - 81	51 ± 11
Five Springs spring-pool	**CYMI**	12	3	11	20 - 38	27 ± 5
	GAAF	0	-	-	-	-
	PRCL	3	0.8	3	34 - 45	41 ± 6
Five Springs stream	**CYMI**	10	0.8	10	23 - 34	27 ± 4
	GAAF	36	3	10	22 - 50	35 ± 10
	PRCL	0	0	-	-	-
Peterson Reservoir	**CYMI**	8	0.7	8	21 - 38	28 ± 5
	GAAF	0	-	-	-	-
	PRCL	0	-	-	-	-
Peterson stream	**CYMI**	124	6.2	83	20 - 41	29 ± 5
	RHON	2	0.1	2	55 - 70	63 ± 11
	GAAF	1	0.1	1	31 - 31	31 ± 0
	PRCL	1	0.1	1	81 - 81	81 ± 0
Cold springs	**PRCL**	26	26	10	42 - 67	51 ± 8
Cold stream	**CYMI**	1	0.1	1	47 - 47	47 ± 0
	PRCL	37	4.6	37	32 - 63	46 ± 8
Cold pool	**PRCL**	18	18	10	42 - 62	52 ± 7

Table A2. Number and size of individuals of species captured seasonally at the Warm Springs Complex of Ash Meadows National Wildlife Refuge, Nevada.

[Spring locations are shown in figure 1. FL, fork length. Species: CYMI - Ash Meadows pupfish, CYPE - Warm Springs pupfish, GAAF - Mosquitofish, LECY - Green Sunfish, MISA - Largemouth Bass, POLA - Sailfin Molly, PRCL - Red Swamp Crayfish, RACA – Bullfrog, RHON - Ash Meadows speckled dace]

Fall 2010

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average± Standard Deviation
North Scruggs spring-pool	**CYPE**	0	-	-	-	-
North Scruggs stream	**CYPE**	95	2.2	85	19 - 41	30 ± 5
South Scruggs spring-pool	**CYPE**	1	1	1	24 - 24	24 ± 0
	PRCL	2	2	2	49 - 50	50 ± 1
South Scruggs stream	**CYPE**	120	2.3	74	18 - 42	31 ± 5
	GAAF	13	0.2	13	21 - 43	31 ± 7
	PRCL	131	2.5	112	21 - 79	49 ± 14
Marsh spring-pool	**CYPE**	0	-	-	-	-
Marsh stream	**CYPE**	64	5.3	35	17 - 37	28 ± 6
North and South Indian spring-pools and streams	Not surveyed due to ongoing restoration					
School spring-pool	**CYPE**	13	13	10	23 - 30	26 ± 3
School Stream	**CYPE**	252	25.2	64	17 - 40	27 ± 4

Spring 2011

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average ± Standard Deviation
North Scruggs spring-pool	**CYPE**	0	-	-	-	-
North Scruggs Stream	**CYPE**	58	1.8	58	21 - 46	33 ± 6
South Scruggs spring-pool	**CYPE**	0	-	-	-	-
	PRCL	2	2	2	37 - 61	49 ± 17
South Scruggs stream	**CYPE**	93	1.8	69	19 - 42	30 ± 6
	GAAF	19	0.4	19	20 - 42	29 ± 5
	PRCL	69	1.3	66	18 - 64	45 ± 11
Marsh spring-pool	**CYPE**	0	-	-	-	-
Marsh stream	**CYPE**	123	11.2	55	20 - 43	29 ± 5
North and South Indian spring-pools and streams	Not surveyed due to ongoing restoration					
School spring-pool	**CYPE**	2	2	2	25 - 27	26 ± 1
School stream	**CYPE**	329	29.9	75	19 - 36	27 ± 3

Table A3. Number and size of individuals of species captured seasonally at the Southern Springs of Ash Meadows National Wildlife Refuge, Nevada.

[Spring locations are shown in figure 1. FL, fork length. Species: CYMI - Ash Meadows pupfish, CYPE - Warm Springs pupfish, GAAF - Mosquitofish, LECY - Green Sunfish, MISA - Largemouth Bass, POLA - Sailfin Molly, PRCL - Red Swamp Crayfish, RACA – Bullfrog, RHON - Ash Meadows speckled dace]

Fall 2010

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average± Standard Deviation
Crystal spring-pool	CYMI	455	75.8	129	17 - 60	30 ± 7
	GAAF	217	36.2	77	18 - 39	27 ± 5
	PRCL	29	4.8	29	46 - 70	58 ± 5
Crystal stream	CYMI	619	14.4	237	17 - 50	30 ± 6
	GAAF	364	8.5	199	20 - 46	30 ± 6
	POLA	68	1.6	40	21 - 65	39 ± 9
	PRCL	561	13	206	27 - 70	54 ± 9
Crystal reservoir	LECY	37	1.8	34	26 - 63	45 ± 9
	MISA	0	-	-	-	-
Crystal marsh	CYMI	13	1.1	13	23 - 25	24 ± 1
	GAAF	1	0.1	1	25 - 25	25 ± 0
	LECY	52	4.3	25	25 - 67	40 ± 12
Horseshoe marsh	CYMI	11	0.7	11	17 - 40	25 ± 6
	GAAF	35	2.3	34	19 - 42	29 ± 5
	POLA	14	0.9	14	17 - 51	28 ± 10
	LECY	1	0.1	1	31 - 31	31 ± 0
	MISA	1	0.1	1	54 - 54	54 ± 0
	PRCL	86	5.7	67	15 - 70	51 ± 13
Kings Pool spring-pool	CYMI	647	107.8	125	17 - 49	32 ± 6
	GAAF	6	1	6	23 - 44	29 ± 8
	POLA	10	1.7	10	22 - 42	31 ± 8
Kings Pool stream	CYMI	137	4.9	81	20 - 48	34 ± 6
	GAAF	123	4.4	99	21 - 48	30 ± 7
	POLA	19	0.7	19	21 - 51	36 ± 7
	PRCL	59	2.1	51	21 - 68	50 ± 10
Point of Rocks stream	CYMI	252	6	131	13 - 55	27 ± 7
	RHON	3	0.1	3	38 - 52	43 ± 8
	GAAF	85	2	57	21 - 46	30 ± 6
	POLA	9	0.2	9	29 - 52	37 ± 7
	PRCL	113	2.7	91	28 - 69	50 ± 9
Bradford 1 spring-pool	RHON	145	24.2	104	25 - 74	44 ± 8
	GAAF	9	1.5	9	19 - 42	26 ± 7
	PRCL	58	9.7	58	25 - 76	43 ± 9
Bradford 1 stream	There is no longer an outflow channel					
Bradford 2 spring-pool	RHON	0	-	-	-	-
	GAAF	466	77.7	130	16 - 39	27 ± 7
	RACA	1	0.2	1	77 - 77	77 ± 0
	PRCL	20	3.3	20	20 - 73	45 ± 15
Bradford 2 stream	CYMI	12	0.3	12	17 - 47	34 ± 10
	RHON	16	0.4	16	31 - 72	59 ± 13
	GAAF	174	4.7	88	20 - 51	37 ± 8
	POLA	15	0.4	15	33 - 64	47 ± 10
	PRCL	131	3.5	115	20 - 74	54 ± 13
Forest spring-pool	CYMI	9	1.5	8	25 - 46	37 ± 7
	GAAF	235	39.2	112	14 - 44	26 ± 7
	POLA	7	1.2	7	17 - 32	22 ± 5
	PRCL	75	12.5	70	21 - 73	46 ± 10
Tubbs spring-pool	RHON	1	0.2	1	58 - 58	58 ± 0
	PRCL	67	11.2	66	25 - 79	55 ± 11
Davis spring-pool	PRCL	11	1.8	11	16 - 74	53 ± 19

Table A3. Number and size of individuals of species captured seasonally at the Southern Springs of Ash Meadows National Wildlife Refuge, Nevada.—Continued.

Fall 2010

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average± Standard Deviation
Jackrabbit spring-pool	CYMI	474	79	125	18 - 52	34 ± 7
	RHON	3	0.5	3	51 - 52	51 ± 1
	GAAF	42	7	42	18 - 50	31 ± 8
	POLA	3	0.5	3	21 - 47	31 ± 14
	PRCL	14	2.3	14	32 - 55	43 ± 7
Jackrabbit stream	CYMI	118	2	106	19 - 52	35 ± 7
	RHON	623	10.4	414	18 - 82	53 ± 13
	GAAF	224	3.7	169	15 - 61	36 ± 8
	POLA	4	0.1	4	21 - 51	34 ± 13
	PRCL	261	4.4	220	21 - 71	50 ± 10
Big Spring spring-pool	CYMI	221	36.8	125	22 - 55	35 ± 6
	GAAF	106	17.7	79	20 - 41	27 ± 4
	POLA	21	3.5	21	26 - 54	37 ± 7
	PRCL	23	3.8	23	28 - 64	49 ± 11
Big spring stream	CYMI	54	2.8	43	21 - 45	33 ± 7
	GAAF	195	10.3	93	15 - 45	31 ± 6
	POLA	18	0.9	18	18 - 51	33 ± 8
	RACA	1	-	-	-	-
	PRCL	94	4.9	91	25 - 71	48 ± 10

Spring 2011

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average ± Standard Deviation
Crystal spring-pool	CYMI	78	13	45	14 - 33	23 ± 4
	GAAF	16	2.7	16	21 - 33	25 ± 4
	PRCL	0	-	-	-	-
Crystal stream	CYMI	1499	28.3	328	18 - 54	33 ± 8
	GAAF	404	7.6	244	8 - 49	31 ± 7
	POLA	100	1.9	58	27 - 62	44 ± 10
	PRCL	273	5.2	213	19 - 78	54 ± 12
Crystal reservoir	LECY	1	-	-	42 - 42	42 ± 0
	MISA	3	0.1	3	340 - 370	350 ± 17
Crystal marsh	CYMI	1	0.1	1	28 - 28	28 ± 0
	GAAF	22	1.7	10	25 - 40	31 ± 5
	LECY	39	3	26	35 - 75	53 ± 11
Horseshoe marsh	CYMI	9	0.6	9	23 - 45	35 ± 7
	GAAF	83	5.2	26	25 - 42	34 ± 5
	POLA	0	-	-	-	-
	LECY	1	0.1	1	52 - 52	52 ± 0
	MISA	0	-	-	-	-
	PRCL	100	6.3	61	24 - 72	49 ± 12
Kings Pool spring-pool	CYMI	635	105.8	117	19 - 49	32 ± 6
	GAAF	21	3.5	21	23 - 42	32 ± 6
	POLA	0	-	-	-	-
Kings Pool stream	CYMI	78	2.8	52	23 - 46	37 ± 5
	GAAF	33	1.2	32	22 - 47	33 ± 9
	POLA	20	0.7	19	27 - 52	36 ± 6
	PRCL	60	2.1	50	26 - 74	53 ± 11

Table A3. Number and size of individuals of species captured seasonally at the Southern Springs of Ash Meadows National Wildlife Refuge, Nevada.—Continued.

Spring 2011

System	Species	Total Catch	Average/trap	n	FL (min-max)	Average ± Standard Deviation
Point of Rocks stream	**CYMI**	368	9	124	18 - 52	29 ± 7
	RHON	0	-	-	-	-
	GAAF	62	1.5	35	22 - 49	32 ± 7
	POLA	11	0.3	11	27 - 43	35 ± 5
	PRCL	123	3	121	22 - 73	52 ± 10
Bradford 1 spring-pool	**RHON**	161	26.8	106	21 - 85	44 ± 12
	GAAF	16	2.7	16	21 - 37	29 ± 4
	PRCL	32	5.3	32	30 - 65	42 ± 9
Bradford 1 stream	There is no longer an outflow channel					
Bradford 2 spring-pool	**RHON**	5	0.8	5	35 - 51	43 ± 6
	GAAF	294	49	129	20 - 46	27 ± 5
	PRCL	54	9	54	24 - 60	43 ± 9
Bradford 2 stream	**CYMI**	34	0.9	29	22 - 51	36 ± 9
	RHON	13	0.3	13	28 - 65	48 ± 12
	GAAF	177	4.7	83	20 - 51	33 ± 8
	POLA	10	0.3	10	25 - 61	40 ± 12
	PRCL	89	2.3	71	22 - 71	52 ± 11
Forest spring-pool	**CYMI**	3	0.5	3	32 - 44	39 ± 6
	GAAF	53	8.8	53	12 - 41	27 ± 5
	POLA	0	-	-	-	-
	PRCL	40	6.7	40	35 - 71	46 ± 9
Tubbs spring-pool	**RHON**	0	0		-	-
	PRCL	28	4.7	28	40 - 72	57 ± 8
Davis spring-pool	**PRCL**	0	-	-	-	-
Jackrabbit spring-pool	**CYMI**	468	0	124	20 - 52	34 ± 8
	RHON	10	0	10	44 - 62	53 ± 5
	GAAF	22	0	22	22 - 46	31 ± 8
	POLA	54	0	54	17 - 52	29 ± 7
	PRCL	11	0	11	42 - 58	49 ± 6
Jackrabbit stream	**CYMI**	68	1.1	62	25 - 56	38 ± 7
	RHON	538	9	386	22 - 83	52 ± 13
	GAAF	28	0.5	28	21 - 55	35 ± 9
	POLA	6	0.1	5	31 - 58	40 ± 10
	PRCL	123	2.1	118	25 - 78	47 ± 11
Big Springs spring-pool	**CYMI**	310	25.8	88	16 - 54	34 ± 8
	GAAF	26	2.2	25	20 - 41	26 ± 5
	POLA	13	1.1	13	22 - 58	36 ± 10
	PRCL	35	2.9	35	27 - 63	48 ± 9
Big stream	**CYMI**	201	9.6	74	17 - 46	35 ± 8
	GAAF	85	4	62	21 - 51	34 ± 8
	POLA	11	0.5	11	28 - 41	35 ± 4
	RACA	1	0	-	-	-
	PRCL	131	6.2	72	31 - 70	51 ± 10

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Scoppettone and others—Relative Abundance and Distribution of Fishes and Crayfish at Ash Meadows National Wildlife Refuge, Nye County, Nevada, 2010–11—Open-File Report 2012–1141