PROGRESS REPORTS

2013

FISH DIVISION

Oregon Department of Fish and Wildlife

2013 Foskett Speckled Dace Investigations

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: 2013 Foskett Speckled Dace Investigations

PROJECT NUMBERS: USFWS Cooperative Agreement F12AC01064 and BLM agreements CCS L12AC20619

PROJECT PERIOD: 01 January 2013 - 31 December 2013

Photograph of the spring pool at Foskett Spring, which is choked with aquatic vegetation.

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This project was financed with funds administered by the U.S. Fish and Wildlife Service and the Bureau of Land Management.

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INTRODUCTION

Speckled dace (*Rhinichthys osculus*) are geographically widespread throughout the western United States and occur in many isolated subbasins and interior drainages in south-central Oregon. The Foskett speckled dace (*R. osculus* ssp.) is represented by a naturally-occurring population that inhabits Foskett Spring and an introduced population that inhabits Dace Spring (Figure 1), both on the west side of Coleman Lake in Lake County, Oregon. Foskett speckled dace was listed as threatened under the federal Endangered Species Act in 1985 (U.S. Fish and Wildlife Service 1985). The Foskett speckled dace became isolated in Foskett Spring at the end of the Pluvial period (9,000-10,000 years ago). Foskett Spring is a natural spring that rises from a springhead pool, flows through a narrow spring brook into a series of shallow marshes, and then disappears into the soil of the normally dry Coleman Lake (Figure 1). The population in Dace Spring was initially established from an introduction of 100 fish from Foskett Spring in 1979-1980 (Williams et al. 1990); however this population failed due to habitat loss (vegetative succession) and lack of successful recruitment. In 2009, the BLM and the U.S. Fish and Wildlife Service (USFWS) completed a habitat restoration project that created two spring-fed pools at Dace Spring. In 2010-2011, Oregon Department of Fish and Wildlife (ODFW) introduced 124 dace from Foskett Springs into these ponds.

The primary recovery objective for this species is long-term persistence through preservation of its native ecosystem (U.S. Fish and Wildlife Service 1997). The recovery plan further states that the conservation and long term sustainability of this species will be met when: 1) long-term protection of its habitat, including spring source aquifers, spring pools and outflow channels, and surrounding lands is assured; 2) long-term habitat management guidelines are developed and implemented to ensure the continued persistence of important habitat features and guidelines will include monitoring of current habitat and investigation for and evaluation of new spring habitats; and 3) research into life-history, genetics, population trends, habitat use and preference, and other important parameters is conducted to assist in further developing or refining criteria 1) and 2), above. Actions needed to meet these criteria include protecting the fish population and its habitat, conserving genetic diversity of the fish population, ensuring adequate water supplies are available, monitoring of the dace population and habitat conditions, and evaluating long-term effects of climatic trends on recovery of this fish population.

In past years, we used a Lincoln-Petersen model to estimate the abundance of Foskett speckled dace. This model assumes that capture probability is constant among individuals within a population, i.e., probability of recapture is not affected by previous capture and all fish are equally vulnerable to the gear. This assumption is typically violated when the most catchable individuals are caught first and more often, and leads to overestimation of capture probabilities and underestimation of abundance. To estimate the magnitude of this bias and to determine the most appropriate protocol for future sampling, we compared two models in 2012, the single-sample Lincoln-Petersen model (Ricker 1975) and a Huggins closed-capture model. We found in 2012 that the Lincoln-Petersen model underestimated abundance by approximately 50 percent and that capture probabilities differed between marked and unmarked fish, among size classes, by trapping location, and by trapping occasion (Scheerer et al. 2012).

Since 2005, we have documented loss of open water habitat due to vegetative succession/encroachment. In 2012-13, BLM conducted a controlled burn in the tule and cattail marshes to reduce the vegetative biomass and hand excavated eight pools, to increase the amount of open water habitat suitable for Foskett speckled dace.

This report updates monitoring initiated by ODFW in 2005 (Scheerer and Jacobs 2005; 2007; 2009; Scheerer 2011; Scheerer et al. 2012) by providing results of monitoring conducted in 2013. Our objectives were to: 1) estimate the abundance of the federally listed Foskett speckled dace, and 2) document the habitat conditions at Foskett and Dace Springs. Specifically, at Foskett Spring, we compared: 1) the area of open water habitat, 2) the species composition of aquatic vegetation (native vs. nonnative), and 3) the abundance of dace in the modified/restored habitats (tule and cattail marshes) pre- and post-restoration to assess the effectiveness of the restoration efforts.

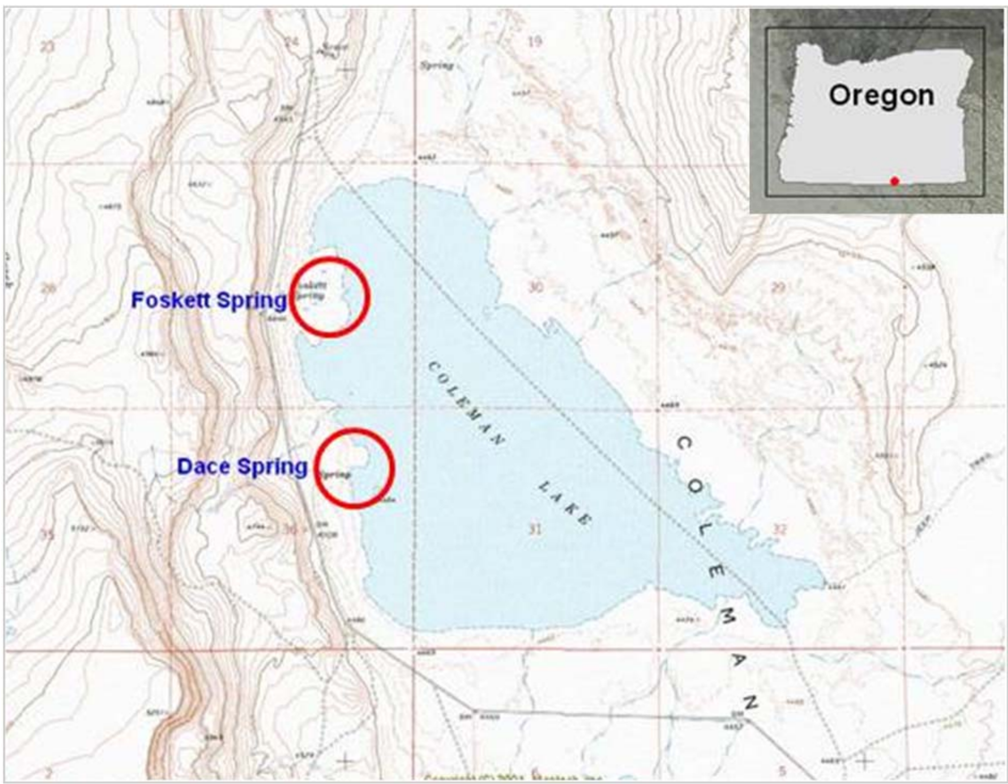

Figure 1. Map showing the locations of Foskett and Dace Springs in the Warner Valley of south central Oregon.

METHODS

We used baited minnow traps (1/16" mesh) to obtain mark-recapture population estimates of Foskett speckled dace at Foskett and Dace Springs from June 25-27, 2013. On Day 1, we distributed the traps haphazardly throughout the spring pool (n=6), springbrook (n=11), tule marsh (n=11), and cattail marsh (n=4) at Foskett Spring and in the two pools (9 traps ea.) at Dace Spring and left them in place for 3-4 h.

At Foskett Spring, we marked all fish that were captured in the tule and cattail marshes with a partial upper caudal fin clip and recorded the number of fish in each of three size categories (small <35 mm TL, medium 35-59 mm TL, and large ≥60 mm TL). After fish were marked, we returned them to the water near the location of capture. The following morning (day 2), we set the traps at approximately the same locations, left them in place for 3-4 h to capture fish, recovered the traps, recorded the number of marked and unmarked fish in each size category, marked all fish with a partial lower caudal fin clip, and released them near the location of capture. On day 3, we pulled the traps, and recorded the total number of unmarked and marked fish (upper caudal, lower caudal, and both) in each size category. In the spring pool and springbrook, we only recorded the number of fish in each of three size categories (no marking) and only trapped on two occasions (days 1 and 2).

At Dace Spring, following capture, we marked all fish with a partial caudal fin clip and returned them to the water to the approximate location where they were captured. The following day, we again fished the traps and recorded the total number of marked and unmarked fish captured. We estimated population abundance using a single-sample mark-recapture procedure and calculated 95% confidence intervals using a Poisson approximation (Ricker 1975).

Using the capture-recapture data, we estimated abundance at Foskett Spring using the Huggins closed-capture model in program MARK (White and Burnham 1999) with three consecutive encounter occasions and three attribute groups (small <35 mm, medium 35-59 mm, and large fish >59 mm). This model requires a minimum of three sampling occasions to estimate capture probabilities and can include covariates that are known to affect capture probabilities (e.g., fish size and habitat characteristics) (Peterson and Paukert 2009). The Huggins model does not directly estimate abundance, but rather abundance (N) is derived using the following formula:

$$N = M_t / (1 - [(1-p_1)(1-p_2)(1-p_3)]),$$

where M_t is the total number of marks in the populations, p_1 is the probability of capture for occasion one, p_2 is the probability of capture for occasion two, and p_3 is the probability of capture for occasion 3.

We calculated abundance estimates separately for the spring pool, springbrook, tule marsh, and cattail marsh. In the spring pool and springbrook, where we sampled on only two occasions and did not mark fish, we estimated abundance using the numbers of fish in each size category on each occasion and the capture probabilities calculated in 2012 (Scheerer et al. 2012). We calculated 95 percent confidence intervals for the estimates according to Chao (1987).

To evaluate which of the independent variables in our Huggins closed-capture model (sampling occasion, fish size, or habitat location) had a greater effect on the dependent variable (capture probability), we examined the parameter estimates for the best approximating capture probability model. The parameter estimates were on a logit scale, so to facilitate interpretation of the parameters we calculated the odds ratios by exponentiating the parameter estimates (Hosmer and Lemeshow 2000). Odds ratios are an estimate of the odds of an event occurring (e.g., capture of a fish) in response to increasing the predictor variable one unit, or the relative differences between two groups. An odds ratio of 1 is interpreted as no effect on the response or no differences between groups. An odds ratio estimate >1 is interpreted as a positive effect. For example, if the odds ratio is 1.24 for small vs. large fish, then small fish are 24% more likely to be captured than large fish. An odds ratio estimate <1 is interpreted as a negative effect. For example, if the odds ratio is 0.322 for sampling occasion 1 versus 2, then fish are approximately 3 times (1/0.322) less likely to be captured on occasion 2, compared to occasion 1. We calculated 95% confidence limits for the odds ratios by exponentiating the 95% confidence limits for the beta estimates

We evaluated the effect of these variables by systematically fitting alternative capture probability models with and without predictors (e.g., body size) and selected the best model using Akaike's Information Criteria with a small sample bias adjustment (AICc; Burnham and Anderson 2002).

We assessed the effects of BLM's vegetative removal and pool excavation at Foskett spring. We mapped the aquatic vegetation in 2013 and compared results to mapping done prior to the habitat restoration in 2012.

RESULTS

We estimated the 2013 Foskett specked dace abundance at 13,142 fish, which was a six fold increase over the 2012 estimate of 1,848 fish (Table 1). To obtain our estimate, we modeled capture probabilities based on fish size, year, sampling occasion, and habitat location. We observed heterogeneity in capture probabilities among fish of different size classes, among habitat locations, and among capture occasions (Table 2). Results from 2013 were similar to those from 2012 (Scheerer et al. 2012). We found that small fish (<35 mm TL) were six times less likely and large fish (≥60 mm TL) were two times less likely to be captured than medium sized fish (35-59 mm). We found that marked fish were four times more likely to be captured than unmarked fish ("trap happy"). We observed heterogeneity in capture probabilities among locations in the spring complex, for example fish were three times more likely to be captured in the spring brook, four times more likely to be captured in the spring pool, and ten times more likely to be captured in the cattail marsh, than in the tule marsh. We also observed heterogeneity in capture probabilities among years. Overall, dace were 1.5 times more likely to be captured in 2013 than in 2012. However, this was size specific, where small fish were six times more likely and large fish were five times less likely to be captured in 2013, compared to 2012. Details regarding the best model beta estimates, odds ratios, and their interpretations are shown in Table 3. All abundance estimates obtained since 2005 at Foskett Spring, with the exception of the 2013 estimate, were significantly lower than the 1997 estimate of 27,787 dace (Dambacher et al. 1997) (Figure 2). From 2009 to 2013, we did not capture any dace in the cattail marsh, as there was no available open water habitat.

In Dace Spring, we captured 21 unique speckled dace, one in the North Pond, twelve in the South Pond, and eight in spring brook upstream of the south pond. We estimated the dace abundance at 34 fish (95% CI: 17-62). While most of the fish we captured were probably fish we stocked in 2010-2011, the presence of fish smaller than

Table 1. Estimates of Foskett speckled dace abundance obtained using the Lincoln-Peterson model, 1997-2012, and the Huggins closed-capture model, 2011-2013. Abundance estimates were not calculated by habitat type using the Huggins model in 2011, because length-frequency data was not recorded separately for each habitat location.

	Lincoln-Petersen model						Huggins model		
Location	1997	2005	2007	2009	2011	2012	2011	2012	2013
Spring pool	204	1,627	1,418	247	322	404	-	633	2,579
	(90 - 317)	(1,157 - 2,281)	(1,003 - 1,997)	(122 - 463)	(260 - 399)	(354-472)	-	(509-912)	(1,985-3,340)
Spring brook	702	755	719	1,111	262	409	-	589	638
	(321 - 1,082	(514 - 1,102)	(486 - 1,057)	(774 - 1,587)	(148 - 449)	(357-481)	-	(498-1024)	(566-747)
Tule marsh	not sampled	425	273	1,062	301	220	-	625	6,891
		(283- 636)	(146 - 488)	(649 - 1,707)	(142 - 579)	(159 - 357)	-	(442-933)	(5,845-8,302)
Cattail marsh	26,881	353	422	158	0	0	0	0	3,033
	(13,158 - 40,605)	(156-695)	(275 - 641)	(57 - 310)					(2,500-3,777)
Entire site	27,787	3,147	2,984	2,830	751	988	1,728	1,848	13,142
	(14,057 - 41,516)	(2,535 - 3,905)	(2,403 - 3,702)	(2,202-3,633)	(616 - 915)	(898-1,098)	(1.269-2,475)	(1,489-2,503)	(10,665-16,616)

Table 2. Foskett speckled dace capture probabilities, listed by habitat location, fish size, and capture occasion. Note, capture probabilities for the spring pool and spring brook are from 2012 (Scheerer et al. 2012).

	Tule marsh				Cattail marsh				Spring pool				Spring brook			
Parameter	Estimate	SE	Lower 95%	Upper 95%	Estimate	SE	Lower 95%	Upper 95%	Estimate	SE	Lower 95%	Upper 95%	Estimate	SE	Lower 95%	Upper 95%
Small Fish																
Capture occasion 1	0.234	0.021	0.195	0.278	0.319	0.035	0.255	0.392	0.229	0.029	0.177	0.291	0.253	0.032	0.195	0.321
Capture occasion 2	0.234	0.021	0.195	0.278	0.081	0.011	0.061	0.106	0.229	0.029	0.177	0.291	0.253	0.032	0.195	0.321
Capture occasion 3	0.128	0.016	0.100	0.162	0.041	0.007	0.029	0.056								
Recapture occasion 2	0.539	0.012	0.516	0.563	0.252	0.014	0.225	0.282								
Recapture occasion 3	0.360	0.010	0.341	0.380	0.242	0.013	0.217	0.269								
Medium fish																
Capture occasion 1	0.224	0.023	0.182	0.273	0.129	0.048	0.060	0.254	0.358	0.032	0.298	0.421	0.361	0.028	0.308	0.418
Capture occasion 2	0.224	0.023	0.182	0.273	0.027	0.011	0.012	0.060	0.358	0.032	0.298	0.421	0.361	0.028	0.308	0.418
Capture occasion 3	0.122	0.017	0.093	0.158	0.013	0.006	0.006	0.030								
Recapture occasion 2	0.526	0.016	0.494	0.557	0.096	0.035	0.046	0.189								
Recapture occasion 3	0.347	0.015	0.319	0.377	0.091	0.033	0.044	0.180								
Large fish																
Capture occasion 1	0.035	0.010	0.020	0.063	No large fish captured				0.096	0.027	0.054	0.161	0.214	0.031	0.158	0.280
Capture occasion 2	0.035	0.010	0.020	0.063					0.096	0.027	0.054	0.161	0.214	0.031	0.158	0.280
Capture occasion 3	0.017	0.005	0.009	0.032												
Recapture occasion 2	0.124	0.030	0.076	0.194												
Recapture occasion 3	0.063	0.016	0.038	0.104												

Table 3. Huggins closed-capture best model beta coefficients, odds ratios, and their interpretations. See "Methods" for a description of these descriptive statistics. Parameters listed with asterisks represent interactions among the two parameters.

Parameter	Estimate	SE	Lower 95%	Upper 95%	Odds Ratio	Interpretation
Intercept	-2.587	0.248	-3.073	-2.100		
Year 2013	0.379	0.145	0.094	0.664	1.46	Dace were 1.5 times more likely (95% CI: 1.1 - 1.9) to be captured in 2013, compared to 2012
Occasion 1, 2	0.967	0.140	0.692	1.242	2.63	Marked and unmarked fish were 2.6 times more likely (95% CI: 2.0 - 3.5) to be caught on occasion 1 and 2, compared to occasion 4 in 2012
Occasion 3	0.233	0.136	-0.032	0.499	1.26	Marked and unmarked fish were 1.3 times more likely (95% CI: -1.0 - 1.7) to be caught on occasion 3, compared to occasion 4 in 2012
Small	-1.690	0.486	-2.644	-0.737	0.18	Small fish were 5.5 times (1/0.18) less likely (95% CI: -14.0 - -2.1) to be captured than medium fish
Large	-0.471	0.163	-0.790	-0.152	0.62	Large fish were (1/0.62) 1.6 times less likely (95% CI: -1.2 - -2.2) to be captured than medium fish
Small*Year 2013	1.746	0.492	0.781	2.710	5.73	Small fish were 5.7 times more likely (95% CI: 2.2 - 15.0) to be captured in 2013, compared to 2012
Large*Year 2013	-1.591	0.323	-2.224	-0.957	0.20	Large fish were 5 times (1/0.20) less likely (95% CI: -9.2 - 0.4) to be captured in 2013, compared to 2012
Spring pool	1.199	0.150	0.906	1.493	3.32	Fish were 3.3 times more likely (95% CI: 2.5 - 4.5) to be captured in the Spring Pool, compared to tule marsh
Spring brook	1.405	0.143	1.125	1.684	4.07	Fish were 4.1 times more likely (95% CI: 3.1 - 5.4) to be captured in the Spring brook, compared to tule marsh
Cattail marsh	-2.347	0.406	-3.143	-1.551	0.10	Fish were 10 times (1/0.10) less likely (95% CI: -23.1 - -4.7) to be captured in cattail marsh, compared to tule marsh
Cattail marsh* occasion 2	1.675	0.075	1.528	1.821	5.34	Fish were 5.3 times more likely (95% CI: 4.6 - 6.2) to be captured on occasion 2 in cattail marsh, compared to other occasions in cattail marsh
Small*spring pool	0.702	0.250	0.211	1.193	2.02	Small fish were 2.0 times more likely (95% CI: 1.2 - 3.3) to be captured in spring pool, compared to small fish at other locations
Large*spring pool	-1.002	0.285	-1.561	-0.442	0.37	Large fish were (1/0.37) 2.7 times less likely (95% CI: -1.6 - -4.8) to be captured in spring pool, compared to large fish at other locations
Small*spring brook	0.749	0.313	-0.256	1.754	2.11	Small fish were 2.1 times more likely (95% CI -1.3 - 5.8) to be captured in the spring brook,compared to small fish at other locations
Small*cattail marsh	1.102	0.407	0.136	1.362	3.01	Small fish were 3.0 times more likely (95% CI: 1.2 - 3.9) to be captured in the cattail marsh, compared to small fish at other locations
Recapture	1.343	0.131	1.087	1.600	3.83	Marked fish were 3.8 times more likely (95% CI: 3.0 - 5.0) to be captured, compared to unmarked fish
Recapture*occasion 4	-0.204	0.106	-0.413	0.004	0.82	Marked fish were (1/0.82) 1.2 times less likely (95% CI: -1.5 - -1.0) to be captured on occasion 4 (in 2012) than other recpture probabilities
Recapture*cattail marsh	0.679	0.114	0.456	0.901	1.97	Marked fish were 2.0 times more likely (95% CI: 1.6 - 2.5) to be captured in the cattail marsh, compared to recpture probabilities at other locations

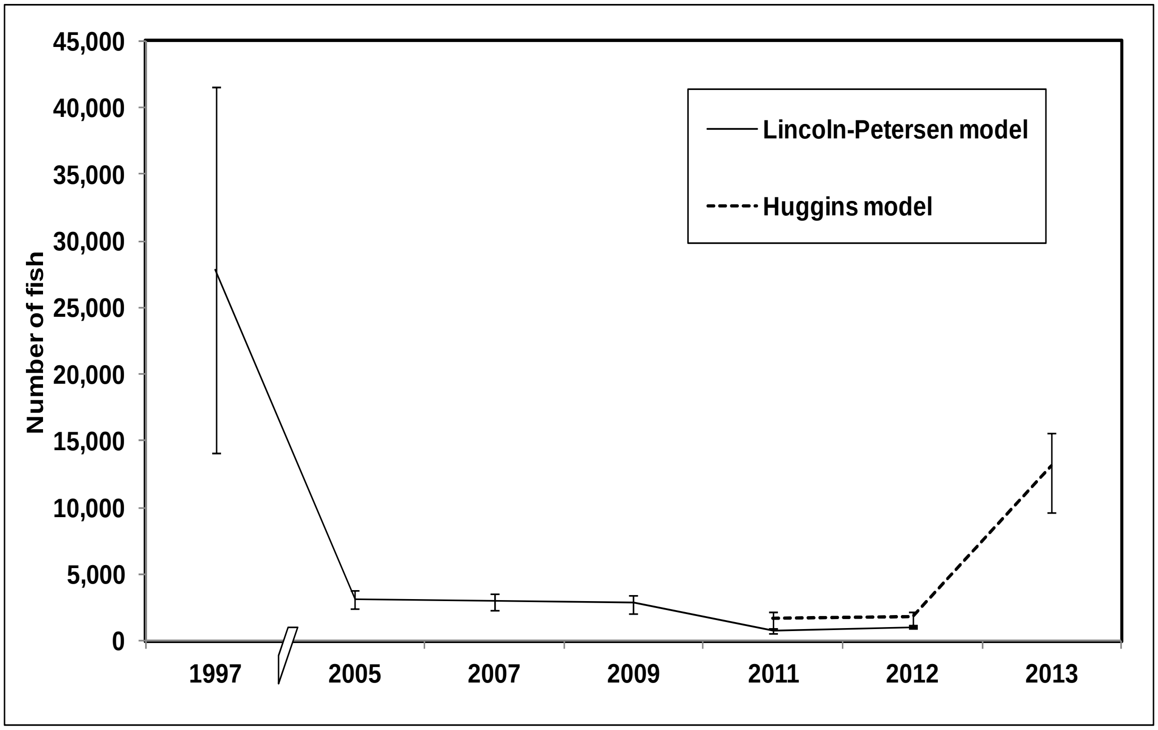

Figure 2. Population estimates for Foskett speckled dace, 1997-2013. Vertical bars represent 95% confidence limits for each estimate. We found the Lincoln-Petersen model underestimated abundance by approximately 50 percent, compared to the Huggins closed-capture model (Scheerer et al. 2012).

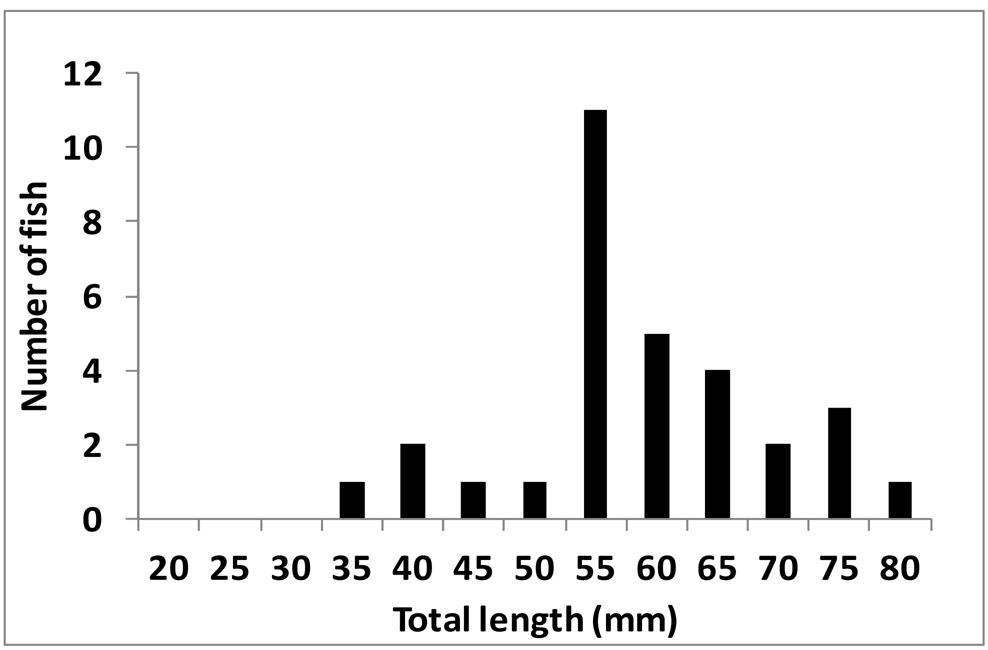

Figure 3. Length-frequency distribution of Foskett dace at Dace Springs, 2013.

50 mm, and the past collection of juvenile dace (Scheerer et al. 2012) suggests there has been some limited recruitment (Figure 3). Assuming all fish larger than 50 mm that we captured in 2013 were from the original stocking (estimate = 29 fish), then the survival of the dace we stocked in 2010-2011 was only 24 percent.

In September 2013, BLM excavated flow-through channels to improve water circulation in the Dace Spring ponds and saw immediate improvement in water clarity (algal bloom subsided) and water quality (dissolved oxygen jumped from 0.1 ppm to over 4.0 ppm). In October 2013, we transferred an additional 200 specked dace from Foskett Spring into the Dace Spring ponds (100 fish ea.).

DISCUSSION

The ODFW Native Fish Investigations Project monitored the status of the federally listed Foskett speckled dace and its habitat, starting in 2005. We found the abundance of Foskett speckled dace declined substantially from 1997 through 2012 (Dambacher et al. 1997; Scheerer and Jacobs 2005, 2007, 2009; Scheerer et al. 2011, 2012). Encroachment by aquatic macrophytes since the habitat was fenced by BLM in 1987 substantially reduced the open-water habitat, with a subsequent decline in the dace population. This is not uncommon in desert spring ecosystems, when springs are fenced and livestock removed, desert spring ecosystems often experience increases in aquatic vegetation, reduction of open-water habitat, and reduction of fish populations (Kodric-Brown and Brown 2007).

The USFWS concluded in 1997 that Foskett specked dace spring habitat was stable, but extremely restricted, and alterations to the spring or surrounding activities that indirectly modify the spring could lead to extinction of the species (US Fish and Wildlife Service 2009). Therefore, the primary recovery objective in the plan was the long-term persistence of the species through preservation of their native ecosystems. According to these criteria, the conservation and long-term sustainability of the Foskett speckled dace will be met when: 1) long-term protection of their habitat, including spring source aquifers, spring pools and outflow channels, and surrounding lands is assured, 2) long-term habitat management guidelines are developed and implemented to ensure the continued persistence of important habitat features including the monitoring of current habitat and investigation for and evaluation of new spring habitats, and 3) research into life-history, genetics, population trends, habitat use and preference, and other important parameters is conducted to assist in further developing and/or refining criteria 1) and 2) above (U.S. Fish and Wildlife Service 1998).

Substantial progress has been made towards meeting the criteria in the Recovery Plan and ensuring the long-term persistence of the population. In 1987, the BLM acquired the 65 hectare parcel of land containing Foskett and Dace Springs and fenced 28 hectares to exclude cattle from both springs. BLM is currently drafting a “Foskett Speckled Dace Cooperative Management Plan” to manage and protect Foskett dace habitat for the conservation and ultimate recovery of Foskett speckled dace. This plan will help develop long-term habitat management guidelines to ensure the continued persistence of dace habitats and guide the cooperators (BLM, USFWS, and ODFW) to work together to implement the conservation strategy. ODFW has been monitoring Foskett dace population abundance trends, habitat use, and habitat preferences since 2005 (Scheerer and Jacobs 2005; 2007; 2009; Scheerer 2011; Scheerer et al. 2012; this study) and found the population was abundant, but declining. Two genetics studies were recently completed. Ardren et al.'s (2010) genetic analysis called into question the taxonomic status of the subspecies. Specked dace from the Warner Basin, including those from Foskett Spring, were found to be closely related, but showed signs of recent isolation from each other. Levels of genetic divergence observed between dace from Foskett Spring, compared to other dace from the Warner Basin, were in the range typically observed between populations belonging to the same species. This study was followed up by a more extensive geographic, taxonomic, and phylogenetic analysis of speckled dace from Foskett Spring and adjacent basins (Hoekzema and Sidlauskas 2012). Their findings confirmed the conclusion of Ardren et al. (2010) that Foskett Spring dace were isolated relatively recently (10,000 years vs. millions of years) and suggest that Foskett Spring dace do not constitute a distinct subspecies under a phylogenetic species concept. Using microsatellites, which evolve more quickly than mitochondrial genes, they found evidence for no recent gene flow, that Foskett Spring is a genetically distinct population, and suggest, with support from their morphological analysis, that Foskett Spring dace likely constitute a distinct evolutionarily significant unit (ESU) and warrant continued Endangered Species Act protection (Hoekzema and Sidlauskis, in review).

The U.S. Fish and Wildlife Service completed the Foskett Specked Dace Five-Year Review (U.S. Fish and Wildlife Service 2009) and specifically recommended: 1) assessing encroachment by aquatic vegetation at Foskett Spring, 2) developing a restoration plan and regular maintenance schedule to increase and maintain suitable open-water habitat, 3) assessing the restoration potential at Dace Spring, and 4) evaluating the feasibility of a Foskett speckled dace transplant effort (U.S. Fish and Wildlife Service 2009).

To address the first recommendation, BLM conducted a controlled burn in 2013 in the tule and cattail marshes at Foskett Spring to reduce the biomass of aquatic vegetation and hand excavated eight pools. In doing so, the open water habitat at Foskett Spring was increased by 180% (APPENDIX A). Controlled burns can be an effective management tool to reduce vegetative biomass, restore open water, and increase plant diversity in desert spring habitats (Kodric-Brown et al. 2007). Immediately after the pools were excavated in the fall/winter of 2012-13, we noted dace moving into the pools, in early spring 2013 we found dace larvae and juveniles were abundant in the pools, and in the summer 2013, we estimated over 13,000 dace at Foskett Spring, with the majority of these (nearly 10,000) in the restored tule and cattail marshes. We also found the marsh habitats were dominated by native aquatic plants, as they were prior to the burn. BLM plans to excavate similar pools in the lower spring brook and to mechanically remove aquatic vegetation from the spring pool in 2014. The second recommendation is being addressed by the management plan discussed previously.

Managers have been attempting to establish a second population of Foskett speckled dace at nearby Dace Spring (recommendations 3 and 4). In 1979-1980, 100 dace were transferred to Dace Spring from Foskett Spring (Williams et al. 1990); however, this population eventually failed due to habitat loss (vegetative succession) and lack of successful recruitment (Dambacher et al. 1997). In 2009, BLM and USFWS created two spring-fed pools at Dace Spring and in 2010-2011; ODFW introduced 124 dace from Foskett Springs into these ponds. In 2011-2013, we documented evidence of recent recruitment at Dace Springs, but also documented substantial algal blooms, periods of low dissolved oxygen, trapping related mortalities, and low survival. In 2013, BLM modified the fresh water delivery from the spring source so that it passes through the ponds; previously, only a single channel existed. We noted an immediate response with improved water clarity and quality in the ponds. In October 2013, we introduced 200 dace from Foskett Spring into the ponds (100 ea.). We plan to transfer 10% of the Foskett Springs population of speckled dace into Dace Springs each year until a total of 500 have been transferred, to minimize impacts to the donor population and potential genetic consequences resulting from drift or founders effect in the recipient population.

In past years we have observed considerable heterogeneity in mark-recapture estimates, suggesting there is likely a trap effect. This has the effect of biasing abundance estimates (Price and Peterson 2010). To quantify and describe the factors influencing this bias, we compared results from the Lincoln-Petersen model, which we used in from 1997 through 2011 (Scheerer and Jacobs 2005; 2007; 2009; Scheerer 2011), with the Huggins closed-capture model, which we used in 2012 and 2013 (Scheerer et al. 2012; this study). We found the Lincoln-Peterson model underestimated dace abundance by approximately 50 percent (Scheerer et al. 2012). We also found that: 1) marked fish were 3.8 times (95% CI: 3.0-5.0) more likely to be captured than unmarked fish, 2) capture efficiency varied among size classes where small fish were 5.5 times (95% CI: 2.1-14.0) less likely to be captured than larger fish, 3) capture probabilities varied by trapping location, for example dace were 3.3 times more likely (95% CI: 2.5-5.5) to be captured in the spring pool and 4.1 times more likely (95% CI: 3.1-5.4) to be captured in spring brook, than in the tule marsh, 4) capture probabilities varied between years, where fish were 1.5 times more likely (95% CI: 1.1-1.9) to be captured in 2013 than in 2012, and 5) capture probabilities varied by trapping occasion. The higher capture probability of marked fish (marked fish were trap happy) violates the assumption of equal capture probabilities among sampling occasions using the Ricker model, and has a major effect on abundance being underestimated using this model, relative to the Huggins model. Likewise, lower capture probabilities for small fish, which comprised a larger proportion of the 2013 population, also results in abundance underestimation. The differences among sampling locations are likely due to the higher density of traps we used in these relatively small habitats. The higher capture probabilities we observed in 2013 were likely due to changes in habitat conditions in the restored marsh, which tended to concentrate fish in these newly created, open-water pools. The variability in capture probabilities among sampling occasions is somewhat perplexing. Conditions at Foskett spring were nearly identical on all occasions over both years (no noticeable changes in temperature, flow, weather, etc.). Something apparently affected dace behavior and catchability, but we have no current explanation.

We recommend continued annual investigations at Foskett and Dace Springs to monitor the status of the Foskett dace populations, to evaluate habitat conditions, and to assess the effects of recent habitat restoration. We also hope to determine how frequently burning and excavation needs to occur at Foskett Spring to effectively maintain open water habitat and prevent future declines in dace abundance.

ACKNOWLEDGEMENTS

Thanks to J. Leal, G. Leal, and P. Green for assistance with the field work. This work was funded by the U.S. Fish and Wildlife Service and the Bureau of Land Management.

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APPENDIX A. Habitat dimensions, by location, at Foskett Spring in 2013. Also included are measurements from 2012 and the changes in open water habitat from 2012 to 2013. We defined open water habitat as habitat which is suitable for speckled dace. Wetted water habitat includes both the open water habitat and emergent wetland habitat, which is unsuitable for dace.

Habitat type	Length (m)	Wetted width (m)	Open water width (m)	Average depth (m)	Wetted area (m^2)	2013 open water area (m^2)	2012 open water area (m^2)	Increase in open water area
Spring pool	4.7	12.2	4.0	0.26	57	4	4	0%
Spring brook	60.5	3.3	0.5	0.17	197	31	25	25%
Tule marsh	100.0	29.3	0.9	0.07	2930	86	43	99%
Cattail marsh	105.0	19.4	1.7	0.04	2032	181	35	416%
total	270.2				5216	301	107	182%

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