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Photograph of the spring brook at Foskett Spring.

Paul D. Scheerer, Shaun Clements
Oregon Department of Fish and Wildlife
28655 Highway 34
Corvallis, Oregon 97333

and

James T. Peterson
USGS Oregon Cooperative Fish and Wildlife Research Unit
104 Nash Hall, Oregon State University
Corvallis, OR 97331-3803

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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 Spring speckled dace (*R. osculus* ssp.) is represented by a single naturally-occurring population that inhabits Foskett Spring (Figure 1) on the west side of Coleman Lake (Warner Lakes Basin) in Lake County, Oregon. Foskett Spring speckled dace were 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). A second population in Dace Spring, located approximately 0.8 kilometer south of Foskett Spring, was established from an introduction of 100 fish from Foskett Spring in 1979-1980 (Williams et al. 1990); however this population eventually failed due to lack of successful recruitment. In 1987, the U.S. Bureau of Land Management (BLM) acquired, through exchange, a 65 hectare parcel of land containing Foskett and Dace Springs. Both sites were fenced to exclude livestock. In 2009, BLM and 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 Recovery Plan for the threatened and rare native fishes of the Warner Basin and Alkali Subbasin states that Foskett speckled dace will probably not be delisted in the near future because of its extremely isolated range and potential for degradation of its habitat from localized events (U.S. Fish and Wildlife Service 1997). The primary recovery objective for this species is long-term persistence through preservation of its native ecosystem. The 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.

Our objectives were to 1) measure the abundance of the federally listed Foskett Spring speckled dace, 2) evaluate the bias in using the Lincoln-Peterson abundance estimator, and 3) document the habitat conditions at Foskett and Dace Springs. In past years, we used a Lincoln-Peterson model to estimate the abundance of Foskett Spring 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-Peterson model (Ricker 1975) and a Huggins closed-capture model. Specifically, we compared these methods to assess whether: 1) marked fish were more likely to be captured compared to unmarked fish, 2) capture efficiency varied among size classes, 3) capture probabilities varied by trapping location, and 4) capture probabilities varied by trapping occasion. 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). This report updates monitoring initiated by ODFW in 2005 (Scheerer and Jacobs 2005; 2007; 2009; Scheerer 2011) by providing results of monitoring conducted in 2012.

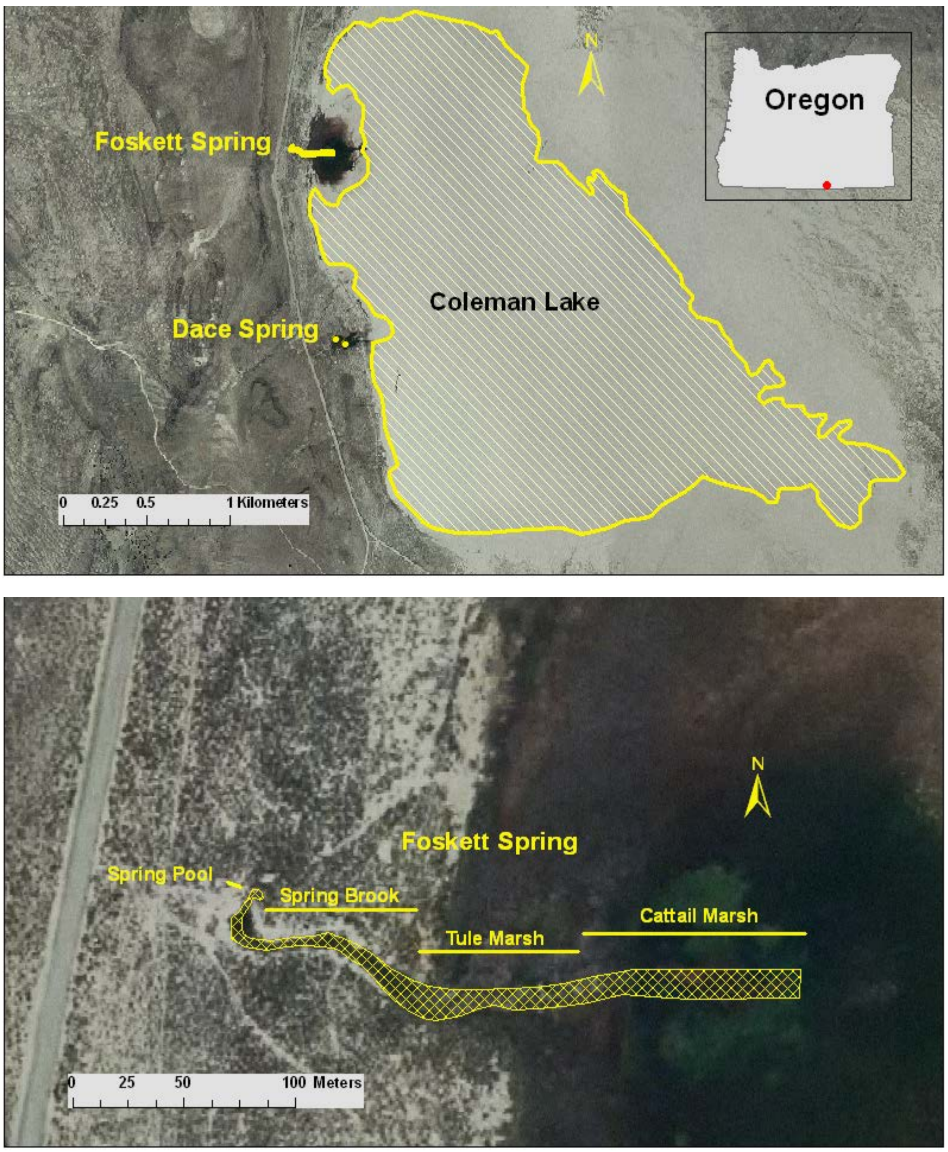

Figure 1. Map showing the locations of Foskett and Dace Springs in the Warner Valley of south central Oregon (top) and the location of distinct habitat areas at Foskett Spring (bottom).

METHODS

We used baited minnow traps (N=28, 1/16” mesh) to obtain mark-recapture population estimates of Foskett Spring speckled dace at Foskett and Dace Springs between 23-26 July, 2012. On Day 1, we distributed the traps haphazardly throughout the spring pool (n=8), springbrook (n=11), and tule marsh (n=11) at Foskett Spring and in the two pools at Dace Spring and left them in place for 3-4 h.

The traps were then recovered and we marked all fish with a partial upper caudal fin clip, recorded the number of fish in each of three size categories (small <35 mm TL, medium 35-59 mm TL, and large $\geq$60 mm TL), and recorded the total length (TL) of a sub-sample of fish (N=154). 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 dorsal fin clip, and released them near the location of capture. On day 3, we set and recovered the traps as described above, recorded the number of marked and unmarked fish (upper caudal, dorsal, or both clips) in each size category, and marked all fish with a partial anal fin clip. On day 4, we pulled the traps, and recorded the total number of unmarked and marked fish (upper caudal, dorsal, anal, and various combination of clips) in each size category.

Using the capture-recapture data we estimated abundance using the Huggins closed-capture model and the Lincoln-Peterson model. For the Huggins closed-capture model we used the program MARK (White and Burnham 1999) with four 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). In contrast to the Lincoln-Peterson model, the Huggins model does not directly estimate abundance, but rather abundance (N) is derived using the following formula:

$$N = M_t / (1 – [(1-p_1)(1-p_2)(1-p_3)(1-p_4)]),$$

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, p_3 is the probability of capture for occasion 3, and p_4 is the probability of capture for occasion 4.

We calculated 95 percent confidence intervals for this estimate according to Chao (1987) and calculated 95 percent confidence intervals for the estimate obtained from the Ricker model using a Poisson approximation (Ricker 1975). We calculated abundance estimates separately for the spring pool, springbrook, and tule marsh. We did not trap in the cattail marsh as we could not locate any open water habitat.

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 (here, 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.

RESULTS

The Lincoln-Peterson model underestimated specked dace abundance by 47%, compared to the Huggins closed-capture model, when we pooled data for all habitat types and size classes at Foskett spring in 2012 (Table 1). We estimated there were 1,848 fish (95% CI: 1,489-2,503) using the Huggins closed-capture model and 988 fish (95% CI: 898-1098) using the Lincoln-Peterson model. For the Huggins estimate, we modeled capture probabilities based on fish size, sampling occasion, and habitat location (spring pool, springbrook, tule marsh). Speckled dace capture probabilities ranged from 0.02-0.80 and varied depending on fish size, habitat location, and capture occasion (Table 2). Probabilities were highest for medium sized fish, in the spring brook, for capture occasions one and two, and for recapture occasion one.

We recalculated the 2011 estimate with the Huggins model, using the catch and length-frequency data from 2011 and the estimated capture probabilities from 2012. We obtained an estimate of 1,728 fish (95% CI: 1,269-2,475), which was not significantly different from the 2012 estimate using the same model (p>0.05). Likewise, the 2011 and 2012 estimates obtained with the Lincoln-Peterson model were not significantly different (p>0.05). We found similar results when we obtained abundance estimates separately for the spring pool, spring brook, tule marsh (all size classes combined), i.e., abundance was underestimated using the Lincoln-Peterson model, (Table 1). Bias was lowest in the spring brook and highest in the tule marsh.

We observed heterogeneity in capture probabilities among fish of different size classes. Small fish (<35 mm TL) were seven times less likely and large fish ($\geq$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 also observed heterogeneity in capture probabilities among locations in the spring complex, for example fish were four times more likely to be captured in the spring brook and spring pool than in the tule marsh. Details regarding the best model beta estimates, odds ratios, and their interpretation are given in Table 4.

All abundance estimates obtained since 2005 at Foskett Spring are significantly lower than the 1997 estimate of 27,787 dace, with 26,881 in the cattail marsh (Dambacher et al. 1997) (Table 3). No dace have been captured in the cattail marsh since 2009 as no open water habitat remains. We have also noted a significant decline in dace abundance in the spring pool since 2005, a habitat which is now choked with aquatic vegetation.

Table 1. Population abundance estimates obtained in 2012 for Foskett Spring speckled dace.

	Huggins model			Lincoln-Peterson model			Percent
Location	Estimate	Lower 95%	Upper 95%	Estimate	Lower 95%	Upper 95%	bias
Spring pool	**634**	509	912	**404**	354	472	36%
Spring brook	**589**	498	1024	**409**	357	481	31%
Tule marsh	**625**	442	933	**220**	159	357	65%
All sites	**1848**	1489	2503	**988**	898	1098	47%

Table 2. Foskett Spring speckled dace capture probabilities, listed by habitat location, fish size, and capture occasion.

	Capture probabilities		
	Mean	Standard error	Range
Spring pool	0.31	0.04	0.07-.079
Spring brook	0.40	0.04	0.14-0.80
Tule marsh	0.15	0.03	0.02-0.51
Small fish	0.20	0.04	0.20-0.60
Medium fish	0.41	0.04	0.10-0.80
Large fish	0.25	0.04	0.07-0.72
Capture occasion 1	0.27	0.05	0.04-0.50
Capture occasion 2	0.27	0.05	0.04-0.50
Capture occasion 3	0.15	0.03	0.02-0.31
Capture occasion 4	0.14	0.03	0.02-0.29
Recapture occasion 1	0.55	0.07	0.13-0.80
Recapture occasion 2	0.38	0.06	0.06-0.64
Recapture occasion 3	0.26	0.05	0.03-0.48

Table 3. Estimates of Foskett Spring speckled dace abundance obtained using the Lincoln-Peterson model, 1997-2011, and the Huggins closed-capture model, 2011-2012. 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-Peterson model					Huggins model	
Location	1997	2005	2007	2009	2011	2011	2012
Spring pool	204 (90 - 317)	1,627 (1,157 - 2,281)	1,418 (1,003 - 1,997)	247 (122 - 463)	322 (260 - 399)	-	633 (509-912)
Spring brook	702 (321 - 1,082	755 (514 - 1,102)	719 (486 - 1,057)	1,111 (774 - 1,587)	262 (148 - 449)	-	589 (498-1024)
Tule marsh	not sampled	425 (283- 636)	273 (146 - 488)	1,062 (649 - 1,707)	301 (142 - 579)	-	625 (442-933)
Cattail marsh	26,881 (13,158 - 40,605)	353 (156-695)	422 (275 - 641)	158 (57 - 310)	0	0	0
Entire site	27,787 (14,057 - 41,516)	3,147 (2,535 - 3,905)	2,984 (2,403 - 3,702)	2,830 (2,202-3,633)	751 (616 - 915)	1,728 (1.269-2,475)	1,848 (1,489-2,503)

Table 4. Huggins closed-capture best model beta coefficients, odds ratios, and their interpretations. See "Methods" for a description of these descriptive statistics.

Parameter	Estimate	Standard error	Odds Ratio	1/odds ratio	Interpretation
Intercept	-2.196	0.302			
Occasion 1, 2	0.869	0.163	2.38	0.42	Marked and unmarked fish were 2.38 times more likely to be caught on occasion 1 and 2
Occasion 3	0.056	0.156	1.06	0.95	Marked and unmarked fish were 1.06 times more likely to be caught on occasion 3
Spring pool	1.292	0.159	3.64	0.27	Fish were 3.64 times more likely to be caught in spring pool relative to tule marsh
Spring brook	1.320	0.148	3.74	0.27	Fish were 3.74 times more likely to be caught in spring brook relative to tule marsh
Small	-1.981	0.541	0.14	7.25	Small fish were (1/0.14) 7.25 times less likely to be captured than medium fish in Tule marsh
Large	-0.434	0.171	0.65	1.54	Large fish were (1/0.65) 1.54 times less likely to be captured than medium fish in tule marsh and spring
Small*spring pool	0.770	0.558	2.16	0.46	Small fish were 2.16 times more likely to be captured in spring pool relative to tule marsh
Large*spring pool	-1.221	0.325	0.30	3.39	Large fish were (1/0.30) 3.4 times less likely to be captured in spring pool compared to tule marsh and
Small*spring brook	1.000	0.565	2.72	0.37	Small fish were 2.7 2 times more likely to be captured in spring brook relative to tule marsh
Recapture	1.377	0.188	3.96	0.25	Marked fish were 3.96 times more likely to be captured compared to unmarked fish
Recapture*occasion 4	-0.590	0.176	0.55	1.80	Marked fish were (1/0.55) 1.8 times less likely to be captured on occasion 4 compared to other occasions

In Dace Spring, we captured 13 unique speckled dace, six in the North Pond, four in the South Pond, and three in the spring head pool. All marked fish were subsequently recaptured. Survival of individuals introduced in 2010-2011 was 11 percent. We found evidence of limited recruitment (2 juvenile dace) near the spring head. Due to the low survival in 2012, we chose not to transfer additional specked dace from Foskett Spring into the Dace Spring ponds in 2012.

Dace captured in 2012 from Foskett Spring ranged from 20-73 mm TL. Dace were of similar size in all habitats; however we collected a slightly higher proportion of the smallest fish from the spring pool. A comparison of the size distribution of dace collected in 2012 at Foskett and Dace Springs is presented in Figure 3; the Dace Spring size distribution was skewed towards larger individuals, relative to the Foskett Spring distribution, suggesting that there has been limited recruitment of translocated individuals.

Habitat conditions at Foskett Spring have changed steadily since 2005, with a large reduction in open-water in all habitat areas, resulting from the expansion of rooted aquatic macrophytes at the site. This has been especially notable in the downstream tule and cattail marshes. Habitat conditions at Dace Spring have changed little since 2009, with the exception of substantial algal blooms.

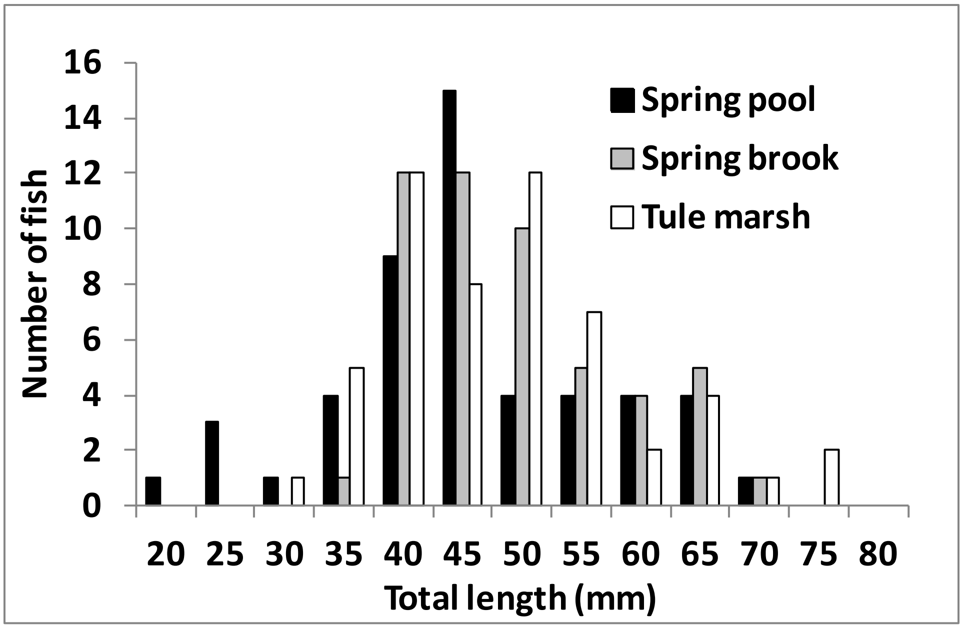

Figure 2. Length-frequency histograms for Foskett Spring speckled dace collected in 2012 from the spring pool, spring brook, and tule marsh.

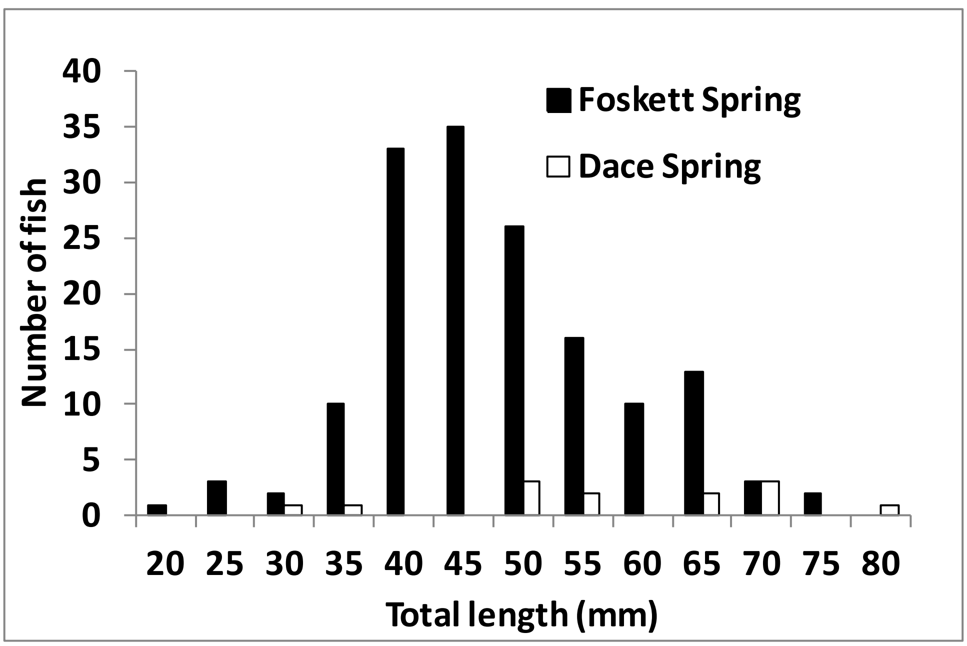

Figure 3. Length-frequency histograms for Foskett Spring speckled dace collected in 2012 from Foskett and Dace Springs.

DISCUSSION

The ODFW Native Fish Investigations Project has monitored the federally listed Foskett Spring speckled dace since 2005; abundance at Foskett Spring has declined substantially in the recent years and is now less than ten percent of the 1997 levels (Dambacher et al. 1997). Examination of length-frequency data suggests a broad age structure with recent recruitment (Scheerer and Jacobs 2005, 2007, 2009; Scheerer et al. 2011, this study). Encroachment by aquatic macrophytes since the habitat was fenced by BLM in 1987 has substantially reduced the open-water habitat, and appears to be limiting the dace population. After springs are fenced and livestock removed, desert spring ecosystems can experience increases in aquatic vegetation, reduction of open-water habitat, and reduction of fish populations (Kodric-Brown and Brown 2007). Initially, the Foskett dace population declined substantially between 1997 and 2005, as vegetative encroachment eliminated open-water habitat in the cattail marsh. Since 2005, substantial vegetative encroachment in the tule marsh and spring pool has also occurred.

Managers have attempted twice to establish a second population of Foskett Spring speckled dace at nearby Dace Spring, which is located approximately 0.8 km south of Foskett Spring. In 1979-1980, 100 dace were transferred to Dace Spring from Foskett Spring (Williams et al. 1990); however, this population eventually failed due to lack of successful recruitment (Dambacher et al. 1997). In 2009, BLM and USFWS completed a habitat restoration project creating 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. Although we have documented some evidence of recent recruitment, we have also documented major algal blooms, periods of low dissolved oxygen, trapping related mortalities indicating respiratory stress (flared gills and gaping mouths), and low survival (11%). In 2013, BLM plans to modify the fresh water delivery from the spring source so that it passes through the ponds (separate inflow and outflow channels). Currently, only a single channel exists. The flow-through design should reduce water stagnation and algal blooms. In addition, BLM and ODFW will periodically harvest algae, as needed, to reduce nutrient levels.

To refine our population abundance estimates and reduce bias, we compared results from the Lincoln-Peterson model used to obtain past estimates with those from the Huggins closed-capture model (program MARK). In 2011, we examined a subset of the mark-recapture data from previous years and found heterogeneity in capture and recapture probabilities both within and between years. This heterogeneity generally resulted in underestimation of population abundance when using the Lincoln-Peterson estimator. In 2012, we using a repeated sampling design and examined relationships between body size, habitat location, and sampling occasion on (re)capture probabilities. We also examined the effects of heterogeneity in capture probabilities on our abundance estimates. The 2012 results revealed that all of these variables affected capture probabilities and that the Lincoln-Peterson model underestimated dace abundance by 31-65%, depending on the habitat sampled. Nonetheless, the recent decline in abundance was evident, regardless of which model we used.

The U.S. Fish and Wildlife Service's Foskett Spring Specked Dace 5-Year Review (U.S. Fish and Wildlife Service 2009) recommended assessing encroachment by aquatic vegetation at Foskett Spring and developing a restoration plan and regular maintenance schedule to increase and maintain suitable open-water habitat for Foskett speckled dace. BLM conducted a controlled burn in 2012 to reduce vegetative biomass in the tule and cattail marshes, and began excavating open-water pools in these locations. Additional hand excavation will be completed in the spring of 2013. 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). BLM also plans to mechanically remove aquatic vegetation from the spring pool and spring brook in the near future.

In 2013, we will assess the effect of BLM's vegetative removal and pool excavation on the abundance of Foskett Spring speckled dace. In 2012, we mapped the aquatic vegetation prior to the habitat restoration. In 2013, we will remap the habitat and estimate dace abundance to quantify the response, if any, to the habitat restoration activities. We will compare: 1) the area and volume of open water habitat, 2) the species composition of aquatic vegetation (submergent vs. emergent; native vs. nonnative), and 3) the abundance (and catch) of dace in the modified/restored habitats (tule and cattail marshes) pre- and post-restoration to assess the effectiveness of the restoration efforts. We also plan to conduct similar monitoring in future, subsequent years to determine how frequently burning and excavation need to occur to effectively maintain open water habitat and prevent future declines in dace abundance.

Another recommendation from the 5-Year Review included assessing the restoration potential at Dace Spring and evaluating the feasibility of a Foskett speckled dace transplant effort (U.S. Fish and Wildlife Service 2009). In 2013, we will monitor habitat conditions and the population abundance of Foskett dace introduced into the Dace Spring ponds. Due to the low survival of translocated individuals to date, we will wait until BLM completes renovation to the water supply ditches before transferring additional dace from the Foskett Springs population. Ultimately, 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.

A recent genetic analysis called into question the taxonomic status of the species (Ardren et al. 2010). 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 the morphological analysis, that Foskett Spring dace likely constitute a distinct evolutionarily significant unit (ESU) and warrant continued Endangered Species Act protection (K. Hoekzema, personal communication).

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LITERATURE CITED

Ardren, W. R., J. Baumsteiger, and C. Allen. 2010. Genetic analysis and uncertain taxonomic status of threatened Foskett Spring speckled dace. Conservation Genetics 11:1299-1315.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical-theoretic approach, second edition. Springer-Verlag, New York, 353 pp

Dambacher, J. M., A. G. Talabere, D. L. Hill, and D. F. Markle. 1997. Foskett speckled dace investigations. Draft Fish Research Progress Report. Oregon Department of Fish and Wildlife and Oregon State University. 7 p.

Hoekzema, K., and B. L. Sidlauskas. 2012. Geographic, taxonomic, and phylogenetic analysis of speckled dace from Foskett Spring and adjacent basins. Report to the Bureau of Land Management, interagency agreements L10AC20526 and LXCCH1204900. 29 p.

Hosmer, D.W., Jr., and S. Lemeshow. 2000. Applied Logistic Regression. Wiley, New York.

Kodric-Brown, A., and J. H. Brown. 2007. Native fishes, exotic mammals, and the conservation of desert spring. Frontiers in Ecology and the Environment 5:549-553.

Kodric-Brown, A., C. Wilcox, J. G. Bragg, and J. H. Brown. 2007. Dynamics of fish in Australian desert springs; role of large mammal disturbance. Diversity and Distribution 13:789-798.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191, Ottawa, Ontario.

Scheerer, P. D., and S. E. Jacobs. 2005. Hutton Spring tui chub and Foskett Spring speckled dace investigations. Fish Research Progress Report, Contract E-2-37. Oregon Department of Fish and Wildlife. 11 p.

Scheerer, P. D., and S. E. Jacobs. 2007. Hutton Spring Tui Chub and Foskett Spring Speckled Dace Investigations. Fish Research Project 134206M085, Annual Progress Report, Corvallis. 10 p.

Scheerer, P. D., and S. E. Jacobs. 2009. Foskett Spring Speckled Dace Investigations. Fish Research Project 13420-08-J814, Annual Progress Report, Corvallis. 7 p.

Scheerer, P. D. 2011. 2011 Foskett Spring speckled dace investigations. Fish Research Project 13420-08-J814, Annual Progress Report, Corvallis. 8 p.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; determination of threatened status for Hutton Tui chub and Foskett speckled dace. U.S. Federal Register 50:12302-12306.

U.S. Fish and Wildlife Service. 1997. Draft recovery plan for the threatened and rare native fishes of the Warner basin and Alkali subbasin. U.S. Fish and Wildlife Service, Portland, Oregon. 82 p.

U.S. Fish and Wildlife Service. 2009. Foskett speckle dace (*Rhinichthys osculus* ssp.) 5-year review summary and evaluation. U.S. Fish and Wildlife Service, Portland, Oregon. 19 p.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement: 120-138.

Williams, J. E., M. A. Stern, A. V. Munhall, and G. A. Anderson. 1990. Conservation status of the threatened fishes in Warner basin, Oregon. Great Basin Naturalist 50:243-248.