INCREASED AMPHIBIAN PRESENCE IN A MONTANE LAKE AFTER FISH REMOVAL, MOUNT RAINIER NATIONAL PARK, WASHINGTON

GARY L LARSON, ROBERT L HOFFMAN

US Geological Survey, Forest and Rangeland Ecosystem Science Center, 777 NW 9th St, Suite 400, Corvallis, OR 97330 USA; rhoff@peak.org

REBECCA LOFGREN, BARBARA SAMORA, SCOTT ANDERSON

National Park Service, Mount Rainier National Park, 55210 238th Avenue East, Ashford, WA 98304 USA

ABSTRACT—During the period 1996–2003, a population of introduced *Salvelinus fontinalis* was eradicated from a montane lake in Mount Rainier National Park, Washington State, USA. Using mostly gill-nets, 2185 fish were removed. Snorkel and visual encounter surveys (n = 10 and 6, respectively) were completed 1996–2001, to document the apparent abundances of amphibian species present in the lake and an adjacent shallow pond during fish presence and removal. During this period only 7 *Ambystoma gracile* larvae and 6 *Rana cascadae* adults were observed in the lake; no amphibians were observed in the pond. After fish removal, lake snorkel and visual encounter surveys (n = 9 and 10, respectively) conducted between 2004 and 2015 collectively documented the apparent increase in abundances of *A. gracilie* (n = 398), *A. macrodactylum* (n = 68), *Ambystoma* spp. (n = 184), *Rana cascadae* (n = 357), and *Ascaphus truei* (n = 12). Pond visual encounter surveys conducted between 2005 and 2012 documented the increased presence of *Ambystoma* spp. (n = 110) and *Rana cascadae* (n = approximately 5600+) larvae. Although the number of amphibian species detected and their apparent abundances varied among surveys and years, the abundances of the amphibian species in Hidden Lake increased markedly after removal of the introduced fish population.

Key words: *Ambystoma gracile, Ambystoma macrodactylum, Ascaphus truei,* fish effects, fish removal, introduced nonnative fish, *Rana cascadae,* species recovery, *Salvelinus fontinalis*

Introduced salmonids can have negative impacts on the abundances of native taxa of montane lakes, especially amphibians (Tyler and others 1998; Knapp and Matthews 2000; Knapp and others 2001; Pilliod and Peterson 2001; Larson and Hoffman 2002). Due in part to this knowledge, the National Park Service recognized that an early management policy of introducing salmonids into naturally fishless lakes was counter to the National Park Service Organic Act of 1916 (39 Stat. F35; available at https://www.nps.gov/grba/learn/management/organic-act-of-1916.htm), which is focused on preserving natural and cultural park resources for future generations. To better understand the impact of introduced salmonids on native amphibian species in montane lakes and their capacity to recover if the introduced fish were removed, Mount Rainier National Park (hereafter MORA) initiated a program in 1996 to eradicate introduced *Salvelinus fontinalis* (Brook Trout) populations from 3 park lakes (Upper Palisades, Harry, and Hidden). Hoffman and others, (2004, 2012) reported on the positive responses in apparent abundances of amphibian populations in 2 of the lakes (Upper Palisades and Harry) after the fish populations were eradicated in 1996 and 1998, respectively. This article summarizes the changes in apparent abundances of 4 amphibian species in the 3rd lake (Hidden) associated with *S. fontinalis* removal, which was completed in 2003.

METHODS

Hidden Lake occupies a cirque located in the northeast corner of MORA (Fig.1). The lake has a surface elevation of 1806 m, a surface area of 2.1 ha, and a maximum depth of 7 m. The north edge of the lake is covered by granitic talus, whereas the rest of the lakeshore is in subalpine forest and underbrush. A shallow (<1 m deep) pond is located on the southeast edge of the lake. The pond is about 0.5 m in elevation above the lake and a small intermittent outlet stream flows from the pond into the lake. A seep-stream flows into the west end of the lake during snow-melt runoff, and a short outlet stream flows east from the lake and quickly cascades down a steep cliff.

Salvelinus fontinalis Removal

Gill nets were used to remove a total of 2185 *S. fontinalis* from Hidden Lake between 1996 and 2003 (Hoffman and Larson, unpubl. data). The use of gill nets has been shown to be an effective method for removing nonnative fish from mountain lakes (Knapp and Matthews 1998; Hoffman and others 2004; Vredenberg 2004; Pope 2008). Prior to removal, we concluded that the population in the lake was successfully reproducing and self-sustaining based on the fact that the lake was last stocked with *S. fontinalis* in 1936 (MORA, unpublished stocking records). The gill nets used to remove the fish were 42-m long and 2-m deep, with 4 sections of monofilament panels of 12.5-, 18.5-, 25-, and 33-mm mesh. Gill nets were fished in multiple sets (2 to 3 times per field season, typically July–September), with 3 to 6 gill nets used per set. Nets were deployed perpendicular to the perimeter of the lake using a 2-person rubber raft to pull each net its full length toward the middle of the lake. Nets were fished with their lead lines resting on the lake bottom. Net locations were arbitrarily selected at various points along the lake shoreline, and fishing effort generally occurred over 2 to 3 d. Nets were fished overnight, fish were removed from the nets the following day, and the nets were reset. Fish were backpacked to the trailhead and disposed of in a park dumpster.

Snorkel and Visual Encounter Surveys

Standard annual snorkel surveys conducted by the US Geological Survey (USGS), 1996 through 2001, and 2005 and 2006 (Fig. 1), were used to assess the apparent abundances of amphibians in the lake (enumerated as the number of individuals per species observed during surveys; Table 1). Surveys were standardized by arbitrarily selecting 4 nearshore transects parallel to the lake shoreline and 2 offshore transects perpendicular to the shoreline. Transect substrate composition ranged from: (1) sand-silt with small gravel; (2) sand-silt and small gravel with some cobble and coarse wood; and (3) substrate comprised primarily of small to large talus-boulders. Transects were 25-m long. Nearshore transect widths extended from the shoreline to approximately 2 m from shore. Offshore transects began 2 m from the shoreline and extended away from the shoreline to the center of the lake. The number of amphibians observed by the snorkeler in the 6 transects constituted a complete survey.

Lake visual encounter surveys (VES) were also completed by the USGS (1996–2001, 2006) to assess the apparent abundances of amphibians in the lake. VES were completed by walking the entire lake perimeter and recording any amphibians observed within a 1-m band of the lake shoreline. The pond adjacent to Hidden Lake was also examined visually for amphibians (Fig. 1).

Snorkel surveys and VES were conducted by MORA staff between 2004 and 2015 according to the survey procedures described in Samora and others (2012). Transects surveyed by MORA staff were of 3 types: (A) the 6 original transects surveyed by the USGS, 1996–2001; (B) 16 transects that were approximate matches to the original USGS transects; and (C) 26 new transects created by MORA staff (Fig. 1). The new transects, rather than representing unique new lake habitat, merely extended the locations in the lake that were surveyed for amphibians. Four-nearshore and 4-offshore transects were completed during each survey, except in 2015 when only 3-nearshore and 3-offshore transects were snorkeled during one of the two 2015 surveys (Table 1). Consistent with USGS methods, transects were 25-m long, and included a nearshore transect and an offshore transect. Nearshore transect widths also extended from the shoreline to approximately 2 m from shore. Offshore transects began 2 m from the shoreline and extended away from the shoreline to the center of the lake. VES were started at a random point on the lakeshore. Surveyors walked the entire perimeter of the lake continuously searching for amphibians and stopping every 50 m to search more intensively. The intensive search plot was a rectangular 1- by 2-m plot extending 1 m from the shoreline toward the center of the lake.

Potential Sources of Survey Count Error

Inventory and monitoring data (such as the data collected in this study), although not

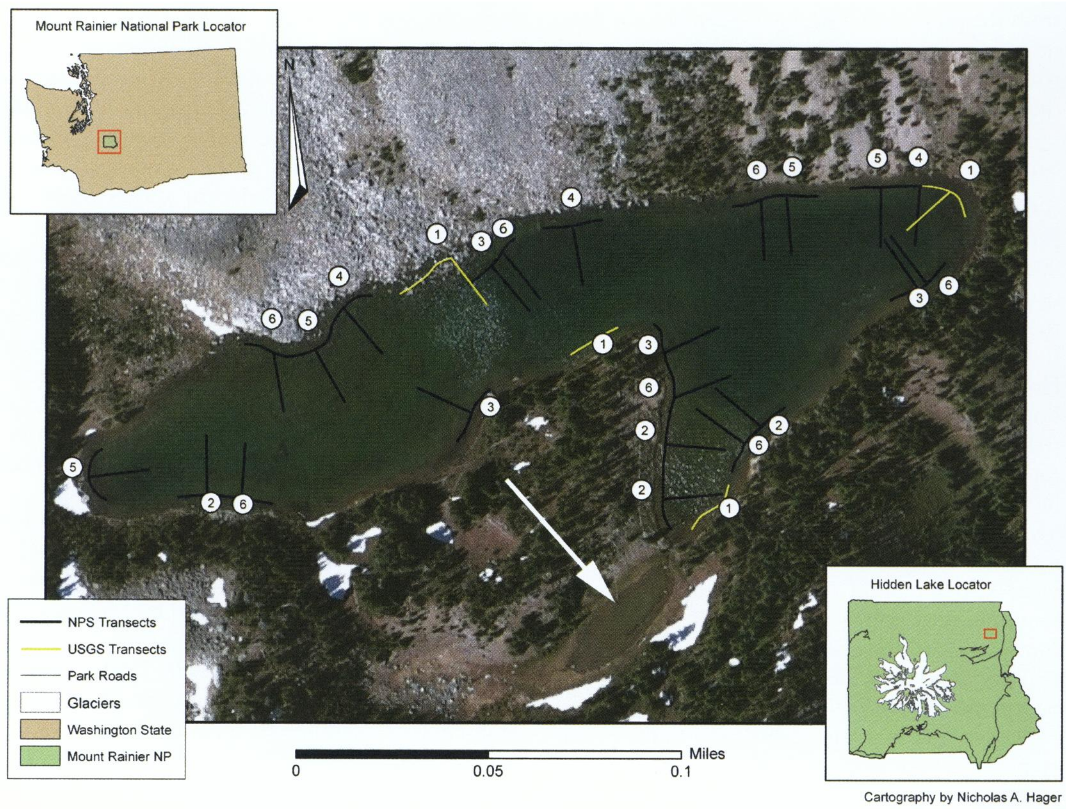

FIGURE 1. Aerial view of Hidden Lake and associated pond (identified by white arrow), showing locations of nearshore and offshore snorkel survey transects: (1) 1996–2001, 2005, 2006; (2) 2004; (3) 2008; (4) 2009; (5) 2011; (6) 2015.

always amenable to rigorous statistical analysis, can provide important baseline information about the status and trends of amphibian species (Heyer and others 1994). While some inventory and monitoring programs use multiple survey techniques, which can be advantageous for more completely surveying a habitat or ecosystem of interest (Heyer and others 1994; Olson and others 1997), it is known that the use of different survey techniques (such as snorkel surveys and VES in this study), different surveyors with varying levels of experience, and differences in survey effort can be sources of error in the enumeration of organisms (Olson and others 1997; Manley and others 2006; Ruiz-Gutiérrez and Zipkin 2011). Additional potential sources of error include: (1) the non-observation of species and individuals, which is related to their probability of detection (Bailey and Adams 2005; Ruiz-Gutiérrez and Zipkin 2011); (2) the spatial constraints of survey techniques (for example snorkel survey transects are much more spatially limited than whole-lake VES); (3) type and complexity of the habitats being surveyed (Ruiz-Gutiérrez and Zipkin 2011; for example complexity decreases the probability of detection); and (4) interannual differences in environmental conditions, such as weather and temperature at the study site (Semlitsch 1985; USEPA 2002; Bailey and Adams 2005). Although we attempted to maintain standardized training and survey protocols for snorkel surveys and VES conducted by USGS and NPS surveyors, the surveys did vary somewhat, primarily with the location of some of the NPS snorkel survey transects (Fig. 1) and addition of the 50-m intensive searches during NPS VES. Because of these potential sources of error, the annual counts we report need to be interpreted as relatively coarse indicators of the presence and abundance of each species, rather than as precise

TABLE 1. Apparent abundances of amphibian species observed in Hidden Lake and adjacent pond, 1996–2015, during snorkel and visual encounter surveys. AMGR = *Ambystoma gracile;* AMMA = *Ambystoma macrodactylum;* AMSP = unidentified *Ambystoma* spp.; RACA = *Rana cascadae;* ASTR[1] = *Ascaphus truei.* Snorkel Survey Transect (SST) types: A = original USGS transects; B = approximate matches to original transects; C = new transects created by MORA staff.

Year	Number surveys	Survey agency	Number transects	SST type	AMGR	AMMA	AMSP	RACA	ASTR[1]	Total
LAKE SNORKEL SURVEYS – FISH PRESENT AND REMOVAL										
1996	3	USGS	18	A	1	0	0	0	0	1
1997	1	USGS	6	A	0	0	0	0	0	0
1998	2	USGS	12	A	4	0	0	0	0	4
1999	2	USGS	12	A	0	0	0	0	0	0
2000	1	USGS	6	A	0	0	0	0	0	0
2001	1	USGS	6	A	2	0	0	0	0	2
LAKE SNORKEL SURVEYS – AFTER FISH ERADICATION										
2004	1	NPS	8	C	31	8	0	1	0	40
2005	1	USGS-NPS	8	A	7	0	0	0	0	7
2006	1	USGS-NPS	8	A	4	4	0	0	0	8
2008	2	NPS	16	B	6	3	5	0	0	14
2009	1	NPS	8	C	2	4	7	0	0	13
2011	1	NPS	8	C	17	0	2	1	0	20
2015	1	NPS	8	B	65	0	0	0	0	65
2105	1	NPS	6	C	24	0	1	0	0	25
LAKE VISUAL ENCOUNTER SURVEYS										
1996–2001	6	USGS	—	—	0	0	0	6	0	6
2004	1	NPS	—	—	0	5	22	28	0	55
2005	2	USGS-NPS	—	—	168	0	0	37	0	205
2006	1	USGS-NPS	—	—	0	0	0	xxx	0	xxx
2008	2	NPS	—	—	21	22	30	163	2	238
2009	1	NPS	—	—	10	10	11	18	3	52
2010	1	NPS	—	—	5	4	85	50	5	149
2012	1	NPS	—	—	16	8	14	12	2	52
2015	1	NPS	—	—	22	0	7	47	0	76
POND VISUAL ENCOUNTER SURVEYS										
1996–2001	6	USGS	—	—	0	0	0	0	0	0
2005	1	USGS-NPS	—	—	0	0	yyy	0	0	yyy
2006	1	USGS-NPS	—	—	0	0	0	zzz	0	zzz
2008	1	NPS	—	—	0	0	50	2800*	0	2850
2009	1	NPS	—	—	0	0	0	1000*	0	1000
2010	1	NPS	—	—	0	0	35	300*	0	335
2012	1	NPS	—	—	0	0	25	1500*	0	1525
2015	1 (pond dry)	NPS	—	—	—	—	—	—	—	—

[1] Stream-inhabiting species present in the Hidden Lake outlet; xxx = many uncounted tadpoles, juveniles, and adults observed around lake perimeter; yyy = many uncounted larvae observed in pond; zzz = many uncounted tadpoles observed in pond; * = estimate of tadpole abundance for entire pond.

representations of species presence and abundance over the duration of the study.

Assessment of Amphibian Apparent Abundances

We used the ΔN method to assess the temporal trends of apparent abundances of amphibian species observed in Hidden Lake for the period 1996 through 2015. This method was originally used by Houlahan and others (2000) and then by Green (2003) to measure changes in population size for a number of amphibian species, and has been shown to be a useful tool for estimating potential increases or declines in amphibian populations. A positive ΔN indicated population increase and a negative ΔN indicated population decline. The total number of individuals of each amphibian species observed during lake-snorkel surveys and VES combined (1996–2015) were used for this assessment (Table 1). The formulae used were: (1) $\Delta N = \log(N+1)_{t+1} - \log(N+1)_t$, for successive years; and (2) $\bar{\Delta}N = \Sigma^{t}_{to}\Delta N/n$, to measure mean temporal trend. $\bar{\Delta}N$ was calculated for individual amphibian species observed in Hidden Lake and for all species combined.

Results

Lake Snorkel Surveys

Only 1 amphibian species, *Ambystoma gracile* (Northwestern Salamander), was observed in Hidden Lake in 1996, 1998, and 2001, during 10 snorkel surveys completed when *S. fontinalis* were present in and being removed from the lake (1996–2001; Table 1). Seven larvae ($\bar{x} = 1.2$ per year, range = 0–4) were observed during this time period. All but 1 individual were present in the transect that was located along the northern talus-dominated shoreline of the lake (Fig. 1).

A total of 192 individuals comprising 3 amphibian species (*A. gracile, Ambystoma macrodactylum* [Long-toed Salamander], and *Rana cascadae* [Cascades Frog]) were observed in 9 snorkel surveys completed after all *S. fontinalis* had been removed from Hidden Lake (2004–2015; Table 1). Although the number of individuals of each species observed and their combined totals varied among years and transect type (see Table 1 caption), the mean total number of amphibians observed increased to 27.4 per year (range = 7–90) compared to the 1996–2001 mean ($\bar{x} = 1.2$ per year, range = 0–4). The primary species observed was *A. gracile* ($n =$ 156; larvae and gilled-adults), followed by a much lower number of *A. macrodactylum* larvae ($n = 19$) and *R. cascadae* ($n = 2$) tadpoles. Fifteen *Ambystoma* identified only to genus were also observed.

Lake Visual Encounter Surveys

During the period 1996–2001, when *S. fontinalis* were present in and being removed from Hidden Lake, a total of 6 *R. cascadae* adults were observed during VES conducted along the lake shoreline (Table 1). No other amphibian species were observed in VES completed during this period.

Additional VES of the Hidden Lake shoreline were completed in 2004, 2005, 2008, 2009, 2012, and 2015 (Table 1), after removal of all *S. fontinalis* from the lake. A total of 827 individuals comprising 4 amphibian species were observed during this time period. The results of a VES conducted in 2006 were not included in this total because the count recorded was a qualitative estimate of the total number of individuals observed; all individuals were *R. cascadae* tadpoles, juveniles, and adults observed around the lake perimeter. Total observations of individuals varied annually, ranging from 52 (2009, 2012) to 238 (2008), and the total number of individuals observed increased for *A. gracile* ($n = 242$; larvae, gilled-adults, terrestrial adults), *A. macrodactylum* ($n = 49$; larvae, adults), *Ambystoma* spp. ($n =$ 169; larvae), and *R. cascadae* ($n = 355$; tadpoles, juveniles, adults), compared to the much lower numbers of individuals of these species observed during VES completed when *S. fontinalis* were present in the lake. The 1st observations of the stream-dwelling species *Ascaphus truei* (Coastal Tailed Frog; $n = 12$ adults), present in the outlet stream of the lake, were also made in 2008, 2009, 2010, and 2012 (Table 1).

TABLE 2. Descriptive statistics for the number of individuals per amphibian species observed in Hidden Lake during the period of fish presence in and removal from the lake (Fish presence-removal, 1996–2001) and after complete fish removal (Fishless, 2004–2015). AMGR = *Ambystoma gracile;* AMMA = *Ambystoma macrodactylum;* AMSP = unidentified *Ambystoma* spp.; RACA = *Rana cascadae;* ASTR = *Ascaphus truei.*

Time period, Species	Total	$\bar{x}$	Range	Median
Fish presence-removal				
AMGR	7	1.2	0–4	0.5
AMMA	0	—	—	—
AMSP	0	—	—	—
RACA	6	1.0	0–3	0
ASTR	—	—	—	—
Fishless				
AMGR	398	44.2	4–175	17
AMMA	68	7.6	0–25	4
AMSP	184	20.4	0–85	14
RACA	357	39.7	0–163	29
ASTR	12	1.3	0–5	0

Assessment of Amphibian Apparent Abundances

Snorkel survey and VES counts combined by year showed that the annual apparent abundances of *A. gracile, A. macrodactylum, Ambystoma* spp., and *R. cascadae* in Hidden Lake were greater during the period of time after complete fish removal from the lake (2004–2015) than during the period of time when fish were present in the lake (1996–2001) (Fig. 2, Table 2). Results for the $\bar{\Delta}$N of amphibians observed in Hidden Lake during the entire period of fish presence-removal and eventual eradication from the lake (1996–2015) also showed a positive temporal trend in apparent abundances for 3 of the 4 species groups for which $\bar{\Delta}$N was calculated. The

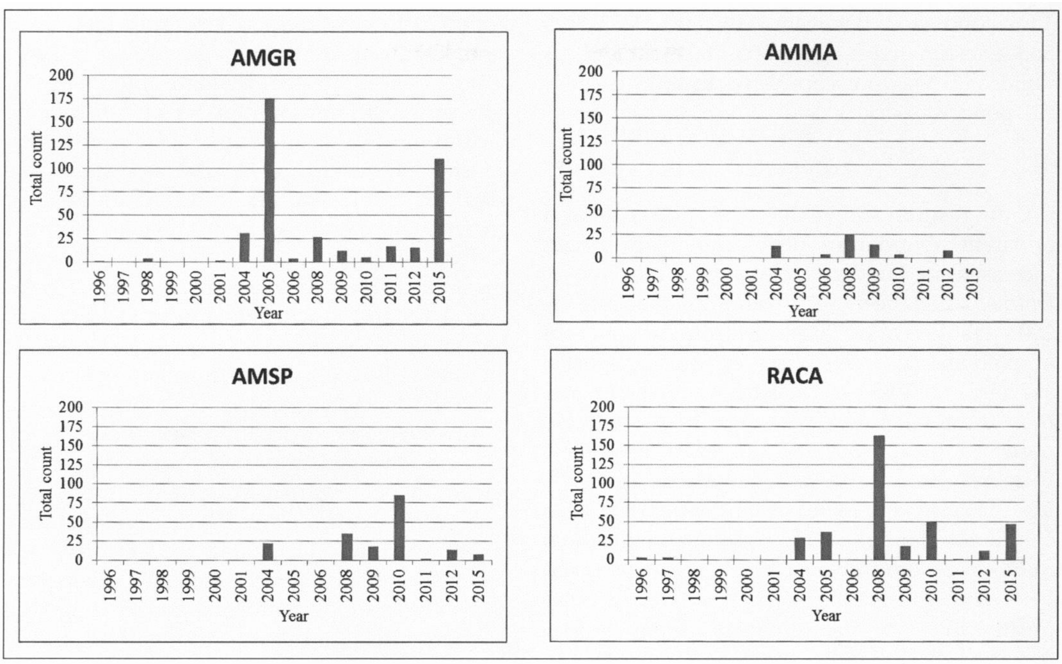

FIGURE 2. Annual total number (total count) of individuals of each amphibian species observed in Hidden Lake during snorkel and visual encounter surveys conducted 1996–2001 (period of fish presence and removal) and 2004–2015 (period after complete fish removal). AMGR = *Ambystoma gracile*; AMMA = *Ambystoma macrodactylum*; AMSP = unidentified *Ambystoma* spp.; RACA = *Rana cascadae*.

$\bar{\Delta}$N calculated for all amphibian species observed was 0.109; $\bar{\Delta}$N for *A. gracile* was 0.125 (similar to the $\bar{\Delta}$N [0.132] calculated by Hoffman and others (2004) for *A. gracile* larvae observed during day snorkel surveys in Harry Lake conducted 1996–2003); $\bar{\Delta}$N for *Ambystoma* spp. was 0.068; and $\bar{\Delta}$N for *R. cascadae* was 0.077. The $\bar{\Delta}$N for *A. macrodactylum* showed no trend ($\bar{\Delta}$N = 0.000).

The mean numbers of *A. gracile* (AMGR) and *R. cascadae* (RACA) observed in snorkel surveys and VES (combined) during the survey period after fish removal (AFR) from Hidden Lake were, for each species, 1 magnitude greater than the mean numbers observed for each species during the survey period before fish removal (BFR) (AMGR: $\bar{x}_{AFR} = 44.2 > \bar{x}_{BFR} = 1.2$, range: AFR = 4–175, BFR = 0–4; RACA: $\bar{x}_{AFR} = 39.7 > \bar{x}_{BFR} = 1.0$, range: AFR = 0–163, BFR = 0–3) (Table 2). Although there was no magnitude difference in the mean number of *A. macrodactylum* observed during the survey periods before and after fish removal, no *A. macrodactylum* were observed in Hidden Lake before fish removal (1996–2001; Fig. 2), whereas the mean number of *A. macrodactylum* observed after fish removal was $\bar{x} =$ 7.6 per year, with a range of 0 to 25 per year (Table 2).

Pond Visual Encounter Surveys

No amphibians were observed in the pond adjacent to Hidden Lake (Fig. 1) during VES conducted between 1996 and 2001 (Table 1). During this period of time *S. fontinalis* were occasionally observed in the pond just after snowmelt (late June, early July) when the lake water-level was high and the pond and lake were connected by an approximately 3- to 6-m water-filled channel (RLH, pers. obs.).

The pond was re-examined for amphibians in 2005, 2006, 2008, 2009, 2010, and 2012 (Table 1). In 2005, many uncounted *Ambystoma* spp. larvae were observed in the pond, as were many uncounted *R. cascadae* tadpoles in 2006, and the total counted number of *Ambystoma* spp. larvae observed in the pond in 2008, 2010, and 2012 was 110. No *Ambystoma* spp. larvae were observed in 2006 and 2009. The estimated total number of *R. cascadae* tadpoles observed during

VES conducted between 2008 and 2012 was 5600+ (estimated range = 300–2800, Table 1). A pond VES was not completed in 2015 because the pond was dry.

Discussion

Our results show that the presence and apparent abundances of 4 amphibian species increased in Hidden Lake after all of the *S. fontinalis* had been removed from the lake by 2003 (Table 1). In 2004, the total number of amphibians (n = 95) observed during snorkel surveys and VES was just over 7 times greater than the total number of amphibians (n = 13) observed in all surveys completed when fish were present in and being removed from the lake. This trend of increased amphibian presence continued through 2015, resulting in the total number of amphibians (n = 1019) observed between 2004 and 2015 being just over 78 times greater than the total number of amphibians observed in the lake prior to complete fish removal. The $\bar{A}$Ns calculated for snorkel surveys and VES combined during the entire period of surveys (1996–2015) further indicated a positive, increasing trend in the apparent abundances of amphibians, especially *A. gracile* and *R. cascadae*, in the lake. The total number of amphibians observed in the pond adjacent to Hidden Lake during VES also increased substantially after fish removal from the lake, from zero pre-removal to an estimated 5600+ post-removal (Table 1).

Several studies have shown that amphibian species can recover in lakes from which introduced nonnative fish have been removed or have gone extinct. Funk and Dunlap (1999) surveyed high-elevation lakes in the northern Bitterroot Mountains of Montana that had been stocked with trout (species not identified). They found that *A. macrodactylum* were able to successfully recolonize 6 lakes from which they had been extirpated, which had previously contained trout that had subsequently gone extinct. Vredenburg (2004) and Knapp and others (2007) examined the recovery of *Rana muscosa* (Mountain Yellow-legged Frog) in several fish-removal lakes in the Sierra Nevada, California. After fish removal (including *Oncorhynchus mykiss* [Rainbow Trout], *Oncorhynchus* hybrids, *Salmo trutta* [Brown Trout], and *S. fontinalis*), *R. muscosa* densities increased and the populations rapidly recovered in the lakes. Pope (2008) conducted a 4-y study that examined, in part, the recovery of *R. cascadae* in 3 fish-removal lakes in the Klamath Mountains of northern California. Within 3 y of fish removal (including *O. mykiss* and *S. fontinalis*), frog density increased dramatically, as did the survival of young adults, realized population growth, and recruitment rates. Finally, Hoffman and others (2004) studied the responses of *A. gracile* in a MORA lake approximately 0.5 km from Hidden Lake that had been stocked with nonnative *S. fontinalis*. They found that the number of larvae, gilled adults, and egg masses observed in the lake increased concurrent with fish removal and extirpation, and that *A. gracile* behavior changed from being primarily nocturnal and habitat-restricted during fish presence to being more active during the day and distributed more widely throughout the lake after fish removal. Because the present study was conducted over a longer time period (20 y) than the previous cited studies, the Hidden Lake results contribute to our understanding that the positive responses of amphibian species to fish removal from lakes appear to be sustained through time. However, the present study, because it had no control, is only a case study whose results can only be interpreted and extrapolated with minimal statistical inference.

The results of this study and those of Larson and Hoffman (2002, 2004), Hoffman and others (2004), and Pope and others (2014) also clearly support the inference that stocking salmonids into naturally fishless lakes, as in MORA, can have dramatic negative effects on the diversity and abundances of native amphibian taxa, which are the native top-vertebrate aquatic predators in many park lakes. These effects could be substantial at the landscape level. At MORA, for example, 44 of 107 known lakes deep enough to support reproducing salmonid populations (>2-m maximum depth; Larson and Hoffman 2002) were stocked years ago, and 31 of these lakes appear to retain reproducing populations of salmonids (MORA, unpubl. data). These deeper lakes are the systems that are typically inhabited by *A. gracile* (Hoffman and others 2003, 2004, 2012; Larson and Hoffman 2002, 2004) and *R. cascadae* (Pope 2008; Pope and others 2014). *Ambystoma macrodactylum* also inhabit some of these deeper MORA lakes (Larson and Hoffman 2002, 2004; Hoffman and others 2003), but this salamander species is predominately associated with shallower ponds (0.7-m median depth; Hoffman and others 2003) that do not support populations of reproducing introduced fish or *A. gracile* that prey upon *A. macrodactylum* larvae (Hoffman and Larson 1999; Larson and Hoffman 2002, 2004). *Ascaphus truei* were also observed during VES of the Hidden Lake outlet stream. This stream-adapted anuran species is endemic to the Pacific Northwest and is considered relatively common and widespread, but in Washington State it is also a taxon of long-term concern and a Forests and Fish Agreement target species (Hallock and McAllister 2005). Feminella and Hawkins (1994) found in laboratory experiments that *A. truei* tadpole activity was reduced when fish (*Onchorhynchus clarki* [Cutthroat Trout] and *S. fontinalis*) presence was detected, and that *O. clarki* did consume *A. truei* tadpoles. Based on these experiments and the fact that *A. truei* were not observed in the Hidden Lake outlet during fish (*S. fontinalis*) presence in the lake, this frog species was likely negatively affected (extirpated) by the presence of fish. Relative to the natural history of these 4 amphibian species, however, *A. gracile* and *R. cascadae* would be the amphibians most likely affected in MORA lakes inhabited by introduced salmonid populations, and the species that benefitted the most from the removal of introduced nonnative fish.

The negative effects of fish on amphibian species is only one aspect of a number of potential causes contributing to the decline of amphibians in the western United States, as well as worldwide. These causes include habitat fragmentation and loss, environmental pollutants, climate change, and an emerging infectious disease chytridiomycosis (Wake and Vredenburg 2008; Hayes and others 2010). The presence of fish in montane lakes and their negative effects on lake-inhabiting amphibian species, however, has a relatively straight-forward solution. The results of our study are another indication that amphibian species are positively affected by the removal of introduced nonnative fish from mountain lakes, and that this positive outcome can be sustained through time, resulting in the restoration of mountain lakes to their original (in most cases) fishless condition.

ACKNOWLEDGMENTS

We thank the personnel of numerous field crews for their support and dedication to the project. We also thank Nicholas A Hager for preparing Figure 1, Marty Fitzpatrick (USGS FRESC) for his helpful comments and suggestions on a previous version of this manuscript, and Karen Pope and 1 anonymous reviewer for providing comments and suggestions that helped improve the quality and content of the manuscript. This study was funded by the USGS Forest and Rangeland Ecosystem Science Center and the National Park Service, and was conducted under the auspices of NPS permits and all applicable Institutional Animal Care and Use Committee guidelines, ACUP # 2763. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the US Government.

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Submitted 31 May 2016, accepted 23 May 2017. Corresponding Editor: Joan Hagar.