Fish and Aquatic Habitat Surveys at Sheldon-Hart Mountain National Wildlife Refuge Complex

Project Report

Prepared by:
Sam Lohr, J. Michael Hudson, Marci Koski, Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
1211 S.E. Cardinal Court, Suite 100
Vancouver, Washington 98683

June 2012

Introduction

The Sheldon-Hart Mountain National Wildlife Refuge Complex consists of Sheldon National Wildlife Refuge (575,000 acres) primarily located in northwest Nevada and Hart Mountain National Antelope Refuge (278,000 acres), which is located about 32 km north of Sheldon National Wildlife Refuge (NWR) in southeast Oregon (Figure 1). Sagebrush-steppe grasslands typical of the Great Basin are the dominant habitats at the refuges, and aquatic habitats consisting of springs, streams, playas, and reservoirs are present. Both refuges were originally established in the 1930s for the purpose of conserving and protecting pronghorn (*Antilocapra americana*) (U.S. Fish and Wildlife Service (USFWS) 1994a, 2011). Today, the refuges also are managed for the purposes of conserving native fish and wildlife characteristic of the Great Basin ecosystem and to provide visitors with compatible recreational and interpretive activities increasing their understanding and appreciation of natural and cultural resources at the refuges (USFWS 1994a, 2011). Achieving conservation purposes primarily relies on the protection, maintenance, and restoration of native habitats and communities.

To help achieve refuge purposes, long-range guidance (15 years), including desired natural resource conditions, management strategies, adaptive management approaches, and research, is described in comprehensive conservation plans (CCPs) and comprehensive management plans (CMPs) developed for individual refuges. Sheldon NWR is nearing completion of a CCP and released a draft for public review in fall 2011 (USFWS 2011). Relative to fish and aquatic habitats, the draft CCP contains objectives to develop a step-down management plan (i.e., detailed plan describing specific strategies and implementation schedules followed to "step down" from general goals and objectives identified in a CCP) for coldwater fisheries and initiate restoration of the Virgin Creek watershed. Implementation of the

restoration is contingent on removal of feral horses and burros. In addition, a strategy for conserving native trout, a priority species identified in the CCP, is to evaluate their requirements and potential for restoration. Hart Mountain National Antelope Refuge (NAR) completed a CMP in 1994 (USFWS 1994a). In an effort to reduce damage in riparian areas and streams, the NAR implemented management that eliminated cattle grazing (USFWS 1994b). Hart Mountain NAR is scheduled to begin developing a CCP in the near future.

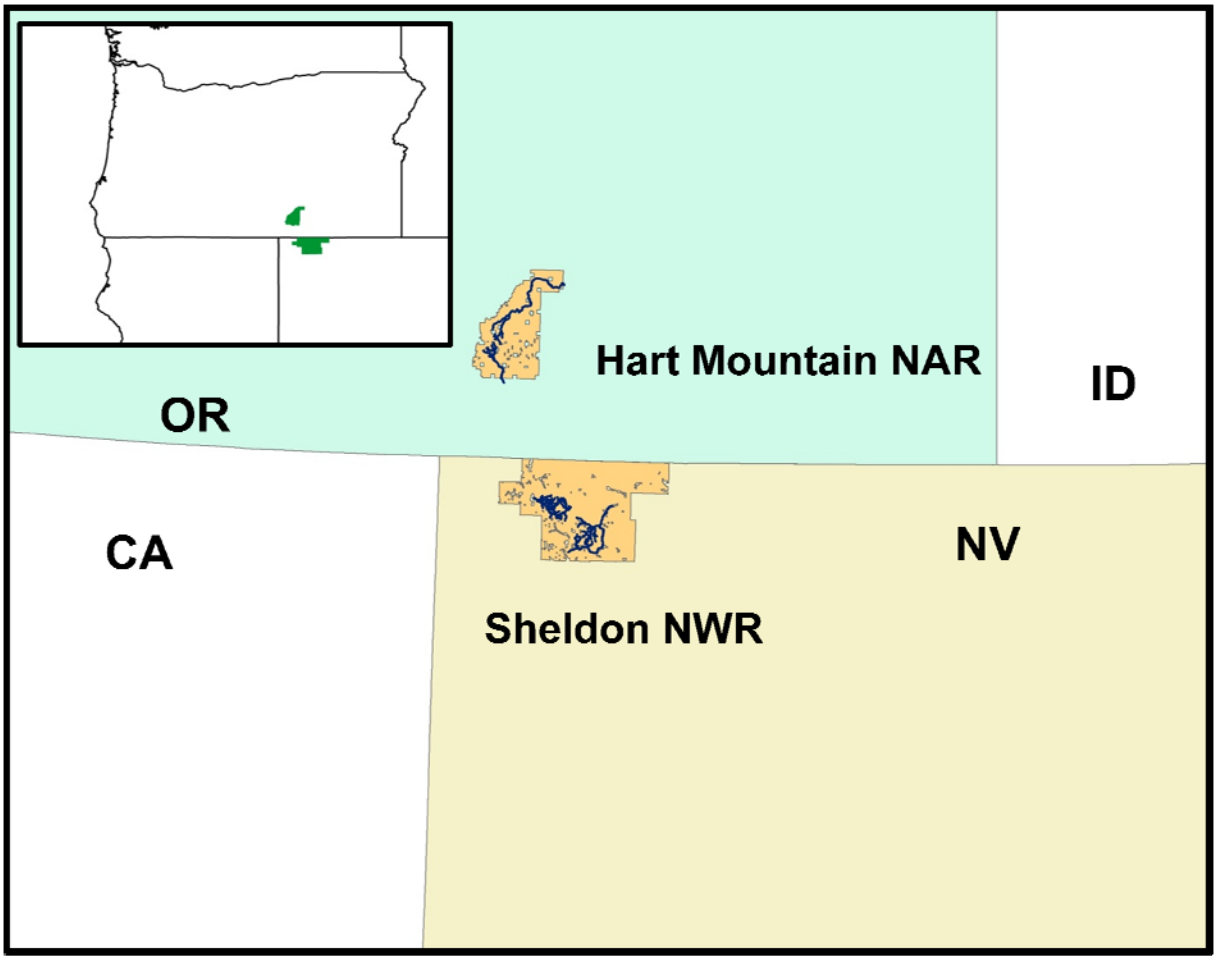

Figure 1. Locations of Sheldon National Wildlife Refuge and Hart Mountain National Antelope Refuge.

In anticipation of the need for information to assist in developing, finalizing, and implementing CCPs, as well as assessing management strategies, baseline fish inventory and aquatic habitat assessment information were identified as primary needs for the Sheldon-Hart

Mountain NWR Complex (USFWS 2005). Previously, refuge-wide fish surveys were conducted at Sheldon NWR during the 1970s (Williams et al. 1980) and surveys at Hart Mountain NAR conducted in the early 1990s (noted in USFWS 1994a). However, recent refuge-wide information on fish distribution and aquatic habitat was unavailable. Such information is necessary to establish and augment a baseline by which to evaluate future management (e.g., potential effects of removing feral horses and burros on aquatic habitats that support native fishes at Sheldon NWR).

Furthermore, the National Wildlife Refuge System developed an Inventory and Monitoring Program (I&M Program) with the purpose to collect, synthesize, and manage information to support resource management at various spatial scales (USFWS 2010a, b). This information is ultimately intended to assist in planning and evaluating the effectiveness of conservation strategies carried out by the USFWS and its partners. Given the potential effects and uncertainties of climate change and other environmental stressors on natural resources, the value of information generated or managed by the I&M Program is anticipated to be critical for detecting potential effects of climate change on natural resources at refuges and informing the development and implementation of appropriate conservation strategies. Eight refuge system-wide priorities (i.e., addressing inventories of abiotic resources and physical features, baseline inventories of biota, status and trends of priority species, disturbance regimes, quality and quantity of water resources, invasive species, supporting adaptive management, and assessing vulnerability to climate change) were identified by the I&M Program. Baseline inventories of biota and inventories of abiotic resources and physical features are priorities that comport with the need for fish surveys and aquatic habitat assessment at the Sheldon-Hart Mountain NWR Complex.

To address the need for baseline inventories of biota and abiotic features, the Columbia River Fisheries Program Office (CRFPO) conducted fish and aquatic habitat surveys at the Sheldon-Hart Mountain NWR Complex. The goal was to establish a baseline of fish community and habitat information for the watersheds of the primary streams supporting native fish at each refuge. The objectives were to document which fish species were present, determine the watersheds that were occupied by these species, to describe the distribution of these fish within various watersheds, and characterize aquatic habitat. In addition, a final objective was to establish and use a systematic, quantitatively rigorous, sample framework and approach that can standardize future assessments of changes in fish occupancy, fish distribution, and aquatic habitats.

Methods

We surveyed the Virgin Creek and Fish Creek watersheds at Sheldon NWR, as well as the Guano Creek and Rock Creek watersheds at Hart Mountain NAR. To guide surveys in these watersheds, we developed a sample framework and identified three tiers (upper, middle, and lower) in the watersheds and sample reaches within each tier. The survey protocol consisted of two primary activities: surveying for fish at reaches where conditions were conducive to electrofishing; and characterizing habitat attributes at sample reaches.

Study Areas

The area of the Virgin Creek watershed included in the sampling framework ranged from Pond 13, considered river km (RK) 0, upstream to RK 43.6 in Virgin Creek (Figure 2). This area was divided into three tiers. The lower tier was 11.6 km long and extended up the mainstem of Virgin Creek to the confluence of Hell Creek. The middle tier consisted of the Hell Creek drainage and extended 12.7 km upstream to the head of Hell Creek. The middle tier included

South Hell Creek and two drainages entering Hell Creek from the south, one with Willow and Elder springs and the other with Martinez, Cherry, and Porcupine springs. The upper tier began at the Hell Creek confluence (RK 11.6) and extended 32.0 km upstream in Virgin Creek. The upper tier included two drainages entering Virgin Creek from the north, one included Box Canyon and Rimrock Spring, and the other included little Buckaroo Spring.

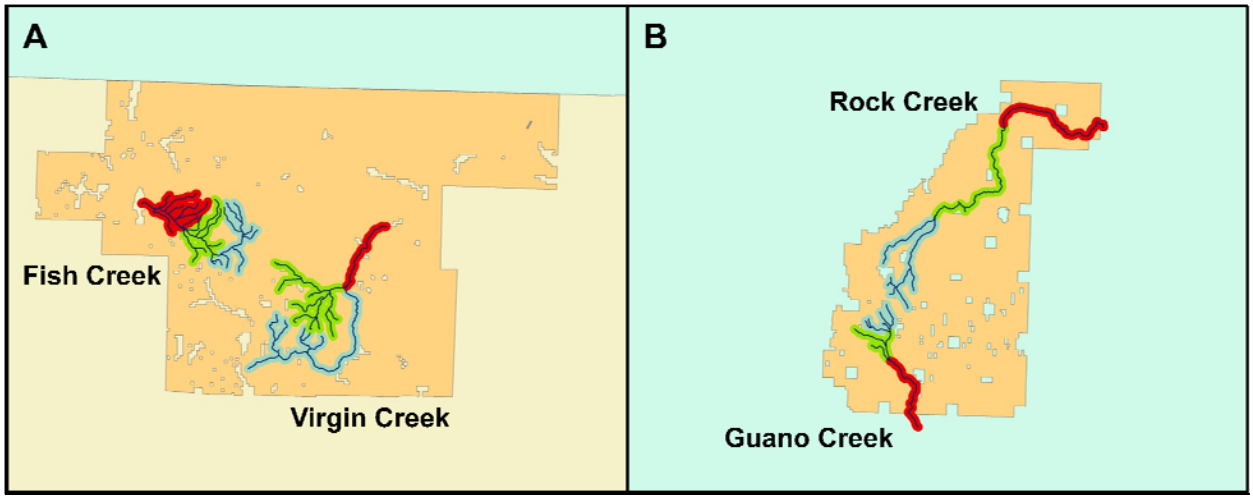

Figure 2. Locations of lower (red), middle (green), and upper (blue) tiers of the sampling areas in the Virgin Creek and Fish Creek watersheds at Sheldon NWR (panel A) and Guano Creek and Rock Creek watersheds at Hart Mountain NAR (panel B).

The area of the Fish Creek watershed ranged from Swan Lake Reservoir, considered RK 0, upstream to RK 23.8 above Horse Canyon (Figure 2). This area was divided into three tiers. The lower tier was 5.7 km long and extended up the mainstem of Fish Creek to below the confluence of the tributary that includes Murdock Spring. One tributary from the south and five from the north enter the lower tier. The middle tier began at the confluence of the tributary that includes Murdock Spring, and extended 6.7 km upstream, ending at the fork leading to Fish Springs to the south and Horse Canyon to the North. One tributary from the south and five from the north enter the middle tier. The upper tier began at the Fish Springs tributary-Horse Canyon fork (RK 12.4) and extended 11.3 km upstream to the farthest point in the stream above Horse

Canyon. Two tributaries enter the tier from the north and five from the south, including the Fish Springs tributary.

The area of the Guano Creek watershed ranged from Jacobs Reservoir, considered RK 0, upstream to RK 22.7 above Post Meadows (Figure 2). This area was divided into three tiers. The lower tier was 13.2 km long and extended up the mainstem of Guano Creek to the confluence of the unnamed tributary entering from the west. The middle tier began at the confluence of the tributary and extended 4.8 km upstream to the confluence with Stockade Creek. This tier included an unnamed tributary and Goat Creek. The upper tier began at the Stockade Creek confluence (RK 18.0) and extended 4.7 km upstream. The upper tier included Stockade Creek and two tributaries that entered Guano Creek from the west.

The area of the Rock Creek watershed ranged from Rock Creek Reservoir, considered RK 0, upstream to RK 60.5 in the headwaters of Rock Creek (Figure 2). This area was divided into three tiers. The lower tier was 21.1 km long and extended up the mainstem of Rock Creek. The middle tier began at RK 21.1 and extended 24.3 km upstream to the confluence with Willow Creek. A short portion of Rattlesnake Draw, a tributary entering Rock Creek from the south, was included in the middle tier. The upper tier began at the Willow Creek confluence (RK 45.4) and extended 15.1 km upstream. The upper tier included Willow Creek and three unnamed tributaries to upper Rock Creek.

Developing a Sample Framework and Identifying Sample Reaches

To define the sample framework and identify potential sample reaches, geospatial data for each of the four watersheds (e.g., stream layers acquired from the National Hydrography Dataset—http://nhd.usgs.gov) were assembled in a geographic information system (ArcGIS). Watersheds for each of the four streams originate within the NWR Complex and these upper

reaches represent the most suitable habitat for native fish. Artificial water impoundments (i.e., Pond 13 for Virgin Creek, Swan Lake Reservoir for Fish Creek, Jacobs Reservoir for Guano Creek, and Rock Creek Reservoir for Rock Creek) were used to delineate the lowermost extent of the sample area in each watershed. These impoundments and areas downstream represent habitat that is relatively unsuitable for native salmonids. To evaluate distribution, these sample areas (Figure 2) were divided into tiers (upper, middle, or lower), based on stream order (Strahler 1957), linear stream distance and relative location in the watershed.

Potential sample sites (i.e., a point associated with a 50-m stream reach) were identified using a random, spatially-balanced design (Generalized Random-Tesselation Stratified (GRTS) design; Stevens and Olsen 2004) in which sample site density was one site per 500 m of stream on average. This design resulted in an ordered list of randomly-selected sites that were spatially balanced throughout each watershed and within each tier of each of the four watersheds. The first 25-35 ordered sites were evaluated as potential sample sites for the survey (Appendix A). Coordinates (Universal Transverse Mercator) and order number of each potential sample site were uploaded to a geographical positioning system receiver (GPS, Garmin GPSmap 76Sx), and also were identified and displayed on field maps. Approaches developed to monitor bull trout (e.g., USFWS 2008; Hudson et al. 2010) have found that, given typical detection probabilities, surveying approximately seven sample reaches (as determined above) within a given area likely provide acceptable estimates of whether fish occupy that area. For example, assuming a (conservative) detection probability of 0.18 (see USFWS 2008), we would be 80% confident that an area is unoccupied if no fish are collected within any one of the seven sample reaches. Posterior estimates of detection probability are often higher than 0.18 (see Hudson et al. 2010), resulting in > 80% confidence that an area is unoccupied when fish are not detected. Therefore,

we assumed that sampling seven reaches per watershed tier in this study would provide an adequate level of confidence (≥80%) for assessing whether fish occupy that tier. Thus, our sampling targeted the first seven ordered, viable sites in each of the three tiers of the watersheds. Once seven viable sites were sampled, additional sites in a tier were not evaluated. A site was considered viable when the reach was conducive to sampling with a backpack electrofisher (i.e., a continuous 50-m reach with the ability to wade most areas, probe both banks from near the mid-channel, and unobstructed by dense vegetation or excessively shallow water).

Surveying for Fish

Between 3 August and 17 September 2011, a two-person crew located sites using a GPS receiver and field maps. For sites determined conducive to electrofishing (i.e. viable), a 50-m reach encompassing the site was measured with a tape along one bank. Water temperature and conductivity were recorded and sampling was conducted to collect fish using a Smith-Root LR24 backpack electrofisher. The crew made a single electrofishing pass starting at the downstream end of the reach and without installing block nets at either end of the reach. One crew member operated the electrofisher while the other netted fish and placed them in a bucket of water. Electrofisher settings were varied depending on conditions (e.g., water depth, temperature, conductivity) and fish response. Electrofishing duration and settings were recorded. For occasions when fish were observed but not collected at a reach, the number of fish observed was noted.

After reaching the upstream end of a sample reach, the crew placed fish in a bucket of aerated water and immediately processed them. All fish were anesthetized using MS-222. Species and fork length (FL, mm) were recorded. Because non-native rainbow trout (*Oncorhynchus mykiss*) historically have been planted in Virgin, Guano, and Rock creeks

(Williams et al. 1980; Behnke 1992; Oregon Department of Fish and Wildlife (ODFW) 2005) and Lahontan cutthroat trout (*O. clarki henshawi*) have been planted in Guano Creek (Behnke 1992, 2007; ODFW 2005), we assumed hybrids were present and considered all salmonids "trout" (i.e. *Oncorhynchus* spp.). Hybridization between trout species can add error to identification. Thus, to definitively assess species composition, a small amount of tissue was removed from the lower caudal fin on a haphazardly-selected subsample of trout (FL > 60 mm) and preserved in vials of 100% ethanol for genetic analysis in the future. Efforts were made to represent each tier within a watershed with tissue samples from at least 30 individuals, with no more than 10 individuals sampled from a single reach. After processing, fish were placed in a recovery bucket of aerated water. After recovery from anesthesia, fish were released within the sample reach from which they were captured. The actual, site-specific detection probability (SSDP) of a species for each watershed was calculated as the proportion of reaches electrofished where a fish from a given species was collected (i.e. if 22 reaches were sampled and trout were captured in 6 of those reaches, the SSDP for this species in this watershed was 0.27).

Due to time constraints, we were unable to survey Rock Creek. However, two areas of Willow Creek, a tributary to the upper tier of Rock Creek, were spot-sampled at the request of Hart Mountain NAR to qualitatively assess the presence of trout. Spot-sampling consisted of haphazardly electrofishing along stream segments upstream and downstream of a canyon area.

Characterizing Habitat

Six transects were established at 10-m intervals along the length of each reach sampled to characterize habitat. Measurements recorded at each transect included wetted width, bank full width, water depths (quarter-width points and maximum depth), and width of overhead cover (i.e., undercut banks, vegetation, or rocks within 0.5 m of water surface that could conceal a fish

from above, or pool/run depths >45 cm). Between each transect, the condition of and dominant vegetation on each bank was visually estimated (i.e., length of banks considered unstable, bare, undercut, and dominated by grass/forb, brush, and shrub/tree). Substrate composition (percent fines (i.e., sand/sediment < 2 mm diameter), gravel (2-32 mm), cobble (32-256 mm), boulder (> 256 mm), and bed rock) and lengths for each habitat type (i.e., riffle, pool, and run) also were visually estimated between transects. Stream shading was estimated at three points of each site (both ends and midpoint) using a densitometer. Gradient was recorded for the greatest distance with clear line of sight for each sample site using a clinometer. Large woody debris (>10-cm diameter, root wads) within the channel or 1 m of the surface were summed for each reach. One to several pictures of each reach were taken with a digital camera.

Results

Virgin Creek

We evaluated 21, 34, and 35 reaches in the lower, middle, and upper tiers, respectively, in the Virgin Creek watershed (Appendix A). Seven reaches were sampled for fish in each the lower and middle tiers, whereas two reaches were sampled in the upper tier (Figure 3). Among the lower, middle, and upper tiers, a total of 6, 17, and 32 reaches, respectively, were found to be dry, and hence fish were absent.

Trout and Alvord chub (*Gila alvordensis*) occupied the Virgin Creek watershed, and were only distributed in the lower tier. Fish were collected at six reaches in the lower tier of Virgin Creek (Figure 3). Trout (Figure 4) were collected at five reaches (reaches 1, 5, 8, 11, and 20; Appendix B); Alvord chub were collected at two reaches (reaches 8 and 12); and no fish were collected at one reach (reach 2). No fish were collected at the seven reaches surveyed in the middle tier or the two reaches surveyed in the upper tier. Site-specific detection probability

for trout was 0.31 for the Virgin Creek watershed (trout were found at 5 of 16 reaches). Thus, our post hoc certainty that trout did not occupy the middle and upper tiers was 93% and 68%, respectively. Site-specific detection probability for Alvord chub was 0.13 for the watershed (chub found at 2 of 16 reaches). Thus, our post hoc certainty that chub did not occupy the middle and upper tiers was 72% and 57%, respectively. For trout, a total of 65 individuals were collected. The range in fork length of trout (37-283 mm) indicated the presence of multiple age classes (Figure 5). Tissue samples were collected from a total of 38 trout (Table 1). For Alvord chub, a total of 18 individuals were collected. The range in fork length of Alvord chub indicated the likely presence of juvenile and adult individuals (Figure 6). Mean time electrofishing at all reaches in Virgin Creek was 127 seconds per reach (range 85-231 seconds; Appendix B).

Aquatic habitat at reaches consisted of both slow- (i.e., pool, 45.4%) and fast-water (i.e., riffle and run, 54.5%) habitats in the lower tier (Table 2). Reaches in the middle and upper tiers consisted almost entirely (≥88%) of fast-water habitat. Fines were the dominant substrate in all tiers, and shrub/tree or brush was the dominant bank vegetation. Ranges in water temperature and conductivity were 11.0-21.7°C and 76-200µS, respectively, among all reaches (Appendix B). Signs of horse use were apparent on stream banks at two reaches, one in the middle tier and the other in the upper tier (Appendices C and D). Signs of beaver activity were apparent at two sites in the lower reach.

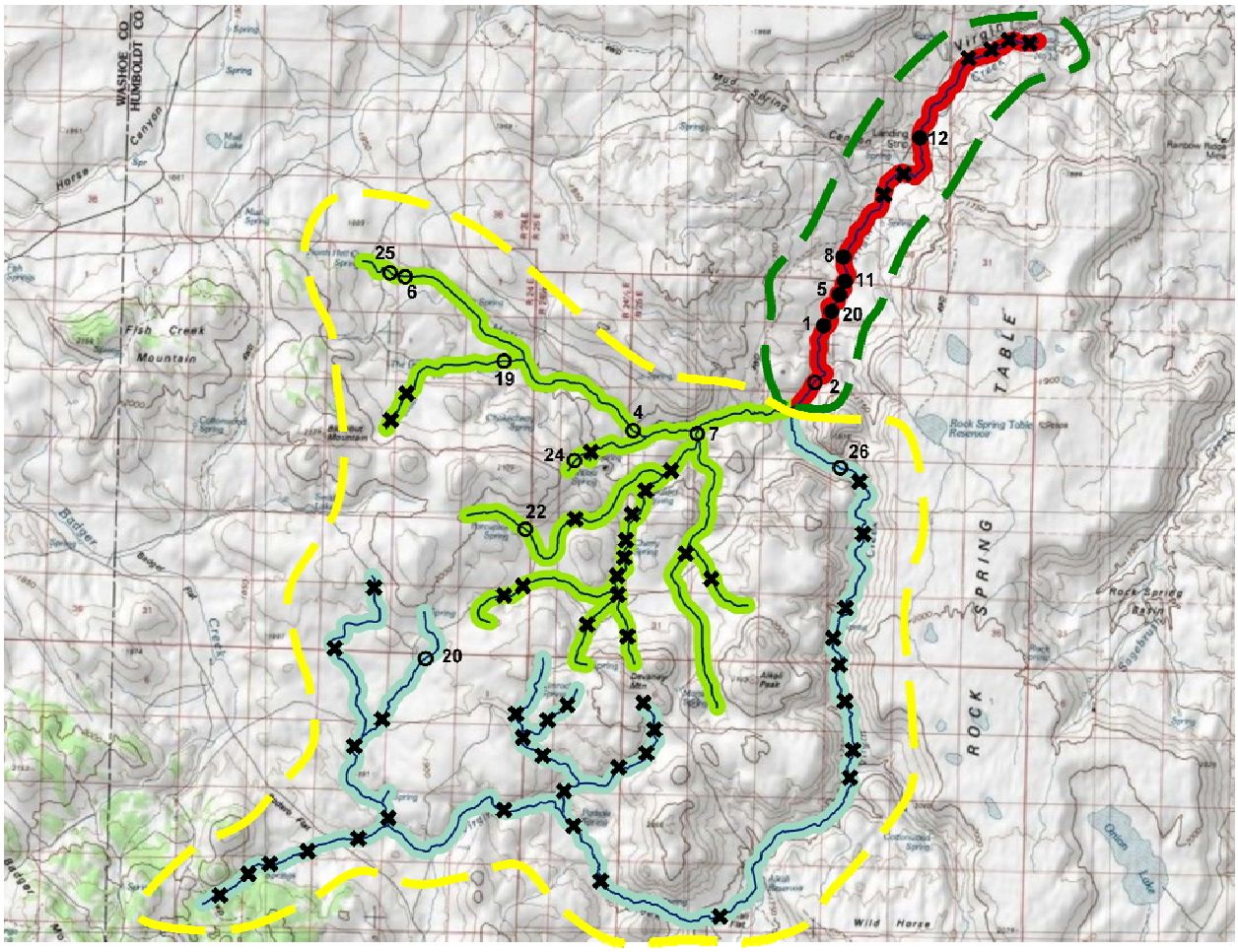

Figure 3. Sample reaches in the lower (red), middle (green), and upper (blue) tiers of the Virgin Creek watershed. Circles indicate reaches sampled (closed—fish collected, open—no fish collected) and associated reach number. Crosses indicate dry reaches that were assessed in an attempt to obtain seven viable reaches. Dashed lines enclose watershed tiers found to be occupied (green) or not occupied (yellow) by fish.

Figure 4. Trout (left) and Alvord chub (right) collected in the lower tier of the Virgin Creek watershed.

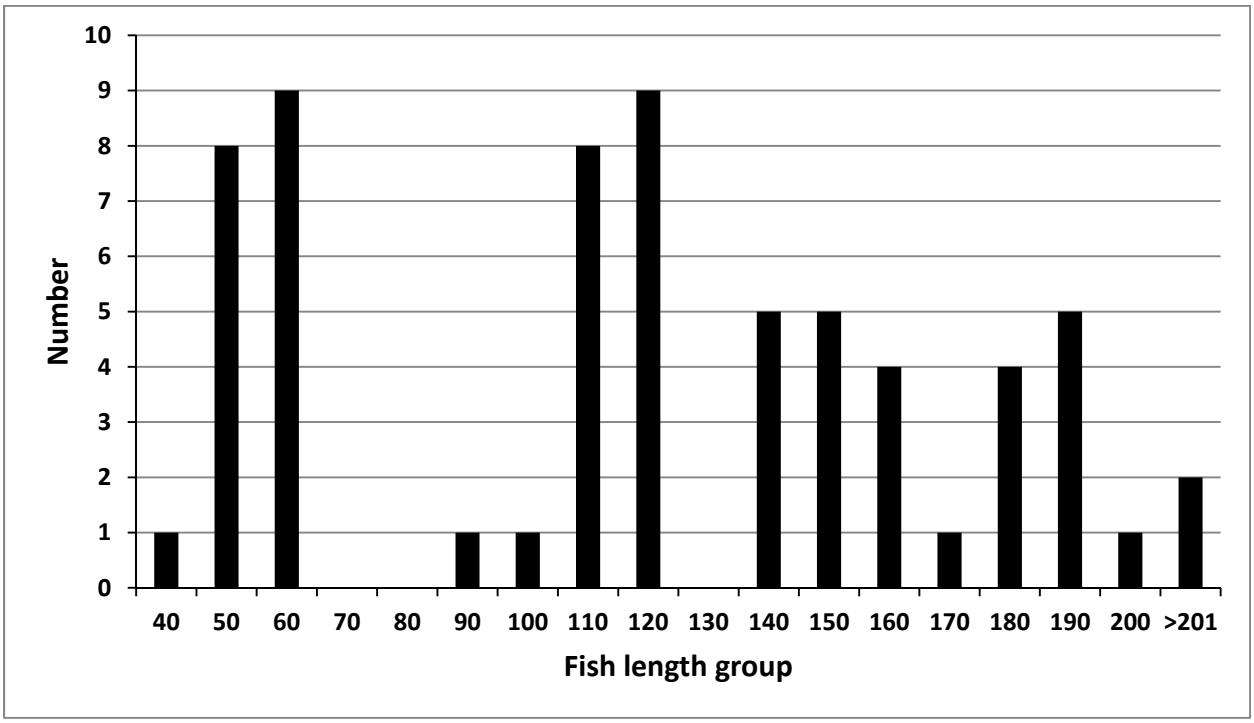

Figure 5. Number of individuals by 10-mm length group (maximum FL of each group presented except for individuals > 201 mm) for 65 trout collected in the lower tier of the Virgin Creek watershed.

Table 1. Reaches, fish species, number of individuals collected, fork length, and number of tissue samples collected from trout in various tiers, by watershed.

Tier	Reaches		Occupied reaches		Total number individuals (mean, range per reach)	Mean fork length (range, mm)	Number tissue samples
	Sampled	Unoccupied	Number of reaches	Species			
			Virgin Creek				
Lower	7	1	5	Trout	65 (13, 7-24)	115 (37-283)	38
			2	Alvord chub	18 (9, 7-11)	74 (54-104)	0
Middle	7	7	0	---	---	---	---
Upper	2	2	0	---	---	---	---
			Fish Creek				
Lower	2	0	2	Sheldon tui chub	111 (56, 47-64)	40 (21-119)	0
Middle	4	1	3	Sheldon tui chub	63 (21, 3-54)	41 (19-107)	0
Upper	0	---	---	---	---	---	---
			Guano Creek				
Lower	7	5	2	Trout	27 (14, 11-16)	163 (61-311)	18
Middle	6	0	6	Trout	61 (10, 2-25)	124 (51-284)	37
Upper	7	5[1]	2	Trout	13 (7, 2-11)	154 (74-255)	10
			Rock Creek[2]				
Willow Creek	---	---	---	Trout	11	144 (61-204)	0

[1] Fish were observed but not collected at two reaches.
[2] Spot sampling only (i.e., haphazardly sampling along a stream segment).

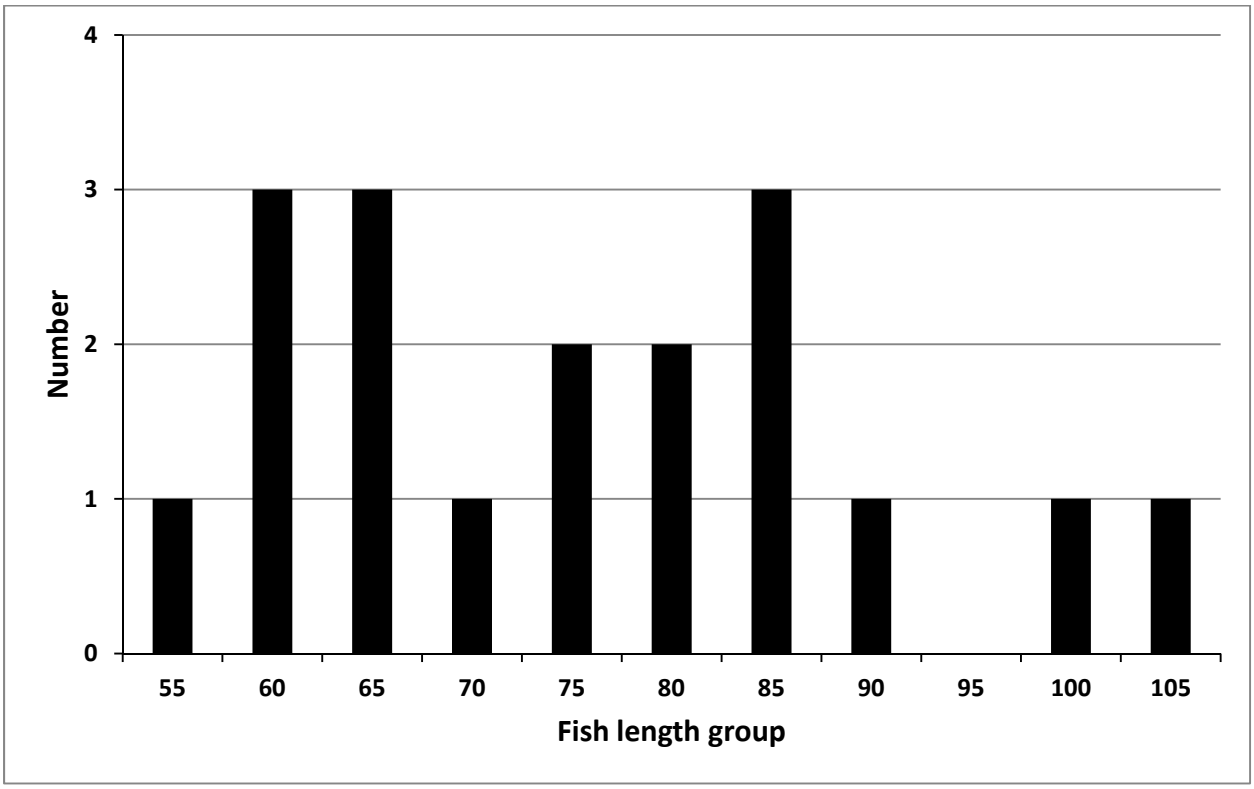

Figure 6. Number of individuals by 5-mm length group (maximum FL of each group presented) for 18 Alvord chub collected in the lower tier of the Virgin Creek watershed.

Fish Creek

We evaluated 35 reaches in each the lower, middle, and upper tiers in the Fish Creek watershed (Appendix A). Two, four, and zero reaches were sampled for fish in the lower, middle, and upper tiers, respectively (Figure 7). Among the lower, middle, and upper tiers, a total of 32, 31, and 34 reaches, respectively, were found to be dry, and hence fish were absent.

Table 2. Aquatic and riparian habitat variables summarized by lower, middle, and upper tiers in the Virgin Creek, Fish Creek, and Guano Creek watersheds at the Sheldon-Hart Mountain National Wildlife Refuge Complex, 2011. Note that water temperature and conductivity are presented in Appendix B.

Tier (no. reaches)	Stream width			Stream depth (m)		Stream bank (%)		Habitat type (%)			Dominant substrate[2] (mean %; range)	Shade (mean %; range)
	Mean wetted (m, range)	Bankfull (m, range)	Overhead cover (%, range)	Mean (range)	Mean max. (range)	Dom. veg.[1] (mean, range)	Bare (mean, range)	Pool (mean, range)	Riffle (mean, range)	Run (mean, range)		
Virgin Creek												
Lower (7)	2.53 (1.6-3.2)	9.71 (4.7-29.6)	51.7 (10.0-94.7)	0.32 (0.15-0.45)	0.64[1] (0.36-0.82)	SH-32.7 (0-94)	17.6 (0-55)	45.4 (4-90)	23.4 (0-48)	31.1 (0-86)	FI-48.4 (18-88)	83.5 (58-97)
Middle (7)	1.91 (1.3-3.0)	9.85 (3.3-38.3)	92.2 (79.2-100)	0.09 (0.03-0.15)	0.22 (0.12-0.34)	BR-51.4 (0-86)	3.1 (0-10)	0.3 (0-2)	99.7 (98-100)	0	FI-98.0 (90-100)	60.9 (58-72)
Upper (2)	2.64 (2.5-2.8)	6.41 (5.7-7.1)	90.5 (89.3-91.6)	0.11 (0.08-0.14)	0.29 (0.25-0.32)	BR-49.0 (18-80)	2.5 (0-5)	12.0 (6-18)	47.0 (0-94)	41.0 (0-82)	FI-75.0 (58-92)	62.2 (58-66)
Fish Creek												
Lower (2)	2.96 (2.7-3.2)	8.17 (7.6-8.7)	7.8 (3.5-12.0)	0.34 (0.32-0.35)	0.60 (0.60)	GR-48.5 (35-62)	5.0 (1-9)	75.0 (60-90)	8.0 (0-16)	17.0 (10-24)	FI-49.0 (48-50)	58.0 (58)
Middle (4)	4.11 (1.2-7.9)	22.67 (4.7-64.5)	58.5 (15.6-80.1)	0.18 (0.08-0.34)	0.31 (0.14-0.52)	GR-57.5 (42-80)	12.5 (0-35)	19.5 (0-78)	50.0 (50-100)	30.5 (0-100)	FI-83.5 (34-100)	58.0 (58)

Table 2. Continued.

Tier (no. reaches)	Stream width			Stream depth (m)		Stream bank (%)		Habitat type (%)			Dominant substrate[2] (mean %; range)	Shade (mean %; range)
	Mean wetted (m, range)	Bankfull (m, range)	Overhead cover (%, range)	Mean (range)	Mean max. (range)	Dom. veg.[1] (mean, range)	Bare (mean, range)	Pool (mean, range)	Riffle (mean, range)	Run (mean, range)		
						Guano Creek						
Lower (7)	4.21 (1.3-7.0)	7.48 (3.7-10.8)	65.8 (0-100)	0.36 (0.31-0.50)	0.84 (0.53-1.40)	GR-71.3 (0-100)	0	46.7 (0-90)	1.4 (0-10)	51.9 (10-100)	FI-62.0 (30-100)	58.0 (58)
Middle (6)	1.58 (1.3-2.0)	2.51 (1.7-3.9)	32.6 (3.1-81.8)	0.31 (0.23-0.38)	0.51 (0.36-0.60)	GR-99.7 (98-100)	0	0	0.3 (0-2)	99.7 (98-100)	GR-61.7 (44-80)	62.7 (58-81)
Upper (7)	1.39 (0.5-2.9)	4.31 (0.6-12.5)	84.5 (49.7-100)	0.10 (0.06-0.14)	0.15 (0.10-0.24)	GR-69.4 (27-100)	0.6 (0-4)	0.6 (0-2)	99.4 (98-100)	0	GR-49.1 (24-85)	86.3 (58-100)

[1] Dominant vegetation: SH-shrub/tree, BR-brush, GR-grass/forb.
[2] Dominant substrate: FI-fines, GR-gravel.

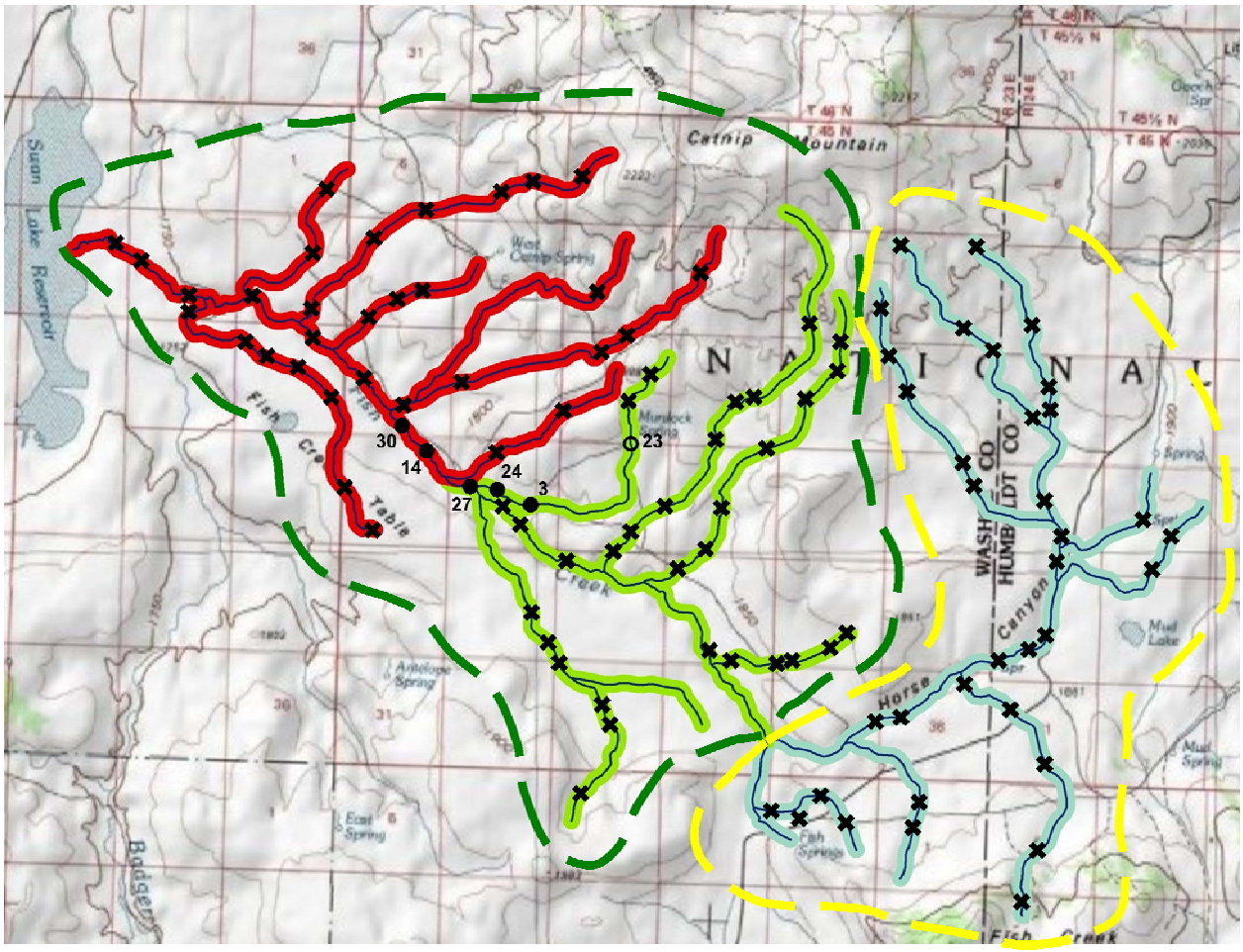

Figure 7. Sample reaches in the lower (red), middle (green), and upper (blue) tiers of the Fish Creek watershed. Circles indicate reaches sampled (closed—fish collected, open—no fish collected) and associated reach number. Crosses indicate dry reaches that were assessed in an attempt to obtain seven viable reaches. Dashed lines enclose watershed tiers found to be occupied (green) or not occupied (yellow) by fish.

Fish were collected at two reaches (reaches 14 and 30) in the lower tier of Fish Creek (Figure 7) and three of four reaches (reaches 3, 24, and 27) in the middle tier. Sheldon tui chub (*G. b. eurysoma*; Figure 8) was the only species collected. Site-specific detection probability for Sheldon tui chub was 0.83 for the Fish Creek watershed. Thus, our post hoc certainty that chub did not occupy the upper tier was nearly 100% because no reaches were viable and all but 1 of 35 reaches were dry. A total of 174 individuals were collected (Table 1). The range in fork length (19-119 mm) indicated the likely presence of juvenile and adult individuals (Figure 9).

Mean time electrofishing at all reaches in Fish Creek was 223 seconds per reach (range 101-316 seconds).

Figure 8. Sheldon tui chub collected in the lower tier of the Fish Creek watershed.

Aquatic habitat at reaches consisted of mostly slow-water (i.e., pool) in the lower tier and fast-water (i.e., riffle and run) habitats in the middle tier (Table 2). Fines were the dominant substrate in both tiers, and grass/forb was the dominant bank vegetation. Ranges in water temperature and conductivity were 7.7-17.9°C and 102-177µS, respectively, among all reaches (Appendix B). Signs of horse use were apparent on stream banks at all reaches sampled (Appendices C and D). There were no signs of beaver activity at any reach.

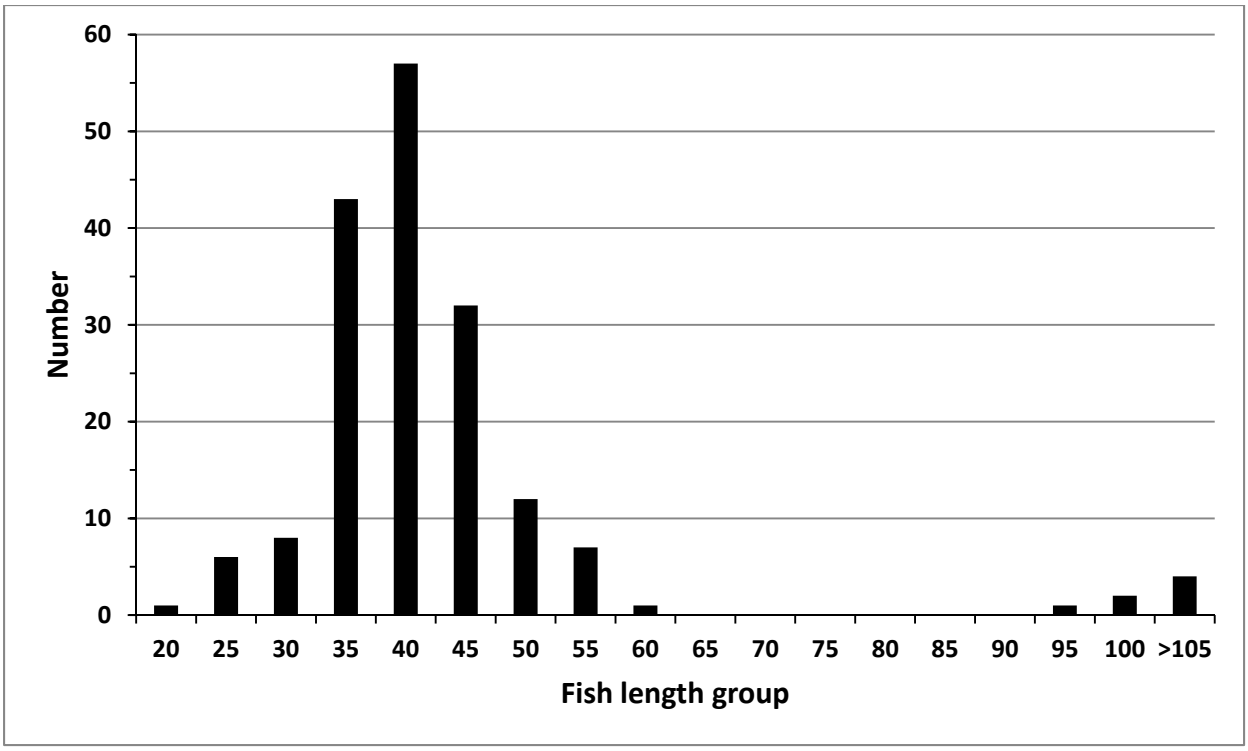

Figure 9. Number of individuals by 5-mm length group (maximum FL of each group presented except for individuals > 105 mm) for 174 Sheldon tui chub collected in the lower and middle tiers of the Fish Creek watershed.

Guano Creek

We evaluated 8, 27, and 15 reaches in the lower, middle, and upper tiers, respectively, in the Guano Creek watershed (Appendix A). Seven reaches were sampled for fish in each the lower and upper tiers, whereas six reaches were sampled in the middle tier (Figure 10). Among the lower, middle, and upper tiers, a total of 0, 17, and 7 reaches, respectively, were found to be dry, and hence fish were absent.

Trout were collected at two reaches in the lower tier of the Guano Creek watershed (reaches 4 and 8; Figure 10), six reaches in the middle tier (reaches 6, 21, 23, 24, 25, and 26), and two reaches in the upper tier (reaches 5 and 9). Unidentified fish also were observed but not collected at two reaches in the upper tier (reaches 1 and 7). Trout (Figure 11) were the only species collected in the Guano Creek watershed. Site-specific detection probability for trout was

0.50 for the Guano Creek watershed. A total of 101 trout were collected (Table 1). The range in fork length (51-311 mm) indicated the presence of multiple age classes (Figure 12). Tissue samples were collected from a total of 65 trout (Table 1). Mean time electrofishing at all reaches in the Guano Creek watershed was 164 seconds per reach (range 80-214 seconds).

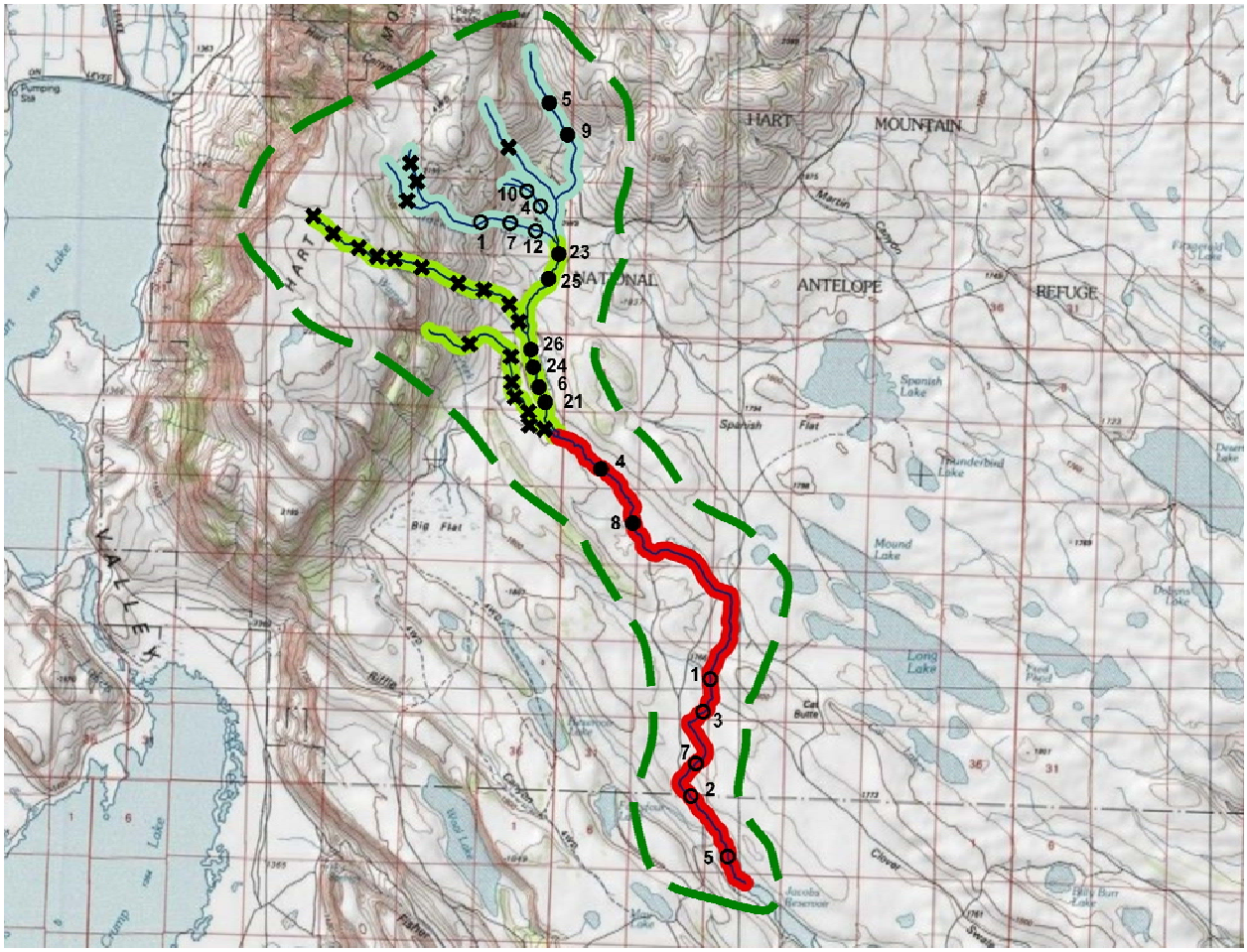

Figure 10. Sample reaches in the lower (red), middle (green), and upper (blue) tiers of the Guano Creek watershed. Circles indicate reaches sampled (closed—fish collected, open—no fish collected) and associated reach number. Crosses indicate dry reaches that were assessed in an attempt to obtain seven viable reaches. Dashed lines enclose watershed tiers found to be occupied (green) or not occupied (yellow) by fish.

Aquatic habitat at reaches consisted of almost equal portions of slow- (i.e., pool, 46.7%) and fast-water (i.e., riffle and run, 53.3%) habitats in the lower tier (Table 2). Reaches in the middle and upper tiers consisted almost entirely (≥99%) of fast-water habitat. Fines were the

dominant substrate in the lower tier, whereas gravel was the dominant substrate in the middle and upper tiers. Grass was the dominant bank vegetation in the three tiers (Appendix C). Ranges in water temperature and conductivity were 8.4-17.8°C and 47-90µS, respectively, among all reaches (Appendix B).

Figure 11. Trout collected in the middle tier (top row, lower left) and upper tier (lower right) of the Guano Creek watershed.

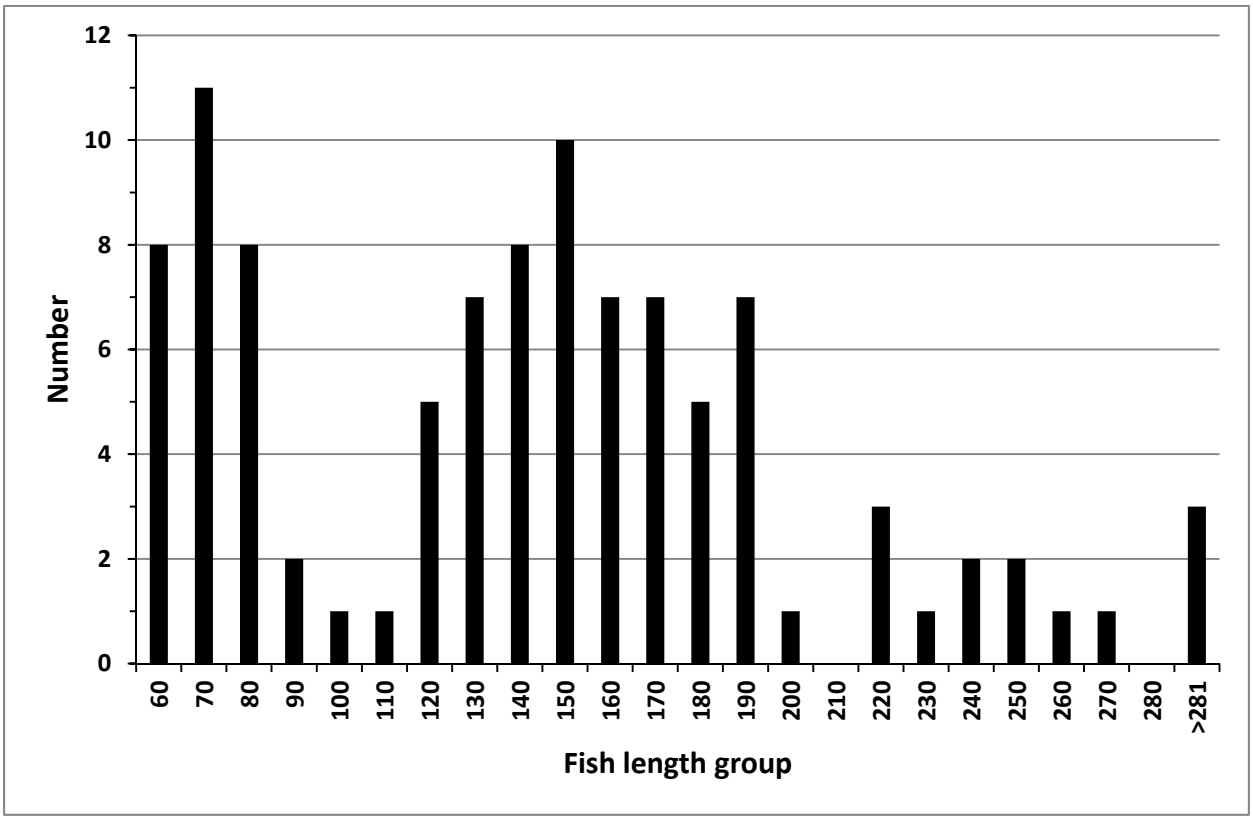

Figure 12. Number of individuals by 10-mm length group (maximum FL of each group presented except for individuals > 281 mm) for 101 trout collected in the Guano Creek watershed.

Rock Creek

Stream segments upstream and downstream of a canyon area were spot-sampled for fish in Willow Creek (Figure 13). A total of 11 trout (Figure 14) were collected in the downstream segment (144 mm mean FL, 61-204 mm range). No fish were collected or observed in the upstream segment. Range in water temperature of Willow Creek during sampling was 6.0-13.0°C.

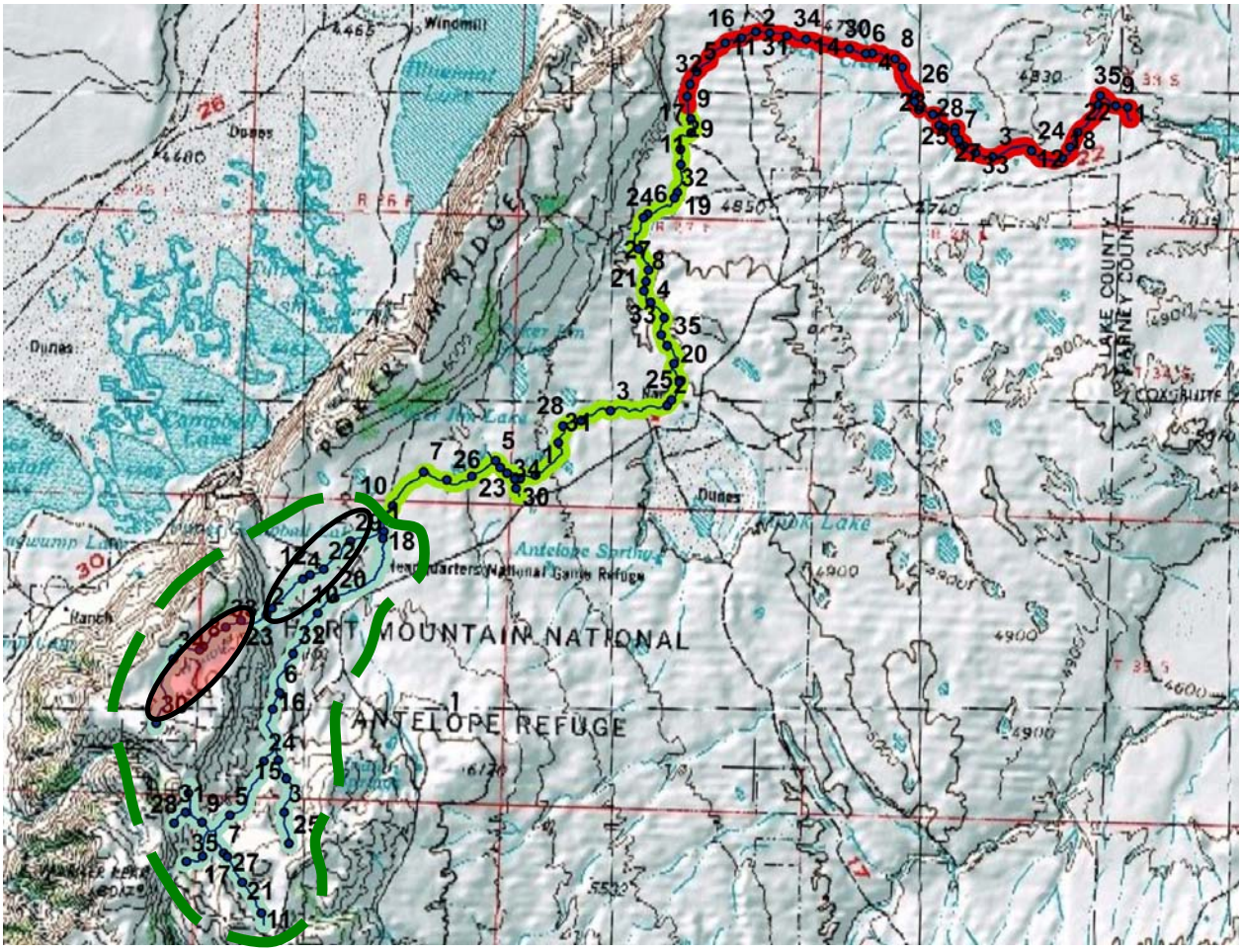

Figure 13. Sample reaches in the lower (red), middle (green), and upper (blue) tiers of the Rock Creek watershed. Circles and numbers indicate reaches identified in the sampling framework. Ovals indicate stream segments that were spot-sampled to assess fish presence in Willow Creek (fish collected-open oval, no fish collected-shaded oval). Green dashed line encloses upper watershed tier, which was found to be occupied. No sampling was conducted in the lower and middle tiers.

Figure 14. Trout collected in the stream segment downstream of the canyon area in Willow Creek.

Discussion

The goal of this work was to establish a baseline of fish community and aquatic habitat information for the Sheldon-Hart Mountain NWR Complex. Objectives were to document fish species presence, determine whether the various species occupy four specific watersheds, describe distribution of fish within watersheds, and characterize aquatic habitats. We applied a systematic approach to establish a sampling framework that can be standardized to assess temporal changes in fish occupancy and distribution as well as course-scale changes in habitat conditions.

The Sheldon-Hart Mountain NWR Complex supported Sheldon tui chub, Alvord chub, and trout, which is consistent with earlier surveys. At Sheldon NWR, three species have been described as native, Sheldon tui chub in the Fish Creek watershed (Williams et al. 1980; Williams and Bond 1981) and Alvord chub and Alvord cutthroat trout in the Virgin Creek watershed (Williams et al. 1980). Although Alvord cutthroat trout have not been formally

recognized as a taxon, pure native cutthroat trout of the Virgin Creek watershed are considered extinct due to hybridization with introduced rainbow trout (Behnke 1992). The same two species of chub were collected in their native watersheds, and trout were collected in the Virgin Creek watershed. At Hart Mountain NAR, trout were the only fish collected in the Rock Creek and Guano Creek watersheds. Redband trout (*O. mykiss*) and tui chub (*G. bicolor*) are considered native to the Rock Creek watershed (ODFW 2005, 2012). Sheldon tui chub are believed native to the Guano Creek watershed (Williams and Bond 1981), and there is controversy about the existence of native trout (ODFW 2005; Behnke 2007).

Alvord chub and trout only appeared to occupy the lower tier of the Virgin Creek watershed. Most reaches conducive to sampling in the in the middle and upper tiers of the Virgin Creek watershed were associated with headwater springs. In contrast, all but one reach sampled in the lower tier were within the Virgin Creek Gorge about 2.0-4.5 km downstream of Hell Creek. During surveys in 1978 and 1979, Williams et al. (1980) did not encounter trout in Virgin Creek upstream of Hell Creek. However, after searching most of the length of Hell Creek, Williams et al. (1980) collected one fish (218 mm standard length), which exhibited rainbow trout characteristics. They suspected that the fish moved into Hell Creek from Virgin Creek during a flood. At one reach in the lower tier Alvord chub and trout were sympatric, and one did not appear to prevent the distribution of the other. This is in contrast to the report of Williams et al. (1980) who found that Alvord chub were never collected with any other fish species, and noted the separation of trout to the south in Virgin Creek Gorge and Alvord chub in the valley to the north as a dramatic example. Interspecific interactions were considered the probable causes for the allopatric distribution of Alvord chub (Williams et al. 1980). Warm water species that have been introduced into the watershed (e.g., sportfish established in

Dufurrena Ponds or guppy (*Poecilia reticulate*) established in the Virgin Valley campground pool) did not appear to occupy the watershed upstream of Pond 13.

For the Fish Creek watershed, Sheldon tui chub were found in both the lower and middle tiers but not the upper tier. This was similar to the findings of Williams et al. (1980) who collected Sheldon tui chub in Fish Creek (approximately 10 km upstream of Swan Lake Reservoir to 4 km downstream of State Route 8A), a tributary to Fish Creek in Horse Canyon, and Swan Lake Reservoir. Distribution of Sheldon tui chub was confined to reaches with sufficient water in the lower tier of Fish Creek and the tributary in the middle tier downstream from Murdock Springs. Virtually all reaches in the upper tier were dry.

For fish distribution at Hart Mountain NAR, trout were found throughout the Guano Creek watershed. This was consistent with previous work where ODFW sampled on three occasions (2004, 2006, and 2010) and collected trout (S. Hurn, ODFW, personal communication). Thus, trout are widely distributed in the Guano Creek watershed. In the Rock Creek watershed, time constraints limited us to conducting a cursory survey of Willow Creek, which contained sample reaches in our upper tier. Trout occupied Willow Creek, thus were distributed in the upper tier of Rock Creek. Portions of the middle and upper tiers in the Rock Creek watershed are included in the Great Basin Redband Trout Assessment Project by ODFW (ODFW 2012). The assessment has entailed fish and habitat surveys of 7-11 sites during 2007 and 2009-2011 in Rock Creek, and has also documented the presence of trout and tui chub. Thus, trout and tui chub are distributed in the middle tier of the Rock Creek watershed.

Aquatic habitats were similar among the Virgin Creek, Fish Creek, and Guano Creek watersheds in the dominance of pool habitat, and associated greater water depth and stream width, in the lower tiers compared to dominance of riffle and run habitats in the middle and

upper tiers. However, both watersheds at Sheldon NWR substantially differed from the Guano Creek watershed in having a mean of 86% of all reaches assessed as dry in the middle and upper tiers compared to a mean of 55% for Guano Creek. This highlights the importance of reaches in the lower tiers as fish habitat given that habitat conditions were assessed during summer, which likely is the most restrictive season for fish at the Sheldon-Hart Mountain NWR Complex. Thus, management activities that protect and restore aquatic habitat in areas occupied by fish during the summer, such as the lower tier in the Virgin Creek watershed and the lower and middle tiers in the Fish Creek watershed where high use by horses was observed, should initially be considered in watershed planning. In addition, the sample framework used and habitat data collected will enable the potential for comparisons with habitat conditions characterized in the future, which will be useful in exploring possible changes in fish presences and distribution.

Standardized protocols allowing for quantitative assessment of fish species distribution were developed for the Virgin Creek, Fish Creek, Guano Creek, and Rock Creek watersheds, and applied to all watersheds except Rock Creek. Reapplying the approach in the future (e.g., 5- or 10-year intervals) will provide consistency in generating information that can be used to address potential questions concerning temporal changes in fish species composition and distribution as well as fish associations with aquatic habitat. Potential questions may focus on assessing effects of specific management actions planned for the future (e.g., involving watershed restoration in Virgin Creek if feral horses and burros are removed or activities associated with a coldwater fisheries management plan to be developed for Sheldon NWR), monitoring possible changes in fish relative to factors affected by climate change or other stressors (of which some may be evident in attributes of aquatic habitat), and determining whether fish distribution seasonally varies (i.e., between the most restrictive season compared to seasons characterized by less

restrictive conditions). To assist in addressing these questions, we recommend installing temperature loggers to generate a time series of water temperature in areas that are not expected to dry, and flow gages (e.g., water depth loggers or crest-stage gages) near junctions between tiers in the watersheds to estimate flow and allow making inferences about the potential for connectivity between tiers.

To better understand fish species presence and the prevalence of hybridization , we also recommend conducting genetic analysis of trout tissue collected during our survey of the watersheds, as well as tissue collected during surveys conducted by others. Trout residing in Virgin Creek are considered rainbow-cutthroat hybrids due to rainbow trout introduced in the 1930s (Behnke 1992; Williams et al. 1980; Tol and French 1988; Bartley and Gall 1991), and rainbow trout were last stocked in Rock Creek in 1973 and Guano Creek during the 1960s (ODFW 2005; Behnke 2007). Information on the genetic disposition of trout in Rock Creek is anticipated in the near future because tissue samples collected for the Great Basin Redband Trout Assessment Project (ODFW 2012) are expected to be analyzed during 2012 with support from the Western Native Trout Initiative, a fish habitat partnership recognized by the National Fish Habitat Action Plan. Guano Creek also was stocked with Lahontan cutthroat trout between 1957 and 1970 (ODFW 2005; Behnke 2007). Trout residing in Guano Creek appear to be cutthroat trout without apparent influence of hybridization with rainbow trout, and some individuals possess spotting patterns similar to descriptions for Alvord cutthroat trout (Behnke 2007). Thus, there is speculation of historical transfer of Alvord basin trout into Guano Creek prior to 1928 (Behnke 2007) and some anglers believe pure Alvord cutthroat trout may persist there (S. Hurn, ODFW, personal communication). Genetic analysis of trout tissue will further our understanding of hybridization in Virgin Creek (e.g., presence of any detectable cutthroat trout genetic

component) and the potential spatial relations of various strains of trout in Guano Creek. This information would assist in clarifying the zoological history of the creek.

Acknowledgements

We gratefully thank personnel of the Sheldon-Hart Mountain NWR Complex, specifically Brian Day, Arron Collins, Gail Collins, and Jeff Mackay, for providing logistical support, lodging, and sharing their extensive knowledge of the NWRs; Kevin Kilbride, Erin Stockenberg, and Jenny Barnett of the R1 NWR I&M Team for funding and logistical support; Shannon Hurn of ODFW and Kim Tisdale of NDOW for providing information and assistance in acquiring scientific collecting permits; and the USFWS Reno office for assistance in obtaining the Nevada scientific collecting permit. The greatest depth of gratitude goes to the field crew of Ben Willis and Cory Stratten whose diligence, hard work, and long days in the field made the project possible.

Literature cited

Bartley, D. M., and G. A. E. Gall. 1991. Genetic identification of native cutthroat trout (*Oncorhynchus clarki*) and introgressive hybridization with introduced rainbow trout (*O. mykiss*) in streams associated with the Alvord basin, Oregon and Nevada. Copeia 1991:854-859.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6.

Behnke, R. J. 2007. Redband trout of the Northern Great Basin. Pages 1-9 *in* R.K. Schroeder and J.D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter, American Fisheries Society, Corvallis.

Hudson, J.M., J.R. Cook, B.P. Silver, and T.A. Whitesel. 2010. Lewis River Bull Trout Recovery Monitoring and Evaluation: Patches, Occupancy and Distribution. 2006-2007 Progress Report. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, Washington.

Oregon Department of Fish and Wildlife. 2005. Oregon Native Fish Status Report, Volume I Species Management Unit Summaries, Volume II Assessment Methods and Population Results. Fish Division. Salem.

Oregon Department of Fish and Wildlife. 2012. Native Fish Investigations Project, Great Basin Redband Trout, data summaries 2007-2011. Available at: http://oregonstate.edu/dept/ODFW/Native Fish/GreatBasinRedband.htm.

Stevens, Jr., D. L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the America Statistical Association 99:262-278.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions American Geophysical Union 38:913-920.

Tol, D., and J. French. 1988. Status of a hybridized population of Alvord cutthroat trout from Virgin Creek, Nevada. American Fisheries Society Symposium 4:116-120.

U.S. Fish and Wildlife Service. 1994a. Hart Mountain National Antelope Refuge Comprehensive Management Plan, Volumes I and II. Final Environmental Impact Statement. Portland, Oregon. May 1994.

U.S. Fish and Wildlife Service. 1994b. Record of Decision for Department of the Interior, U.S. Fish and Wildlife Service, Hart Mountain National Antelope Refuge Comprehensive Management Plan Final Environmental Impact Statement. Lake County, Oregon. August 3, 1994.

U.S. Fish and Wildlife Service. 2005. NWR-CRFPO Workshop 2005: A report on a workshop between National Wildlife Refuges in Region 1 and the Columbia River Fisheries Program Office July 20, 2005 Vancouver, Washington. December 2005.

U.S. Fish and Wildlife Service. 2008. Bull Trout Recovery: Monitoring and Evaluation Guidance. Report prepared for the U.S. Fish and Wildlife Service by the Bull Trout Recovery and Monitoring Technical Group (RMEG). Portland, Oregon, Version 1.

U.S. Fish and Wildlife Service. 2010a. Strategic Plan for Inventories and Monitoring on National Wildlife Refuges: Adapting to Environmental Change. U.S. Fish and Wildlife Service, National Wildlife Refuge System. September 1, 2010.

U.S. Fish and Wildlife Service. 2010b. Operational Business Addendum Blueprint for Inventory and Monitoring and National Wildlife Refuges: Adapting to Environmental Change. U.S. Fish and Wildlife Service, National Wildlife Refuge System. September 1, 2010.

U.S. Fish and Wildlife Service. 2011. Sheldon National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Impact Statement. Lakeview, Oregon. September 2011.

Williams, J. E., C. D. Williams, and C. E. Bond. 1980. Fishes of the Sheldon National Wildlife Refuge. Department of Fisheries and Wildlife, Oregon State University. Corvallis.

Williams, J. E., and C. E. Bond. 1981. A new subspecies of tui chub (Osteichethys: Cyprinidae) from Guano basin, Nevada and Oregon. The Southwestern Naturalist 26:223-230.

Appendix A. Reach number, coordinates (UTM Zone 11N, NAD83), and comments on potential sample reaches among three tiers in the Virgin Creek, Fish Creek, Guano Creek, and Rock Creek watersheds.

Reach number	X coordinate	Y coordinate	Comments
		Virgin Creek lower tier	
1	323062.92594000000	4624408.16868000000	**8/3/11, sampled**
2	322896.54501100000	4623264.91579000000	**8/3/11, sampled**
3	325553.69967900000	4629420.76117000000	8/10/11, not sampled, closed in with rushes
4	323680.42823800000	4626370.49095000000	8/10/11, not sampled, beaver pond
5	323473.89763600000	4625235.89793000000	**8/16/11, sampled**
6	326553.88705900000	4630852.47165000000	8/10/11, not sampled, dry with scattered pools
7	327424.99574200000	4631271.06368000000	8/10/11, not sampled, dry
8	323614.05949300000	4626044.67606000000	**8/2/11, sampled**
9	325260.55156700000	4628165.80236000000	8/1/11, not sampled, shallow, veg
10	325494.95045600000	4628359.25188000000	8/1/11, not sampled, shallow, veg
11	323564.53311900000	4625422.23091000000	**8/16/11, sampled**
12	325399.30378100000	4629108.42992000000	**8/18/11, sampled**
13	324894.77297100000	4628227.16884000000	8/1/11, not sampled, dry scattered pools, veg
14	324144.04074500000	4627099.61371000000	8/10/11, not sampled, dry
15	326275.84163700000	4630370.35617000000	8/10/11, not sampled, width, veg
16	328179.10508100000	4631354.86724000000	8/10/11, not sampled, dry
17	322719.56534300000	4622968.99718000000	8/3/11, not sampled, shallow, veg
18	325634.57679900000	4629569.76936000000	8/10/11, not sampled, veg
19	327010.91422800000	4631039.66728000000	8/10/11, not sampled, dry
20	323281.07870600000	4624820.82774000000	**8/16/11, sampled**
21	324473.24493500000	4627424.51641000000	
22	324513.69883800000	4627562.30434000000	
23	322985.03217900000	4623942.92050000000	
24	327093.44914300000	4631064.60423000000	
25	323801.47430100000	4626562.12045000000	
26	324623.57427200000	4627974.82115000000	8/1/11, not sampled, scattered pools, veg
27	323008.60701600000	4624187.19065000000	

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Virgin Creek middle tier	
1	318475.00683500000	4619431.49320000000	8/5/11, not sampled, dry
2	313376.85959800000	4623066.87027000000	8/4/11, not sampled, dry
3	315644.75760900000	4618206.74108000000	8/4/11, not sampled, dry
4	318576.42648700000	4622144.00088000000	**8/9/11, sampled**
5	317664.74462200000	4621646.40303000000	8/9/11, not sampled, dry
6	313000.76627500000	4625785.61125000000	**8/7/11, sampled**
7	320144.70434400000	4621927.01052000000	**8/8/11, sampled**
8	318264.70444100000	4618278.49035000000	8/5/11, not sampled, dry
9	320349.48769900000	4622302.35231000000	8/8/11, not sampled, veg
10	320507.77198200000	4618637.49574000000	8/4/11, not sampled, dry
11	315453.62211400000	4618181.25359000000	8/4/11, not sampled, dry (seep downstream)
12	318861.07112600000	4620708.91307000000	8/6/11, not sampled, dry
13	318326.89335900000	4618717.78640000000	8/5/11, not sampled, dry
14	319751.50167400000	4619080.51666000000	8/4/11, not sampled, dry
15	317472.44959400000	4617328.94817000000	8/7/11, not sampled, dry
16	319424.86961100000	4621112.21536000000	8/6/11, not sampled, dry
17	317166.86977300000	4619981.88667000000	8/7/11, not sampled, dry
18	318373.08610500000	4619117.19776000000	8/5/11, not sampled, dry
19	315361.43344700000	4623755.48791000000	**8/9/11, sampled**
20	318505.15064900000	4619824.03765000000	8/5/11, not sampled, dry
21	312848.46743300000	4622315.73301000000	8/4/11, not sampled, dry
22	316195.34585100000	4619621.91036000000	**8/7/11, sampled**
23	318503.89255200000	4616963.49727000000	8/7/11, not sampled, dry
24	317328.16255800000	4621496.64494000000	**8/9/11, sampled**
25	312865.78841200000	4625873.82500000000	**8/15/11, sampled**
26	320200.77391700000	4621670.07920000000	8/8/11, not sampled, dry
27	321736.62757900000	4622508.54492000000	8/3/11, not sampled, (possible to sample)
28	318188.90826000000	4618378.54553000000	8/7/11, not sampled, dry
29	320136.18366400000	4622091.58598000000	8/8/11, not sampled, (possible to sample)
30	320985.11153400000	4618012.95433000000	8/7/11, not sampled, dry
31	317448.27297000000	4623200.57022000000	Not observed
32	314941.41261600000	4617810.63417000000	8/7/11, not sampled, dry
33	318773.09221800000	4621086.80107000000	8/6/11, not sampled, dry
34	317618.01150000000	4618206.62259000000	8/7/11, not sampled, dry
35	319904.11391600000	4619331.37467000000	8/4/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Virgin Creek upper tier	
1	323756.55178000000	4613845.80518000000	8/4/11, not sampled, dry
2	312475.63938800000	4618103.22370000000	8/7/11, not sampled, dry
3	316605.10963500000	4614305.39022000000	8/18/11, not sampled, dry
4	318981.48005200000	4615467.44132000000	8/8/11, not sampled, dry
5	311760.25605000000	4612423.89110000000	8/4/11, not sampled, dry
6	316966.55382200000	4613239.03101000000	8/18/11, not sampled, dry
7	316661.14087200000	4615276.38168000000	8/18/11, not sampled, dry
8	323344.39744800000	4616977.05467000000	8/15/11, not sampled, dry
9	309777.16460700000	4611804.68578000000	8/4/11, not sampled, dry
10	319147.08463800000	4614703.47095000000	8/8/11, not sampled, dry
11	315932.97291000000	4615153.39461000000	8/18/11, not sampled, dry
12	315302.44490900000	4613205.99785000000	8/18/11, not sampled, dry
13	323624.55209400000	4615625.57591000000	8/15/11, not sampled, dry
14	322370.42302200000	4622419.48393000000	9/5/11, not sampled, (shallow/veg)
15	308533.12306300000	4610926.32387000000	8/8/11, not sampled, dry
16	311989.15895900000	4614558.66015000000	8/7/11, not sampled, dry
17	324014.29028200000	4620861.12128000000	9/5/11, not sampled, dry
18	311469.39395900000	4617057.60234000000	8/7/11, not sampled, dry
19	318259.04665500000	4614026.94277000000	8/8/11, not sampled, dry
20	313656.36482200000	4616679.55508000000	**8/18/11, sampled**
21	324039.99669400000	4619652.50191000000	8/15/11, not sampled, dry
22	312501.47695100000	4615034.26741000000	8/7/11, not sampled, dry
23	323736.44112900000	4614215.39309000000	8/4/11, not sampled, dry
24	315999.17944500000	4614964.24361000000	8/18/11, not sampled, dry
25	323543.86235300000	4617694.47168000000	8/15/11, not sampled, dry
26	323478.88118400000	4621263.37782000000	**9/5/11, sampled**
27	312811.71192700000	4612767.93024000000	8/7/11, not sampled, dry
28	316906.55575900000	4615437.95628000000	8/18/11, not sampled, dry
29	320323.03764200000	4610565.31703000000	8/18/11, not sampled, dry
30	310262.61438500000	4611855.80132000000	8/8/11, not sampled, dry
31	323431.13710200000	4616294.40019000000	8/15/11, not sampled, dry
32	309544.65113500000	4611682.78988000000	8/8/11, not sampled, dry
33	318111.03430900000	4611146.13295000000	8/18/11, not sampled, dry
34	318716.45402700000	4614207.33070000000	8/8/11, not sampled, dry
35	317013.64369900000	4612875.29990000000	8/18/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Fish Creek lower tier	
1	296926.54683900000	4632426.69627000000	9/14/11, not sampled, dry
2	297456.03587000000	4630564.09311000000	9/14/11, not sampled, dry
3	293699.38575800000	4634711.02447000000	9/12/11, not sampled, dry
4	301192.15486800000	4633383.74450000000	8/17/11, not sampled, dry
5	296163.96849300000	4632972.76333000000	9/14/11, not sampled, dry
6	298090.47949000000	4634046.59860000000	8/17/11, not sampled, dry
7	300029.69355800000	4635645.83304000000	8/17/11, not sampled, dry
8	296602.06086100000	4634579.79997000000	8/17/11, not sampled, dry
9	300270.22857900000	4632249.01473000000	9/6/11, not sampled, dry
10	297958.92457800000	4632372.56103000000	9/14/11, not sampled, dry
11	302315.57264100000	4634323.30532000000	8/17/11, not sampled, dry
12	297624.81863800000	4634930.09267000000	8/17/11, not sampled, dry
13	295770.68238100000	4633168.99815000000	9/14/11, not sampled, dry
14	298101.05445100000	4631827.55107000000	**9/16/11, sampled**
15	299269.31236800000	4633835.45808000000	8/17/11, not sampled, no channel, flow
16	295020.03394400000	4633803.52374000000	9/12/11, not sampled, dry
17	296631.34095600000	4633334.16897000000	9/14/11, not sampled, dry
18	297393.14372700000	4632735.77813000000	9/14/11, not sampled, dry
19	297165.73466100000	4631018.71563000000	9/14/11, not sampled, dry
20	294013.72792300000	4634569.60529000000	9/12/11, not sampled, dry
21	300818.93905900000	4633111.19324000000	8/17/11, not sampled, dry
22	297762.91234800000	4633885.66137000000	8/17/11, not sampled, dry
23	299552.47761300000	4635612.60875000000	8/17/11, not sampled, dry
24	296630.14667300000	4635369.21751000000	8/17/11, not sampled, dry
25	299512.73959500000	4631760.71597000000	9/6/11, not sampled, dry
26	298738.60984800000	4632709.10729000000	9/14/11, not sampled, dry
27	298524.16899400000	4635275.14385000000	8/17/11, not sampled, dry
28	295698.74282300000	4633963.90020000000	9/14/11, not sampled, dry
29	296600.19128700000	4633769.53336000000	9/14/11, not sampled, dry
30	297864.43775300000	4632130.29421000000	**9/16/11, sampled**
31	300737.24900700000	4633914.09046000000	8/17/11, not sampled, dry
32	294990.83863700000	4633961.54337000000	9/12/11, not sampled, dry
33	297502.96782500000	4633725.70334000000	8/17/11, not sampled, dry
34	296583.49805200000	4632791.53553000000	9/14/11, not sampled, dry
35	300581.05291700000	4635706.57992000000	8/17/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Fish Creek middle tier	
1	303369.91803700000	4628544.54922000000	8/15/11, not sampled, dry
2	303964.45719200000	4633462.42587000000	8/17/11, not sampled, dry
3	299753.23158000000	4630856.29863000000	**9/17/11, sampled**
4	301914.81347900000	4629865.16261000000	8/15/11, not sampled, dry
5	302787.50615700000	4628613.54161000000	8/15/11, not sampled, dry
6	300948.30707700000	4627685.70956000000	9/14/11, not sampled, dry
7	302809.03208700000	4632349.69774000000	8/17/11, not sampled, dry
8	299531.79753500000	4630744.39293000000	8/15/11, not sampled, dry
9	304506.50975300000	4628979.11061000000	8/15/11, not sampled, dry
10	300278.07138500000	4628453.31190000000	9/14/11, not sampled, dry
11	301650.11132000000	4632856.30231000000	8/17/11, not sampled, dry
12	300345.04090100000	4630072.57697000000	9/6/11, not sampled, dry
13	302338.54238400000	4631288.62010000000	8/17/11, not sampled, dry
14	303878.20796900000	4632416.80034000000	8/17/11, not sampled, dry
15	300528.93793000000	4626580.50729000000	9/14/11, not sampled, dry
16	301095.92963700000	4630266.68305000000	8/17/11, not sampled, dry
17	303489.55766300000	4628561.55712000000	8/15/11, not sampled, dry
18	304375.95415400000	4633162.26115000000	8/17/11, not sampled, dry
19	299725.07068800000	4630557.96619000000	9/6/11, not sampled, dry
20	302161.62524100000	4630021.78823000000	8/15/11, not sampled, dry
21	302460.89501800000	4628641.82035000000	8/15/11, not sampled, dry
22	300844.06620800000	4627983.32223000000	9/14/11, not sampled, dry
23	301286.66001100000	4631825.66418000000	**9/17/11, sampled**
24	299225.52970200000	4631144.08593000000	**9/17/11, sampled**
25	302583.44885900000	4630573.59978000000	8/17/11, not sampled, dry
26	303179.83391700000	4631674.60016000000	8/17/11, not sampled, dry
27	298960.33267500000	4631147.43978000000	**9/16/11, sampled**
28	300134.60899200000	4628802.34591000000	9/14/11, not sampled, dry
29	301279.72096400000	4632464.23306000000	8/15/11, not sampled, dry
30	299832.54925100000	4629187.75240000000	9/14/11, not sampled, dry
31	304354.15900800000	4632870.09217000000	8/19/11, not sampled, dry
32	301036.97210600000	4630206.76403000000	8/17/11, not sampled, dry
33	301443.43986600000	4630675.07485000000	8/17/11, not sampled, dry
34	304193.97003500000	4628757.11762000000	8/15/11, not sampled, dry
35	302622.05284100000	4632165.22605000000	9/14/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Fish Creek upper tier	
1	305475.91703600000	4626236.51028000000	8/4/11, not sampled, dry
2	307573.72198100000	4630067.50317000000	8/4/11, not sampled, dry
3	307261.34170800000	4632137.18242000000	9/6/11, not sampled, shallow, horse damage
4	305003.17248500000	4627733.38547000000	8/15/11, not sampled, dry
5	309133.04916300000	4630099.55424000000	8/17/11, not sampled, dry
6	305249.36476400000	4634746.60446000000	8/17/11, not sampled, dry
7	307424.88401100000	4627000.25471000000	8/4/11, not sampled, dry
8	307109.79469800000	4625632.36829000000	8/17/11, not sampled, dry
9	304151.82793400000	4626592.09998000000	8/17/11, not sampled, dry
10	307636.38875200000	4630376.45763000000	8/17/11, not sampled, dry
11	307476.41547500000	4632465.42756000000	9/6/11, not sampled, dry
12	306264.87365100000	4631317.37998000000	9/6/11, not sampled, dry
13	305035.58338700000	4633184.04541000000	9/6/11, not sampled, dry
14	303757.63450500000	4626294.12538000000	8/17/11, not sampled, dry
15	307235.49052300000	4633457.55748000000	9/6/11, not sampled, dry
16	306963.10321000000	4628697.01743000000	8/17/11, not sampled, dry
17	305559.75872700000	4626562.36608000000	8/15/11, not sampled, dry
18	307414.04383200000	4628972.59901000000	8/17/11, not sampled, dry
19	306377.06556500000	4634735.46657000000	9/6/11, not sampled, dry
20	305397.53422700000	4632430.38792000000	9/6/11, not sampled, dry
21	304831.09202900000	4627650.05120000000	8/19/11, not sampled, dry
22	308884.53363600000	4629712.82964000000	8/17/11, not sampled, dry
23	304982.98578300000	4633880.13719000000	9/6/11, not sampled, dry
24	307338.69388400000	4628800.44140000000	8/17/11, not sampled, dry
25	307052.73403100000	4624916.50228000000	8/17/11, not sampled, dry
26	304436.53042000000	4626210.41392000000	8/17/11, not sampled, dry
27	307456.16101100000	4630778.47636000000	8/17/11, not sampled, dry
28	307478.64376900000	4632181.03578000000	9/6/11, not sampled, dry
29	306359.66844200000	4631165.78130000000	9/6/11, not sampled, dry
30	306183.22237100000	4633532.46482000000	9/6/11, not sampled, dry
31	306950.70135500000	4627787.69101000000	8/17/11, not sampled, dry
32	303245.16322200000	4626386.36888000000	8/17/11, not sampled, dry
33	308793.40066200000	4630635.33675000000	8/17/11, not sampled, dry
34	306649.01264200000	4633147.61998000000	9/6/11, not sampled, dry
35	306213.88076500000	4628269.84686000000	8/17/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Guano Creek lower tier	
1	279363.59644400000	4690311.51785000000	**8/29/11, sampled**
2	278984.75477300000	4687849.53739000000	**8/30/11, sampled**
3	279305.58216300000	4689826.21394000000	**8/29/11, sampled**
4	276903.51551000000	4694959.29924000000	**9/1/11, sampled**
5	279849.86690100000	4686307.31447000000	**8/30/11, sampled**
6	279772.99043000000	4692190.88968000000	8/31/11, not sampled, width, veg
7	278814.19867800000	4688331.96091000000	**8/30/11, sampled**
8	277718.11692700000	4693788.79481000000	**9/1/11, sampled**
9	279008.26379700000	4689294.54266000000	
10	278762.74583200000	4693029.17742000000	
11	279332.82666000000	4687436.38500000000	
12	277584.03037400000	4694253.65433000000	
13	278293.44266400000	4693121.88867000000	
14	279588.52109500000	4687066.60100000000	
15	277965.79079500000	4693178.10419000000	
16	279402.63721800000	4692364.62613000000	
17	277673.77872800000	4693885.88017000000	
18	278682.43330100000	4693062.77000000000	
19	279675.09717100000	4691049.22328000000	
20	279173.39762200000	4688679.82887000000	
21	278912.23266900000	4688449.71877000000	
22	276873.74135700000	4694978.19646000000	
23	279111.35762300000	4688646.36272000000	
24	277345.00708700000	4694639.13233000000	
25	277106.36692900000	4694843.54415000000	

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Guano Creek middle tier	
1	275683.46751400000	4695837.08533000000	8/20/11, not sampled, dry
2	275617.85335800000	4695921.67259000000	8/20/11, not sampled, dry
3	275483.10275000000	4698197.79086000000	9/19/11, not sampled, veg
4	274298.40997700000	4697510.41966000000	8/22/11, not sampled, shallow, veg
5	275251.37074500000	4696402.21871000000	8/22/11, not sampled, dry
6	275639.44376300000	4696956.39689000000	**8/22/11, sampled**
7	271512.52740400000	4699740.28637000000	8/22/11, not sampled, dry
8	272746.58671000000	4699310.76146000000	8/22/11, not sampled, dry
9	272809.92477000000	4699295.52303000000	8/22/11, not sampled, dry
10	275362.21652900000	4697858.21275000000	8/22/11, not sampled, dry
11	275127.42953800000	4697219.21950000000	8/22/11, not sampled, dry
12	274022.43846500000	4698807.54403000000	8/22/11, not sampled, dry
13	273966.78050200000	4697487.80094000000	8/22/11, not sampled, shallow, slope
14	274782.77543000000	4697635.34342000000	8/22/11, not sampled, dry
15	274502.52499700000	4698663.09459000000	8/22/11, not sampled, dry
16	271013.29818800000	4700141.92498000000	8/22/11, not sampled, dry
17	273288.55670000000	4699112.26085000000	8/22/11, not sampled, dry
18	273761.12160600000	4697660.35349000000	8/22/11, not sampled, shallow, slope
19	275360.27812200000	4697964.91502000000	8/22/11, not sampled, dry
20	276009.66487200000	4695655.02693000000	8/20/11, not sampled, dry
21	275744.69301500000	4696523.16728000000	**8/22/11, sampled**
22	272145.82980600000	4699396.49491000000	8/22/11, not sampled, dry
23	276139.64065600000	4699333.67252000000	**9/1/11, sampled**
24	275532.17066900000	4697234.68915000000	**8/31/11, sampled**
25	276011.96622800000	4699008.11456000000	**8/31/11, sampled**
26	275522.63464700000	4697295.45795000000	**8/31/11, sampled**
27	275328.83660900000	4696366.86999000000	8/20/11, not sampled, dry

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Guano Creek upper tier	
1	274441.45115000000	4700052.98882000000	**8/21/11, sampled**
2	273015.45242900000	4701282.76537000000	8/22/11, not sampled, dry
3	272990.00471500000	4701323.68490000000	8/22/11, not sampled, dry
4	275654.67958100000	4700602.56113000000	**8/20/11, sampled**
5	275973.67331400000	4702572.33714000000	**8/20/11, sampled**
6	275000.13440500000	4701782.28924000000	8/20/11, not sampled, dry
7	275495.59717800000	4699974.64114000000	**9/2/11, sampled**
8	276020.61601100000	4700673.61907000000	8/21/11, not sampled, veg
9	276203.15967000000	4702173.17405000000	**8/21/11, sampled**
10	275428.85403300000	4700825.79547000000	**8/21/11, sampled**
11	272720.85217800000	4701056.69200000000	8/22/11, not sampled, dry
12	275868.59243800000	4699868.66412000000	**8/23/11, sampled**
13	273785.67766700000	4700299.84440000000	
14	273102.73119400000	4700429.72207000000	
15	272548.20304100000	4701288.14743000000	8/22/11, not sampled, dry
16	275677.56576800000	4699924.36426000000	
17	274620.08843600000	4702560.26030000000	8/20/11, not sampled, dry
18	276294.41602800000	4700744.33222000000	
19	275236.11225700000	4701559.49968000000	8/20/11, not sampled, dry
20	276038.00748500000	4700030.55767000000	
21	276498.97946000000	4701006.73430000000	
22	275990.61398300000	4699794.69693000000	
23	275847.69032500000	4700907.06365000000	
24	275978.61520400000	4702559.94354000000	
25	275786.59971400000	4702922.25085000000	
26	275163.62447000000	4700902.62612000000	
27	274873.10810600000	4700156.60571000000	
28	275580.02226000000	4703380.53507000000	
29	273014.42750400000	4700508.75341000000	
30	274136.38407400000	4700071.05682000000	
31	273317.92438700000	4700546.12214000000	
32	276463.91388000000	4701763.97570000000	

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Rock Creek lower tier	
1	306653.42805500000	4729752.07512000000	
2	294583.88243700000	4732195.39256000000	
3	302262.85709800000	4728129.31075000000	
4	298355.57155900000	4731501.11681000000	
5	292665.63216900000	4730901.28727000000	
6	298151.58948400000	4731483.96985000000	
7	301158.63576400000	4728687.86733000000	
8	299096.85171000000	4731317.54368000000	
9	306260.97608800000	4729788.33710000000	
10	299730.39006200000	4729922.41933000000	
11	293580.98549200000	4731845.76743000000	
12	304782.04257900000	4728443.02429000000	
13	301321.47264000000	4728480.91821000000	
14	296215.98054500000	4731943.11105000000	
15	300530.81538500000	4729150.54495000000	
16	294100.27379500000	4731989.79000000000	
17	305696.46529900000	4729823.21826000000	
18	304530.01731000000	4728090.27209000000	
19	299325.95634800000	4731039.12557000000	
20	299869.56480500000	4729665.99558000000	
21	292345.31292300000	4730095.82169000000	
22	305019.44588300000	4728930.51261000000	
23	300320.77404100000	4729517.45743000000	
24	303522.23148100000	4728327.66270000000	
25	301043.93713100000	4729081.65387000000	
26	299755.53992100000	4730166.14786000000	
27	301040.47565700000	4728906.06335000000	
28	300705.84450600000	4729067.87564000000	
29	295024.44192200000	4732153.28563000000	
30	297614.93111500000	4731641.33659000000	
31	294568.64560600000	4732191.10722000000	
32	292444.52680200000	4730489.39822000000	
33	301714.70609400000	4728259.59952000000	
34	295587.56527600000	4732072.49040000000	
35	305757.72547500000	4730119.59370000000	

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Rock Creek middle tier	
1	287426.54725000000	4717790.47753000000	
2	291703.46323000000	4720057.52808000000	
3	289855.21587200000	4719870.68784000000	
4	291165.77333100000	4723395.33524000000	
5	286130.80983400000	4718253.64237000000	
6	291069.60955400000	4726266.12012000000	
7	283794.29725300000	4717897.58049000000	
8	291006.14523900000	4724081.14914000000	
9	292473.36506800000	4729362.19186000000	
10	282788.89054400000	4716778.62532000000	
11	292135.56264400000	4727876.03773000000	
12	286287.04118000000	4718039.87218000000	
13	290761.63986900000	4725141.37022000000	
14	292093.10287100000	4720796.84243000000	
15	291601.96955400000	4722904.03836000000	
16	288912.72458300000	4719565.54865000000	
17	292487.32869400000	4728911.58258000000	
18	286924.55287200000	4717682.58816000000	
19	292034.53921700000	4726965.94072000000	
20	291921.36640400000	4721420.62355000000	
21	290943.17440100000	4723777.12707000000	
22	286752.24895400000	4717659.52314000000	
23	285366.24589500000	4717742.88514000000	
24	290934.82633000000	4726162.56674000000	
25	291832.04159500000	4720235.88087000000	
26	284544.78490700000	4717634.14527000000	
27	291099.79223000000	4724449.11224000000	
28	288311.70926600000	4719379.81284000000	
29	292124.41651100000	4728374.45479000000	
30	286790.58876700000	4717361.29903000000	
31	288172.05623400000	4718841.45651000000	
32	291938.56924100000	4726795.48452000000	
33	291513.63170100000	4722355.77957000000	
34	286498.38878700000	4717860.49318000000	
35	291705.70253000000	4721989.39429000000	

Appendix A. Continued.

Reach number	X coordinate	Y coordinate	Comments
		Rock Creek upper tier	
1	282496.43599200000	4715960.65555000000	
2	278692.20127000000	4713240.06532000000	
3	279264.36045200000	4706825.46753000000	
4	279875.39971500000	4714399.42703000000	
5	277512.52447900000	4706740.30934000000	
6	279122.68813200000	4710721.61707000000	
7	277305.21181300000	4705504.52882000000	
8	276637.00127100000	4712214.32075000000	
9	276603.54544100000	4706509.42377000000	
10	280362.94717900000	4713307.17825000000	
11	278527.41359100000	4703561.18613000000	
12	280107.34548300000	4714550.44384000000	
13	278874.65913200000	4713448.98595000000	
14	279077.97137000000	4708520.50662000000	
15	279335.52107600000	4707921.97268000000	
16	278903.83076400000	4710181.24121000000	
17	276612.24130600000	4705398.22232000000	
18	282476.17368100000	4715734.40052000000	
19	276163.31237200000	4707458.72225000000	
20	280906.68628000000	4713794.37713000000	
21	277904.97890900000	4704557.86799000000	
22	280546.81352000000	4714728.28455000000	
23	277870.44168700000	4713066.14251000000	
24	278611.46621300000	4708495.53182000000	
25	279415.69350500000	4705827.74034000000	
26	276524.55573000000	4712108.58390000000	
27	277421.01526200000	4705380.04919000000	
28	275688.98788500000	4706479.29267000000	
29	281409.68022400000	4715636.09801000000	
30	275113.13582800000	4709725.09275000000	
31	276064.19191900000	4706828.54099000000	
32	279562.84156200000	4711982.95721000000	
33	277370.58695100000	4712850.78445000000	
34	275669.09395700000	4711807.01059000000	
35	276090.98676300000	4705225.95773000000	

Appendix B. Electrofishing settings, conditions, and fish collected.

Reach	Date	Time	Water temp (C)	Conductivity (µS)	Weather	Electrofishing				Species	N	FL (mm)	
						Time (sec)	Volts	Freq. (Hz)	Duty cycle (%)			Mean (SD)	Range
Virgin Creek lower tier													
1	8/3/11	1430	18.0	192.7	Hot/clear	231	325	30	14	Trout	10	105.7 (52.86)	44-186
2	8/3/11	1145	13.4	176.4	Sunny	118	300-325	30	12	No fish	---	---	---
5	8/16/11	1240	15.2	200	Sunny	135	325-375	30	14	Trout	7	128.1 (40.29)	53-186
8	8/2/11	1400	17.0	--	Sunny	128	325-375	30	14	Trout	13	106.1 (44.02)	46-181
										Alvord chub	7	72.1 (12.02)	54-88
11	8/16/11	1025	14.3	196	Clear/cool	151	300-375	30	12-14	trout	24	129.5 (47.12)	37-213
12	8/18/11	1415	18.5	153.2	Clear/hot	122	325-375	30	12-14	Alvord chub	11	74.5 (16.18)	57-104
20	8/16/11	1445	16.8	195.2	Sunny	140	350-375	30	14	Trout	11	93.9 (76.48)	40-283
Virgin Creek middle tier													
4	8/9/11	1300	15.5	127	Partly cloudy/breezy/ hot	137	300	30	12	No fish	---	---	---

Appendix B. Continued.

Reach	Date	Time	Water temp (C)	Conductivity (µS)	Weather	Electrofishing				Species	N	FL (mm)	
						Time (sec)	Volts	Freq. (Hz)	Duty cycle (%)			Mean (SD)	Range
6	8/7/11	1509	20.4	107.7	Partly cloudy/hot	137	300	30	12	No fish	---	---	---
7	8/8/11	1112	11.0	122.7	Breezy/clear/ warm	110	300	30	12	Not fish	---	---	---
19	8/9/11	1600	16.5	78.8	Partly cloudy/breezy/ warm	110	300-350	30	12	No fish	---	---	---
22	8/7/11	1245	21.7	102.8	Hot/partly cloudy	106	300	30	12	No fish	---	---	---
24	8/9/11	1440	14.1	56.8	Partly cloudy/breezy/ hot	112	300	30	14	No fish	---	---	---
25	8/15/11	1030	14.5	75.6	Partly cloudy/breezy/ cool	102	325	30	12	No fish	---	---	---
					Virgin Creek upper tier								
20	8/18/11	1200	16.5	112.3	Clear/hot	85	325	30	12	No fish	---	---	---
26	9/5/11	1140	15.5	183.6	Partly cloudy/hot	110	300	30	12	No fish	----	---	---
					Fish Creek lower tier								
14	9/16/11	1200	16.2	168.1	Clear/cool	297	325	30	12	Sheldon tui chub	64	41.0 (17.85)	21-119

Appendix B. Continued.

Reach	Date	Time	Water temp (C)	Conductivity (µS)	Weather	Electrofishing				Species	N	FL (mm)	
						Time (sec)	Volts	Freq. (Hz)	Duty cycle (%)			Mean (SD)	Range
30	9/16/11	1045	15.3	177.2	Clear/cool	247	200-350	30	12	Sheldon tui chub	47	39.3 (6.32)	23-59
Fish Creek middle tier													
3	9/17/11	1045	10.8	101.9	Clear/cool	154	325	30	12	Sheldon tui chub	3	42.0 (6.56)	36-49
23	9/17/11	1150	15.2	110.2	Clear/cool	101	325	30	12	No fish	---	---	---
24	9/17/11	0920	7.7	129.2	Clear/cool	220	325	30	12	Sheldon tui chub	6	39.2 (4.65)	32-44
27	9/16/11	1415	17.9	141.2	Cloudy/cool/ breezy	316	325	30	12	Sheldon tui chub	54	41.4 (17.81)	19-107
Guano Creek lower tier													
1	8/29/11	1205	15.4	80.4	Clear/hot	138	375-400	30-34	18	No fish	---	---	---
2	8/30/11	1330	17.5	81.5	Clear/hot/ breezy	190	375	30	16	No fish	---	---	---
3	8/29/11	1105	15.2	80.2	Clear/hot	202	375-400	30	16-18	No fish	---	---	---
4	9/1/11	1250	11.5	72.4	Clear/warm	194	350-375	30	16	Trout	11	176.7 (69.62)	61-311
5	8/30/11	1230	17.8	82.3	Clear/hot/ breezy	184	375	30	16	No fish	---	---	---

Appendix B. Continued.

Reach	Date	Time	Water temp (C)	Conductivity (µS)	Weather	Electrofishing				Species	N	FL (mm)	
						Time (sec)	Volts	Freq. (Hz)	Duty cycle (%)			Mean (SD)	Range
7	8/30/11	1015	15.2	80.1	Clear/cool/ breezy	203	375-400	30	16	No fish	---	---	---
8	9/1/11	1030	10.0	73.7	Clear/cool/ breezy	162	350	30	16	Trout	16	153.7 (58.14)	74-306
Guano Creek middle tier													
6	8/22/11	1635	16.1	73.2	Clear/breezy/ Warm	177	400	30	18	trout	25	101.1 (49.82)	51-228
21	8/22/11	1530	16.0	76.0	Sunny/warm	214	375-400	30	16-18	Trout	14	139.9 (69.71)	53-284
23	9/1/11	1600	11.8	74.5	Clear/cool/ breezy	132	375	30	16	Trout	2	126 (4.24)	123-129
24	8/31/11	1115	11.5	76.4	Clear/cool/ breezy	194	350-375	30	16-18	trout	6	133.2 (59.74)	64-219
25	8/31/11	1410	12.8	71.2	Clear/warm	193	350-375	30	16	trout	6	123.5 (40.42)	60-173
26	8/31/11	1245	12.4	74.3	Clear/cool/ breezy	188	350-375	30	16	Trout	8	158.0 (62.86)	63-267
Guano Creek upper tier													
1	8/21/11	1030	--	--	Clear/hot	80	350	30	14	1 fish obs	---	---	---

Appendix B. Continued.

Reach	Date	Time	Water temp (C)	Conductivity (µS)	Weather	Electrofishing				Species	N	FL (mm)	
						Time (sec)	Volts	Freq. (Hz)	Duty cycle (%)			Mean (SD)	Range
4	8/20/11	1130	11.2	56.8	Partly cloudy/breezy/ warm	141	375	30	16	No fish	---	---	---
5	8/20/11	1000	9.6	52.0	Partly cloudy/cool	105	375	30	16	Trout	2	179.0 (25.46)	161-197
7	9/2/11	0940	8.4	90.2	Clear/cool/ breezy	120	300-350	30	16	2 fish obs	---	---	---
9	8/21/11	1600	13.4	47.1	Hot/cloudy/rain	202	375	30	16	Trout	11	149.2 (58.42)	74-255
10	8/21/11	1400	11.2	52.6	Partly cloudy/hot	112	375	30	16	No fish	---	---	---
12	8/23/11	1135	14.0	84.2	Clear/hot	140	325	30	16	No fish	---	---	---
					Willow Creek								
---	9/3/11	AM	6-13	---	---	---	---	---	---	Redband	11	144.1 (45.13)	61-204

Appendix C. Habitat characteristics summarized by reach.

Reach Date	Width (m)			Mean depth (m)	Max depth (m)	Bank vegetation and condition (%)						Slope (%)	Habitat type (%)			Shade (%)	Substrate type (%)[1]					LWD[2]
	Wetted	Bank full	Cover (%)			Bare	Grass forbs	Brush	Shrub tree	Eroding	Under cut		Pool	Riffle	Run		FI	GR	CO	BO	BR	
Virgin Creek lower tier																						
1 8/3	2.37 (1.04)	6.44 (3.04)	54.8	0.33 (0.14)	0.64	23	7	45	25	0	0	1	42	22	36	88.3	50	0	30	0	20	0
2 8/3	3.23 (0.99)	4.66 (1.01)	94.7	0.22 (0.21)	0.64	0	16	80	4	0	0	3	4	10	86	76.8	88	1	2	9	0	0
5 8/16	3.08 (1.61)	6.49 (1.58)	28.1	0.43 (0.27)	0.80	0	0	6	94	0	0	1.5	46	8	46	85.9	61	20	12	1	6	0
8 8/2	2.81 (1.33)	6.42 (3.51)	10.0	0.45 (0.53)	>1.6	55	45	0	0	0	0	4	52	48	0	87.0	34	20	15	9	22	0
11 8/16	2.04 (1.09)	7.68 (1.79)	55.1	0.32 (0.24)	0.82	41	5	23	31	0	0	1	66	34	0	93.3	18	14	37	19	12	0
12 8/16	1.59 (0.47)	29.59 (1.70)	55.2	0.36 (0.16)	0.60	0	78	22	0	0	0	1	90	0	10	58.4	56	44	0	0	0	0
20 8/16	2.62 (0.98)	6.69 (0.55)	64.2	0.15 (0.09)	0.36	4	3	18	75	2	0	1	18	42	40	87.0	32	45	22	1	0	0
Virgin Creek middle tier																						
4 8/9	1.27 (0.30)	3.51 (1.15)	86.1	0.11 (0.04)	0.20	9	11	80	0	0	0	3	0	100	0	61.2	96	4	0	0	0	0
6 8/7	1.62 (0.58)	5.18 (2.09)	79.2	0.10 (0.07)	0.34	0	72	28	0	0	0	2	2	98	0	58.4	100	0	0	0	0	0
7 8/8	2.14 (0.50)	4.29 (0.79)	99.7	0.14 (0.08)	0.28	3	11	86	0	0	0	2	0	100	0	59.9	100	0	0	0	0	0
19 8/9	2.13 (1.10)	38.33 (15.38)	96.7	0.15 (0.09)	0.31	0	23	77	0	0	0	2.5	0	100	0	58.4	100	0	0	0	0	0
22 8/7	1.45 (0.41)	3.28 (0.95)	85.8	0.06 (0.05)	0.18	10	90	0	0	0	0	6	0	100	0	58.4	100	0	0	0	0	0
24 8/9	1.81 (2.11)	--	98.0	0.03 (0.03)	0.12	0	52	38	10	0	0	16	0	100	0	71.8	90	6	4	0	0	0

[1] FI=fines, GR=gravel, CO=cobble, BO=boulder, BR=bedrock.
[2] Large woody debris, number of pieces within sample reach.

Appendix C. Continued.

Reach Date	Width (m)			Mean depth (m)	Max depth (m)	Bank vegetation and condition (%)						Slope (%)	Habitat type (%)			Shade (%)	Substrate type (%)[1]					LWD[2]
	Wetted	Bank full	Cover (%)			Bare	Grass forbs	Brush	Shrub tree	Eroding	Under cut		Pool	Riffle	Run		FI	GR	CO	BO	BR	
25 8/15	2.96 (0.65)	4.51 (0.54)	100	0.05 (0.04)	0.12	0	49	51	0	0	0	2	0	100	0	58.4	100	0	0	0	0	0
Virgin Creek upper tier																						
20 9/5	2.81 (2.83)	7.10 (3.71)	89.3	0.14 (0.11)	0.32	0	82	18	0	0	0	4.5	18	0	82	58.4	92	4	4	0	0	0
26 9/5	2.47 (1.29)	5.71 (0.78)	91.6	0.08 (0.05)		5	0	80	15	0	0	1	6	94	0	86.4	58	15.4	27	2.6	0	0
Fish Creek lower tier																						
14 9/16	3.18 (1.29)	8.74 (3.29)	3.5	0.32 (0.12)	0.60	9	35	56	0	0	0	1	90	0	10	58.4	48	50	2	0	0	0
30 9/16	2.74 (1.46)	7.60 (1.03)	12.0	0.35 (0.16)	0.59	1	62	37	0	0	0	0.5	60	16	24	58.4	50	34	16	0	0	0
Fish Creek middle tier																						
3 9/17	3.24 (2.30)	64.51 (13.42)	69.4	0.13 (0.04)	0.26	0	50	50	0	0	0	1	0	100	0	58.4	100	0	0	0	0	0
23 9/17	1.22 (0.39)	4.67 (0.85)	15.6	0.08 (0.03)	0.14	0	80	20	0	0	0	5	0	100	0	58.4	34	19	44	3	0	0
24 9/17	4.12 (0.86)	7.71 (1.22)	80.1	0.15 (0.07)	0.31	35	42	23	0	29	0	0.5	0	0	100	58.4	100	0	0	0	0	0
27 9/16	7.86 (0.79)	13.80 (2.25)	68.8	0.34 (0.12)	0.52	15	58	27	0	13	0	1	78	0	22	58.4	100	0	0	0	0	0
Guano Creek lower tier																						
1 8/29	6.18 (2.10)	8.38 (2.13)	95.8	0.50 (0.26)	1.40	0	100	0	0	0	0	1	40	0	60	58.4	70	20	10	0	0	0
2 8/29	6.99 (2.05)	10.76 (2.15)	85.5	0.37 (0.28)	0.84	0	0	100	0	0	0	1	52	0	48	58.4	30	48	22	0	0	0
3 8/29	5.71 (1.31)	8.98 (1.46)	85.8	0.33 (0.19)	0.78	0	100	0	0	0	0	1.5	47	0	53	58.4	84	16	0	0	0	0

Appendix C. Continued.

Reach Date	Width (m)			Mean depth (m)	Max depth (m)	Bank vegetation and condition (%)						Slope (%)	Habitat type (%)			Shade (%)	Substrate type (%)[1]					LWD[2]
	Wetted	Bank full	Cover (%)			Bare	Grass forbs	Brush	Shrub tree	Eroding	Under cut		Pool	Riffle	Run		FI	GR	CO	BO	BR	
4 9/1	1.82 (0.49)	5.71 (0.47)	0	0.36 (0.12)	0.53	0	17	66	20	0	0	1	0	0	100	58.4	45	44	8	3	0	0
5 8/30	2.69 (1.72)	5.26 (1.52)	100	0.34 (0.17)	0.80	0	100	0	0	0	0	0.5	90	0	10	58.4	100	0	0	0	0	0
7 8/30	4.82 (1.83)	9.54 (1.97)	90.0	0.31 (0.28)	0.85	0	100	0	0	0	0	0.5	90	0	10	58.4	54	12	30	4	0	0
8 9/1	1.27 (0.28)	3.72 (1.19)	3.2	0.33 (0.18)	0.70	0	82	18	0	0	0	1	8	10	82	58.4	51	48	1	0	0	0
Guano Creek middle tier																						
6 8/22	1.96 (0.62)	2.53 (0.47)	38.8	0.30 (0.12)	0.59	0	100	0	0	0	0	1	0	0	100	58.4	24	76	0	0	0	0
21 8/22	1.38 (0.26)	1.87 (0.80)	3.1	0.34 (0.11)	0.60	0	100	0	0	0	10.5	1	0	0	100	58.4	26	74	0	0	0	0
23 9/1	1.82 (0.40)	--	81.8	0.38 (0.09)	0.53	0	100	0	0	0	7	3.5	0	2	98	81.8	10	44	46	0	0	0
24 8/31	1.29 (0.22)	2.52 (0.54)	11.7	0.24 (0.09)	0.46	0	98	0	2	0	8.5	2	0	0	100	58.4	0	80	19	1	0	0
25 8/31	1.48 (0.37)	1.72 (0.35)	48.2	0.23 (0.07)	0.36	0	100	0	0	0	19	2	0	0	100	60.6	18	52	30	0	0	0
26 8/31	1.55 (0.45)	3.93 (1.12)	12.1	0.36 (0.11)	0.52	0	100	0	0	0	5	1	0	0	100	58.4	36	44	19	1	0	0
Guano Creek upper tier																						
1 8/21	1.32 (0.34)	1.67 (0.39)	100	0.14 (0.09)	0.37	0	32	0	100	0	26	15	2	98	0	100	4	37	51	8	0	9
4 8/20	2.91 (3.15)	5.08 (4.90)	85.2	0.11 (0.05)	0.22	4	27	3	66	0	2	5	0	100	0	95.2	38	40	22	0	0	6
5 8/20	0.83 (0.22)	2.64 (2.15)	64.5	0.11 (0.05)	0.20	0	29	19	52	0	8	4	2	98	0	75.7	0	68	26	6	0	0

Appendix C. Continued.

Reach Date	Width (m)			Mean depth (m)	Max depth (m)	Bank vegetation and condition (%)						Slope (%)	Habitat type (%)			Shade (%)	Substrate type (%)[1]					LWD[2]
	Wetted	Bank full	Cover (%)			Bare	Grass forbs	Brush	Shrub tree	Eroding	Under cut		Pool	Riffle	Run		FI	GR	CO	BO	BR	
7 9/2	1.04 (0.74)	5.59 (1.70)	91.8	0.09 (0.06)	0.22	0	100	0	45	0	0	6	0	100	0	76.8	36	24	38	2	0	0
9 8/21	1.15 (0.18)	2.08 (0.61)	100	0.07 (0.04)	0.22	0	100	0	80	0	20.5	5	0	100	0	97.6	18	52	27	3	0	2
10 8/21	1.93 (1.73)	12.54 (15.90)	100	0.06 (0.03)	0.14	0	98	0	82	0	4	16	0	100	0	100	3	85	12	0	0	4
12 8/23	0.53 (0.06)	0.56 (0.05)	49.7	0.09 (0.03)	0.12	0	100	0	0	0	0	3	0	100	0	58.4	60	38	0	2	0	0

Appendix D. Comments about sample reaches from field notes.

Site	Comments
	Virgin Creek lower tier
1	---
2	---
5	Some beaver activity.
8	Could not measure maximum depth on transect 6. (>1.6 m)
11	---
12	Channel appears to be an excavated ditch.
20	Some beaver activity.
	Virgin Creek middle tier
4	Congested with plants.
6	---
7	No real channel through grasses until walked through.
19	Congested with plants. Wetted width is channel width, in marshy areas. Bankfull widths are approximated.
22	Bare banks from horses.
24	A lot of springs, bankfull width unmeasurable, left bank slopes downhill, right bank uphill with a defined channel for most. Water ends about 0.1 mile downstream of site, congested with plants.
25	Spring fed, grassy.
	Virgin Creek upper tier
20	Intermittent pools with overgrown mats of plants/water in between. Some horse damage.
26	---

Appendix D. Continued.

Site	Comments
	Fish Creek lower tier
14	High horse activity/damage.
30	High horse activity.
	Fish Creek middle tier
3	Many channels, wetted width measured for main channel, heavy horse activity, actual wetted area very wide but very shallow. Cover is only in main channel. In marshy area.
23	Some horse activity. Spring fed. Spring is 50 m above the sample site.
24	High horse activity, lots of frogs.
27	Horse activity on both banks.
	Guano Creek lower tier
1	Channel spits at transect 4, main channel to the left.
2	Side channel on left bank between transects 3 to 5.
3	Marshy, wide wetted area, deep.
4	Brush under trees with grass at reach 3 (i.e., between transects 3 and 4).
5	---
7	Split channel at transect 4.
8	---
	Guano Creek middle tier
6	---
21	Open meadow, meandering stream.

Appendix D. Continued.

Site	Comments
23	Wetted width is marshy area where new stream joins from the rights. Bankfull width over 70 m.
24	---
25	---
26	---
	Guano Creek upper tier
1	Mixed tree/shrub and grass, very overgrown. Tree canopy with grass understory. Thick overgrowth made electrofishing difficult. One salmonid seen but not caught. Nine pieces of LWD, all > 3 m in length and >10 cm in diameter.
4	Very overgrown with shrubs and trees. Six pieces of LWD, five > 3 m in length and > 10 cm in diameter, one is a rootwad.
5	---
7	About 30 m of site open water and 20 m with thick overgrowth. Side channel left of main the entire length of site. Tree overstory with shrub understory. Saw two small fish in thick overgrowth but could not catch with net, in faster shallow water.
9	Aspens growing in creek. Tree overstory and grass understory. LWD-two piece, both > 3 m in length and >10 cm in diameter.
10	Thick vegetative overstory (bush) and understory (grass/forb). Side channel to the left between transects 1 and2. LWD-four pieces, all > 3 m in length and >10 cm in diameter.
12	Runs through open meadow, riparian areas has moisture.
	Willow Creek
---	Spot-sampled upstream of canyon area (upstream of GRTS site 33 for upper Rock Creek), where no fish were found, and downstream (between GRTS sites 2 and 24), where fish were present. Water temperature was 6 C upstream and 11-13 C downstream.