WATERSHED MANAGEMENT ADVISORY BOARD
MEETING AGENDA

Wednesday, August 24, 2016
5:15 to 6:45 PM
Madison Avenue Meeting Room

Agenda Item	Action	Estimated Time
Introductions/Election of FY 16-17 Leadership		5
Additions/Modifications to the Agenda		5
Approval of the June 22, 2016 meeting minutes. Attached.	Action	5
Community Comments		5
City Council Report	Information	5
New Business: • FY 15/16 Forest Activities Report: Jennifer Ward	Information	5
Old Business • 2016/17 Harvest Planning: Matt Fehrenbacher • Barred Owl Study: Jennifer Ward • Annual Fish Survey: Jennifer Ward	Information Information Information	15 5 5
Staff reports: Tom Hubbard, Jennifer Ward, Matt Fehrenbacher	Information	15
Board Member Reports/Requests • WMAB Annual Report: Chairwoman McDonald • Streamflow Studies: Richard Heggen • Working Group Reports	Information	20
Adjourn		

BOARD MEMBERS:
Jessica McDonald, Chair
David Hibbs, Vice-Chair - excused
Charlie Bruce
Richard Heggen
Steve Rogers
Jacque Schreck
Sheryl Stuart

Joel Hirsch, City Council Liaison

Next Meeting: Wednesday, Sep. 28, 5:15pm, Madison Avenue Meeting Room
http://www.corvallisoregon.gov/index.aspx?page=219

WATERSHED MANAGEMENT ADVISORY BOARD
MINUTES
June 22, 2016

DRAFT

Present
Jessica McDonald, Chair
David Hibbs, Vice-Chair
Charlie Bruce
Jacque Schreck
Richard Heggen
Steve Rogers
Joel Hirsch, City Council Liaison

Staff
Jennifer Ward, Public Works
Tom Hubbard, Public Works
Mark Miller, Trout Mountain Forestry

Visitors
Ken McCall, Oregon Hunters Association
Shane Hetzler, Trout Mountain Forestry

Excused
Sheryl Stuart

SUMMARY OF DISCUSSION

Agenda Item	Information Only	Held for Further Review	Recommendations
I. Call Meeting to Order/Introductions	X		
II. Review of Agenda	X		
III. Review of April 27, 2016 Minutes			Approved
IV. Community Comments • Naming Watershed Tributaries	 N/A		
V. City Council Report			
VI. New Business • FY 16/17 Financial Overview	 X		
VII. Old Business • 2016/17 Harvest Planning • Annual Tour Debrief	 X X		
VIII. Staff Reports	X		
IX. Board Member Requests and Reports • Finance and Habitat Working Group Reports • WMAB Annual Report • Streamflow Studies • Summer Meeting Schedule	 N/A X N/A		 July meeting canceled.
X. Adjourn			

CONTENT OF DISCUSSION

I. Call Meeting to Order/Introductions
Chair McDonald called the meeting to order and those present introduced themselves.

II. Review of Agenda

Ms. Ward recommended having Mr. Miller discuss the harvest plan closer to the beginning of the meeting.

III. Review of Minutes

Board Member Bruce moved to approve the April minutes; Board Member Rogers seconded the motion and the minutes were approved unanimously.

IV. Community Comments

Visitor Ken McCall reported that he was recently at the County Museum and discovered an album with historical photos from the watershed. He has an appointment to go back and make copies of the photos.

Naming Watershed Tributaries

Not discussed.

V. City Council Report

None.

VI. New Business

FY 16/17 Financial Overview

Ms. Ward provided an overview of the City's budgeting process and shared the watershed budget for the 2016-17 fiscal year. The Board discussed the possibility of a fund reserve and asked staff to bring back numbers of what it costs to run the watershed without a harvest to get a baseline.

VII. Old Business

2016/17 Harvest Planning

Mr. Miller provided an overview of the 2016-17 harvest. He stated that the plan and layout are complete and the bid process is just beginning and should be ready by mid-September. He noted that this will be a two-year harvest plan, in two areas, with about half the acreage being cable-yarded and the other half being tractor-yarded. There are some Marbled Murrelet restrictions in the area which have been factored into the harvest plan. Overall, the harvest should produce over one million board feet over nearly 110 acres.

Annual Tour Debrief

Ms. Ward reported that approximately 30 community members attended. She shared feedback from the attendees' comment cards. Ms. Ward asked the Board if, considering the low attendance, staff should put so much effort into the annual tour. Mr. Rogers opined that more needs to be done to attract community members to the tour, as the watershed is an important resource and more people should know about it. Staff will work with the Public Information Officer to increase advertising.

VIII. Staff Reports

Mr. Hubbard reported that the emergency response plan is progressing and staff is still in the process of gathering information.

Ms. Ward reported that the watering system for Old Peak Meadow is almost ready. She will send out emails as the watering dates are determined, the first being June 30.

Ms. Ward noted that the fish survey reports were in the Board's meeting packet. She will reformat a small portion before emailing the final document to the Board and posting it to the website. The Board raised some concerns with the report and asked that they be discussed at the next meeting.

Mr. Miller reported the following:

- He has taken a number of tours to the watershed.
- Siuslaw National Forest has discovered some discrepancies in its Marbled Murrelet and Spotted Owl data for its harvests. The discrepancy at the National Forest is internally generated and does not impact harvests on the Corvallis Forest or the endangered species survey data on which harvests are based.

IX. Board Member Requests and Reports

Finance and Habitat Working Group Reports
Both groups had nothing to report.

WMAB Annual Report
Chair McDonald presented a draft of the report and asked the Board to submit suggestions for the report via email to finalize the report for the next meeting.

Streamflow Studies
Not discussed.

Summer Meeting Schedule
The Board agreed to cancel the July meeting.

X. Adjourn

The meeting was adjourned at 6:55 p.m.

NEXT MEETING: August 24, 2016, 5:15 p.m., Madison Avenue Meeting Room

Effects of Experimental Removal of Barred Owls on Population Demography of Northern Spotted Owls in Washington and Oregon—2015 Progress Report

Open-File Report 2016–1041

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

Effects of Experimental Removal of Barred Owls on Population Demography of Northern Spotted Owls in Washington and Oregon—2015 Progress Report

By J. David Wiens, Katie M. Dugger, Krista E. Lewicki, and David C. Simon

Open-File Report 2016-1041

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

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

U.S. Geological Survey, Reston, Virginia: 2016

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
	Volume	
acre-foot	1,233.48	cubic meter

International System of Units to Inch/Pound

Multiply	By	To obtain
	Volume	
liter (L)	0.2641	gallon (gal)

Effects of Experimental Removal of Barred Owls on Population Demography of Northern Spotted Owls in Washington and Oregon—2015 Progress Report

By J. David Wiens[1], Katie M. Dugger[2], Krista E. Lewicki[1], and David C. Simon[1]

Abstract

Evidence indicates that competition with newly established barred owls (*Strix varia*) is causing rapid declines in populations of northern spotted owls (*Strix occidentalis caurina*), and that the long-term persistence of spotted owls may be in question without additional management intervention. A pilot study in California showed that lethal removal of barred owls in combination with habitat conservation may be able to slow or even reverse population declines of spotted owls at local scales, but it remains unknown whether similar results can be obtained in larger areas with different forest conditions and where barred owls are more abundant. In 2015, we implemented a before-after-control-impact (BACI) experimental design on two study areas in Oregon and Washington with at least 20 years of pre-treatment demographic data on spotted owls to determine if removal of barred owls can improve population trends of spatially associated spotted owls. Here we provide an overview of our research accomplishments and preliminary results in Oregon and Washington in 2015.

Background and Study Objectives

Barred owls (*Strix varia*) have expanded their geographic range from eastern to western North America, and their newly expanded range now completely overlaps that of the federally threatened northern spotted owl (*S. occidentalis caurina*). Evidence indicates that competition with invading barred owls is causing rapid declines in populations of spotted owls, and that the long-term persistence of spotted owls may be in question without additional management intervention (Wiens and others, 2014; Dugger and others, 2016). A pilot study in coastal California indicated that lethal removal of barred owls in combination with habitat conservation may be able to slow or even reverse population declines of spotted owls at local scales (Diller and others, 2016), but it remains unknown whether similar results can be obtained in larger areas with different forest conditions and where barred owls are more abundant.

[1]U.S. Geological Survey.
[2]Oregon Cooperative Fish and Wildlife Research Unit.

In 2013, the U.S. Fish and Wildlife Service released a Final Environmental Impact Statement and Record of Decision for the experimental removal of barred owls to benefit northern spotted owls (U.S. Fish and Wildlife Service, 2013). Four study areas were identified with at least 20 years of pre-treatment demographic data on spotted owls to test whether competitive interactions with barred owls cause population declines of spotted owls, and if so, whether active management of barred owls can improve population trends of spotted owls. Experimental removals were initiated in Hoopa/Willow Creek in northern California in 2013. Preliminary results from that portion of the study are summarized by Higley (2014, Barred owl experimental removal: Hoopa study area end of season report) and Franklin and others (2015).

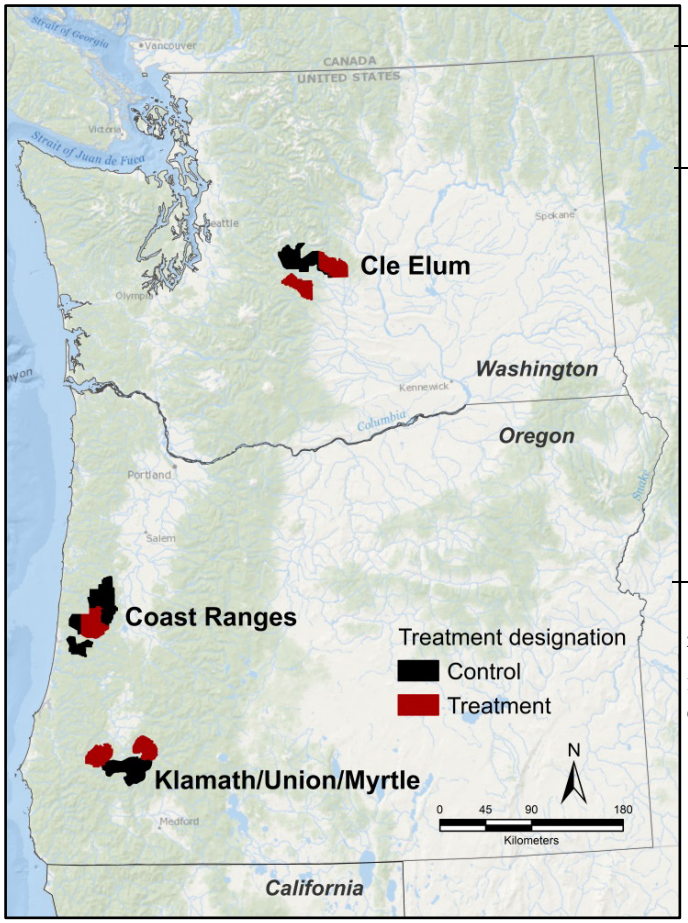
In 2015, we initiated surveys and experimental removal of barred owls in three study areas in Washington and Oregon. The overarching goal of the study is to test the research hypothesis that the presence of barred owls causes declines in the population rate of change of spotted owls (λ), or one of the demographic components driving declines in populations (survival, reproduction, recruitment, site occupancy dynamics; Johnson and others, 2008). Specific objectives are to:

1. Determine the effect of experimental removal of barred owls on population dynamics of spotted owls with respect to site-occupancy dynamics, reproductive output, survival, recruitment, and annual rate of population change (λ_t).
2. Estimate pre- and post-removal differences in the proportion of area used and intensity of use by barred owls in control and treatment portions of each study area.
3. Estimate the amount of effort and cost required to maintain low numbers of barred owls and achieve positive effects on vital rates of territorial spotted owls

Herein we provide an overview of our research accomplishments in Oregon and Washington in 2015.

Experimental Study Areas

In 2015, we initiated the study in three study areas in Washington and Oregon (fig. 1). The study areas vary in climate, vegetation composition, and topography, but all are dominated by conifer or mixed conifer-hardwood forests (Dugger and others, 2016). These areas were selected based on many considerations, including availability of pre-treatment demographic data on spotted owls, land ownership, and the need to identify the effect of barred owls on spotted owls across the broad range of forest conditions (U.S. Fish and Wildlife Service, 2013). The study areas are comprised of mostly federal lands, but fieldwork also occurred on adjacent State and private lands with the written permission of the landowner. A mixture of ownerships was included so that results and inferences from the study would not be limited to certain ownerships and forest conditions in the spotted owl's geographic range.



Study area and treatment level	Area (km^2)	Number of historical spotted owl territories	Number of barred owl survey hexagons[1]
Cle Elum			
Treatment	775	45	113
Control	670	32	111
Coast Ranges			
Treatment	607	46	106
Control	1,085	58	176
Klamath/Union/Myrtle[2]			
Treatment	765	83	146
Control	755	86	136

[1]Barred owl survey hexagons are 500-ha each in size.

[2]Fieldwork on this study area was not completed in 2015 because of insufficient land access to conduct pre-treatment surveys of barred owls.

Figure 1. Control (no barred owls removed) and treatment (barred owls removed) portions of three study areas in Washington and Oregon used to examine the effects of experimental removal of barred owls on population demography of northern spotted owls.

Methods

Owl Surveys and Demographic Monitoring

This study uses species-specific surveys of spotted owls and barred owls to track annual changes in populations of both species on control and treatment portions of each study area. Surveys of spotted owls were conducted by biologists and agencies already responsible for the long-term demographic monitoring of northern spotted owls under the Northwest Forest Plan (Lint and others, 1999, Dugger and other, 2016). Under this monitoring program, spotted owls are surveyed each year to document site occupancy, locate owls, confirm bands of previously color-marked owls, band previously unmarked owls, and determine the number of young produced by territorial pairs. Demographic monitoring of spotted owls will continue in all study areas over the duration of the experiment to document post-treatment population trends.

We used a survey protocol specifically developed for barred owls (U.S. Fish and Wildlife Service, 2015) in combination with the general occupancy survey design developed by Wiens and others (2011) to track annual changes in occurrence and intensity of use of barred owls on control and treatment portions of each study area. Our sampling scheme for barred owls used a standard occupancy design (MacKenzie and others, 2002, 2006) in which a grid of 500-ha hexagons (Wiens and others, 2011) were overlaid on each study area and surveyed repeatedly over three sampling periods: March 1–May 8 (Period 1); May 9–July 17 (Period 2); and July 18–September 30 (Period 3). Sampling periods were established to approximate mean transition dates between incubation, nestling, and fledgling-dependency breeding stages of barred owls (Wiens and others, 2011, 2014). During each survey occasion, observers used an amplified megaphone (Wildlife Technologies, Manchester, N.H.) to broadcast digitally recorded barred owl calls at established call points distributed to provide complete coverage of each survey hexagon. A hexagon was considered to be used by a territorial pair of barred owls if: (1) both sexes were observed within 400 m of each other on ≥1 visits; (2) both sexes were observed perched together at the same time; or (3) at least one adult was observed with young (Wiens and others, 2011). Additional details on the survey design and field protocols we used to survey barred owls are provided in Wiens and others (2011) and U.S. Fish and Wildlife Service (2015).

Barred Owl Removals

We used well-established field protocols for experimental removal and scientific collection of barred owls (U.S. Fish and Wildlife Service, 2013; Diller and others, 2014, 2016). We primarily used lethal removal methods for barred owls. Barred owls detected in treatment areas during surveys were lethally removed using 12-gauge shotguns with non-toxic bird shot. Our protocol for removals prohibits collection of nesting barred owls with dependent young (U.S. Fish and Wildlife Service, 2013). As a consequence, removals occurred during the nonbreeding season (September–March). We anticipated frequent colonization of barred owls into areas where barred owls have been removed (Yackulic and others, 2014; Diller and others, 2014, 2016), so we conducted regular follow-up visits to determine occupancy at these sites and conduct additional removals of barred owls as needed. These efforts will ultimately permit us to estimate re-colonization rates of experimental treatment areas by barred owls following removals.

Lethal and non-lethal removal of barred owls was authorized under Federal Fish and Wildlife Permit No. M1B14305B-4, Oregon Department of Fish and Wildlife Scientific Taking Permit No. 111-15, and Washington State Scientific Collection Permit No. HENSON 15-290. All survey and removal methods, and field personnel engaged in these activities, were approved by the Institutional Animal Care and Use Committee (IACUC) at Oregon State University prior to initiating fieldwork.

Data Summary and Analysis

We used survey data on spotted owls to summarize pre-treatment occupancy and reproductive status of spotted owls on control versus treatment portions of the Cle Elum and Coast Ranges study areas. We followed Lint and others (1999) in determining site occupancy, pair status, and reproduction of spotted owls. We used Theissen polygons (Dugger and others, 2016) to delineate historical territories used by spotted owls in each study area. For barred owls, we summarized survey detections of territorial pairs obtained during the breeding season using: (1) the mean center of repeated survey detections of a territorial pair; or (2) the location of fledged young (Wiens and others, 2011). We used this method to characterize general numbers and distribution of territorial pairs of barred owls detected in control versus treatment portions of each study area, but relied on estimation methods described below to more accurately quantify and track the occurrence of barred owls in these landscapes.

Estimation of Proportion of Area Used and Intensity of Use by Barred Owls

We used single-season occupancy models (MacKenzie and others, 2002, 2006) in program MARK (White and Burnham, 1999) to estimate the probability of detecting ≥1 barred owl at sampling unit i during survey occasion t, given presence (p), and the proportion of sampled area used by barred owls (ψ). This method uses the spatial pattern of detections and non-detections over repeated visits to sample sites to estimate occurrence of a species while accounting for imperfect detection during surveys. A sample site in our study was a 500-ha hexagon used to survey barred owls. Territory boundaries of individual barred owls may overlap >1 survey hexagon, so we interpreted the occupancy parameter (ψ) as the probability of ≥1 barred owl using a hexagon during the breeding season (MacKenzie and others, 2006). For each study area, we considered models where detection probabilities (p) were held constant, varied with survey occasion (t), or increased/decreased from survey Period 1 to Period 3 (T). We assessed evidence for a pre-treatment difference in ψ and p between control and treatment sites by comparing support for models with and without treatment area effects. In total, we ranked eight candidate models using information-theoretic methods (Burnham and Anderson, 2002). We assessed fit of single-season occupancy models to our data using a bootstrap estimate of the Pearson's chi-square statistic (MacKenzie and Bailey, 2004).

As an alternative measure of barred owl occurrence, we explored the use of the Royle/Nichols occupancy-abundance model (Royle and Nichols, 2003) to estimate intensity of use of sample sites by barred owls. This model estimates density (λ, the average number of individuals per sample site), and assumes that detection histories among sample sites are independent. Our survey protocols minimized the likelihood of detecting the same individuals in adjacent sampling units, but we could not rule out this possibility entirely because sample plots were not centered on actual territories and barred owls were not individually marked. As a consequence, estimates of λ are likely to overestimate actual density of barred owls, so we interpreted estimates of λ as the average number of individuals using a sample unit, and r_i as the unconditional probability of detecting ≥1 barred owl at sampling unit i during the breeding season (Royle and Nichols, 2003). The model assumes that use intensity across sites follows a Poisson distribution (with mean=λ), so we also considered an alternative model with a negative-binomial distribution to test the validity of this assumption. We assessed evidence for pre-treatment

differences between control and treatment areas in λ and r by comparing models with and without treatment area effects. We did not consider time-dependency in r because the model assumes constant detection probability within a season (Royle and Nichols, 2003). All sample sites in our analysis were of equal size (500 ha), which permitted us to estimate intensity of use for an entire study area as: $\widehat{N} = \hat{\lambda} \times n_s$, and $SE(\widehat{N}) = SE(\hat{\lambda}) \times n_s$ (where $\hat{\lambda}$ is the estimated mean intensity of use per sample plot, and n_s is the number of sample sites surveyed (Royle, 2004).

Research Accomplishments and Preliminary Results

We completed surveys of barred owls on the treatment and control portions of the Cle Elum and Coast Ranges study areas during March–September, and initiated removals of barred owls on treatment portions of these study areas in September. Surveys of barred owls were initiated on the Klamath/Union/Myrtle study area but were incomplete because of delays in securing land access and research agreements with private landowners. As a consequence, experimental removal was not initiated in this study area, and we focus on preliminary results from research activities completed in Cle Elum and Coast Ranges study areas only. Land access agreements are being secured to initiate surveys and experimental removal of barred owls on the Klamath/Union/Myrtle study area in March 2016.

Owl Surveys and Demographic Monitoring

Spotted Owls

Surveys of spotted owls were completed at a total of 181 territories historically used by spotted owls on the experimental portions of the Cle Elum and Coast Ranges study areas (table 1). At least one spotted owl was detected at 36 (20%) of 181 territories, whereas territorial pairs of spotted owls were detected at a total of 21 (12%) territories. Pre-treatment, naïve (i.e., uncorrected for imperfect detection) estimates of the proportion of historical territories used by spotted owls tended to be greater in control versus treatment portions of both study areas, but sample sizes were very small. Note that estimates of occupancy and reproduction of spotted owls we report here are specific to the experimental (control/treatment) portion of each long-term demographic study area, so estimates may vary from those reported for all portions of these study areas being monitored under the Northern Spotted Owl Northwest Forest Plan Monitoring Program (for additional details, see: http://www.reo.gov/monitoring/reports/northen-spotted-owl-reports-publications.shtml).

Table 1. Northern spotted owl survey effort, detections at historical territories, and reproduction on control and treatment portions of the Cle Elum and Coast Ranges experimental study areas, Washington and Oregon, 2015.

Experimental study area	Historical spotted owl territories surveyed	Territories used by ≥1 spotted owl (% of sites surveyed)	Territories used by spotted owl pair (% of sites surveyed)	Territories with ≥1 young fledged (% of sites with pairs)
Cle Elum, Washington	77	11 (14%)	7 (9%)	3 (43%)
Treatment	45	4 (9%)	2 (4%)	1 (50%)
Control	32	7 (22%)	5 (16%)	2 (40%)
Coast Ranges, Oregon	104	28 (27%)	14 (13%)	3 (21%)
Treatment	46	10 (22%)	3 (7%)	0
Control	58	18 (31%)	11 (19%)	3 (27%)

Barred Owls

We attempted to survey each barred owl sample site on three occasions, but logistical difficulties with initial access resulted in fewer than three surveys of several sites (table 2). Future surveys will be more efficient because survey routes have been established, permission to conduct surveys on all ownerships has been secured, and the number of surveyors for each study area has been increased. We surveyed barred owls at least once at 223 and 277 sample sites over three sampling periods and recorded a total of 582 and 1,222 detections of non-juvenile barred owls in the Cle Elum and Coast Ranges study areas, respectively. On average, we observed more detections of individual barred owls per 500-ha sample sites in Coast Ranges (mean=2.91 ± 1.98 [SD]) than in Cle Elum (mean=1.93 ± 1.57 [SD] barred owls detected per site; fig. 2). In many cases, we were able to detect >1 territorial pair of barred owls simultaneously from the same call-point, which permitted us to differentiate among pairs at these sites. One sample hexagon in the Oregon Coast Ranges, for example, had 10 detections of individual barred owls during a single survey occasion, which included three territorial pairs and one additional male that was apparently single.

Based on the criteria we used to summarize survey observations of territorial pairs of barred owls, we detected a total of 141 territorial pairs in Cle Elum (77 in treatment areas, 64 in control area), and 277 territorial pairs in Coast Ranges (113 in treatment area, 164 in control area; appendix A). The mean number of pairs of barred owls detected within historical territories of spotted owls (i.e., Thiessen polygons) was 1.27 ± 1.02 (SD) in Cle Elum (range = 0–4), and 1.89 ± 1.12 (SD) in the Oregon Coast Ranges (range = 0–4), with negligible pre-treatment differences between treatment and control areas.

Table 2. Barred owl survey effort and detections obtained over three survey periods in the Cle Elum and Coast Ranges experimental study areas, Washington and Oregon, 2015.

Study area	Survey period	Survey dates	Sites surveyed	Sites with ≥1 barred owl detected (% of sites surveyed)
Cle Elum, Washington	1	March 1–May 8	90	61 (68%)
	2	May 9–July 17	120	79 (66%)
	3	July 18–September 30	143	116 (81%)
	All occasions	March 1–September 30	223	173 (78%)
Coast Ranges, Oregon	1	March 1–May 8	92	80 (87%)
	2	May 9–July 17	201	154 (77%)
	3	July 18–September 30	221	191 (86%)
	All occasions	March 1–September 30	277	245 (88%)

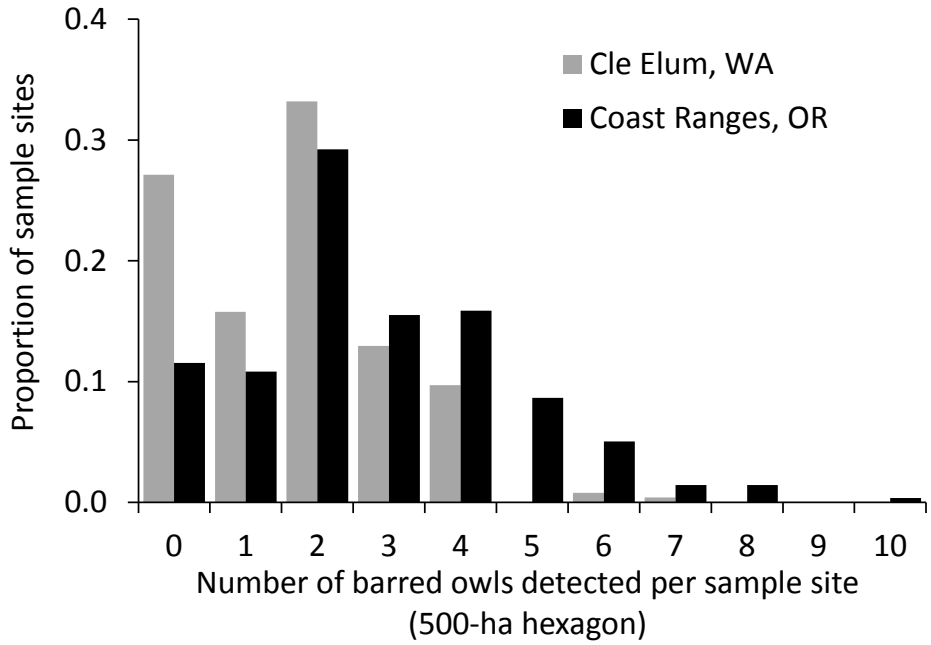


Figure 2. Proportion of sample sites (500-ha survey hexagons) with up to 10 individual barred owls detected during nighttime surveys of barred owls completed in Washington and Oregon, 2015.

Proportion of Area Used and Intensity of Use by Barred Owls

We found no evidence of lack of model fit for the Cle Elum (χ^2= 1059.0, P = 0.310, $\hat{c}$ = 1.03) or Oregon Coast Ranges (χ^2= 1411.2, P = 0.840, $\hat{c}$ = 1.02) study areas, indicating adequate fit of single-season occupancy models to survey data for barred owls. The estimated conditional probability of detecting ≥1 barred owl during a single survey occasion (p) ranged from 0.81 in Coast Ranges to 0.94 in Cle Elum (table 3). Single-season occupancy models that accounted for time-dependency among survey occasions in detection rates received greater support than models that did not (appendixes B and C). Model-averaged, pre-treatment estimates of proportion of area used (ψ) and intensity of use (λ) by barred owls varied little between treatment and control portions of each study area (table 2), and models that included an effect of treatment area on these parameters were not strongly supported by the data (appendixes B and C).

Estimates of intensity of use of control and treatment areas by barred owls (N) also were similar in each study area, although we observed wide confidence intervals around estimates in the Coast Ranges (table 3). Estimates of intensity of use from the Royle/Nichols model (λ, N) do not represent actual numbers of barred owls because individuals could have been detected in >1 sample site, which could lead to positive bias in terms of inferring density. Nonetheless, the model does permit a means to estimate use of landscapes by barred owls while accounting for large differences in the numbers of barred owls detected among sample sites (e.g., fig. 2). Future analyses will incorporate spatial data (e.g., distribution of old forest within sample plots) to account for potential sources of spatial heterogeneity in estimates of use and use intensity by barred owls. We also note that our estimates of unconditional detection (r) from the Royle/Nichols model assumed constant detection rates during the breeding season—an assumption that was probably violated given the level of within-season variation we found in the conditional probability of detection (p). We were uncertain how within-season variation in detection rates might have influenced estimates of intensity of use, but per-visit detection rates were consistently high (>80%), so bias of parameter estimates should be minimal.

Table 3. Model averaged estimates, with standard errors (SE) and lower (LCI) and upper (UCI) 95%-confidence intervals, of the proportion of area used (ψ), intensity of use of 500-ha sample sites (λ), and conditional (p) and unconditional (r) probabilities of detection for barred owls in two study areas in Washington and Oregon, 2015.

[An index of total numbers of barred owls using treatment versus control portions of each study area (N) is also included]

Parameter	Cle Elum, Washington				Coast Ranges, Oregon			
	Estimate	SE	LCI	UCI	Estimate	SE	LCI	UCI
$\psi_{treatment}$	0.835	0.038	0.747	0.896	0.969	0.020	0.891	0.992
$\psi_{control}$	0.814	0.039	0.725	0.879	0.967	0.019	0.902	0.990
$p_{period\ 1}$	0.816	0.052	0.692	0.897	0.883	0.035	0.794	0.937
$p_{period\ 2}$	0.838	0.048	0.721	0.912	0.806	0.042	0.710	0.876
$p_{period\ 3}$	0.938	0.026	0.827	0.979	0.885	0.026	0.823	0.928
$\lambda_{treatment}$	1.918	0.270	1.388	2.447	4.755	1.645	1.531	7.978
$\lambda_{control}$	1.869	0.262	1.355	2.382	4.476	1.393	1.747	7.206
r_{season}	0.679	0.070	0.529	0.799	0.378	0.109	0.197	0.601
$N_{treatment}$	427.6	60.2	309.6	545.7	1317.1	455.6	424.2	2210.0
$N_{control}$	416.7	58.4	302.2	531.2	1240.0	385.8	483.8	1996.2

Barred Owl Removals

Experimental removal of barred owls was initiated in late September in treatment portions of the Cle Elum and Coast Ranges experimental study areas, and will continue through March 2016. As a consequence, we report preliminary results through December 31, 2015 only. From September 19 to December 31, we removed a total of 254 individual barred owls in Washington and Oregon (116 females, 128 males, and 10 barred owls of undetermined sex; table 4). This represented approximately 46 and 44% of the total number of individual barred owls detected during surveys of treatment areas in Cle Elum and Coast Ranges, respectively. We anticipate the number of barred owls removed to increase as we continue to expand removal activities during January–March 2016. The preliminary sample included a minimum of 71 territorial pairs of barred owls (i.e., cases where a male and female were both collected within 150-m apart on the same removal occasion). With one exception, we used lethal removal methods for all barred owls collected. The exception was a single adult male barred owl that was captured in the Coast Ranges treatment area and transported to a permanent holding facility at the High Desert Museum in Bend, Oregon, for educational purposes.

Table 4. Total number of individual barred owls removed from treatment portions of the Cle Elum and Oregon Coast Ranges study areas, Washington and Oregon, September–December 2015.

Month, 2015	Cle Elum, Washington	Coast Ranges, Oregon
September	27	15
October	74	83
November	5	44
December	1	5
Total	107 (50 female, 54 male, 3 undetermined sex)	147 (66 female, 74 male, 7 undetermined sex)

We fired 258 shots from 12-gauge shotguns to lethally remove 253 barred owls from experimental treatment areas. We had three cases where the first shot was not lethal so a second shot was immediately taken, and two cases where a shot was taken that apparently missed the bird. Both missed shots were taken from close range (<15 yards), and in both cases the targeted owl was observed flying away into the forest canopy, apparently unharmed. Nineteen (7.5%) of 253 barred owls required euthanasia to ensure rapid death following a single, apparently non-lethal shot. Euthanasia was administered immediately following a non-lethal shot using a Ballista penetrating bolt device (Bunny Rancher, Frankfort ME) approved for use on barred owls by the IACUC. We successfully recovered 252 carcasses of barred owls following lethal removal; we were unable to recover the carcass of one female barred owl in Cle Elum that got stuck in a tree that was unsafe to climb.

Schedule to Completion

Year	Tasks
Year 1 (2015)	• Survey both species on control and treatment areas (March–August) • Initiate removals of barred owls on designated treatment areas in Coast Ranges (COA) and Cle Elum (CLE; September–December) • **Year 1 progress report** summarizing surveys and removals (February 2016)
Year 2 (2016)	• Continue removal of barred owls on COA and CLE treatment areas during the non-breeding season (January–March) • Survey both species on control and treatment areas (March–August); initiate pre-treatment surveys on Klamath (KLA) • Conduct removals of barred owls on designated treatment areas in COA and CLE; initiate removals on KLA (September–December) • **Year 2 progress report** including a preliminary analysis of first-year treatment effects on barred owls in COA and CLE (January 2017)
Year 3 (2017)	• Conduct opportunistic removal of barred owls in all treatments (January–March) • Survey both species on control and treatment areas (March–August) • Conduct removals of barred owls on designated treatment areas (September–December) • **Year 3 progress report** (January 2018)
Year 4 (2018)	• Conduct opportunistic removal of barred owls (January–March) • Survey both species on control and treatment areas (March–August) • Conduct removals of barred owls on designated treatment areas (September–December) • **Year 4 progress report** including an assessment of treatment effect on occupancy, survival, and λ_t of spotted owls; determine study area-specific need to continue experiment for additional year(s) in COA and CLE
Year 5 (2019)	• If needed and decided upon by all study participants based on results of study in Year 4, conduct additional removals of barred owls on designated treatment areas (January–March) • Conduct opportunistic removals of barred owls on KLA (September–December) • Survey both species on control and treatment areas (March–August) • **Year 5 progress report** including an assessment of treatment effect on occupancy, survival, and λ_t of spotted owls; determine need to continue experiment for additional year(s) (January 2019)

Acknowledgments

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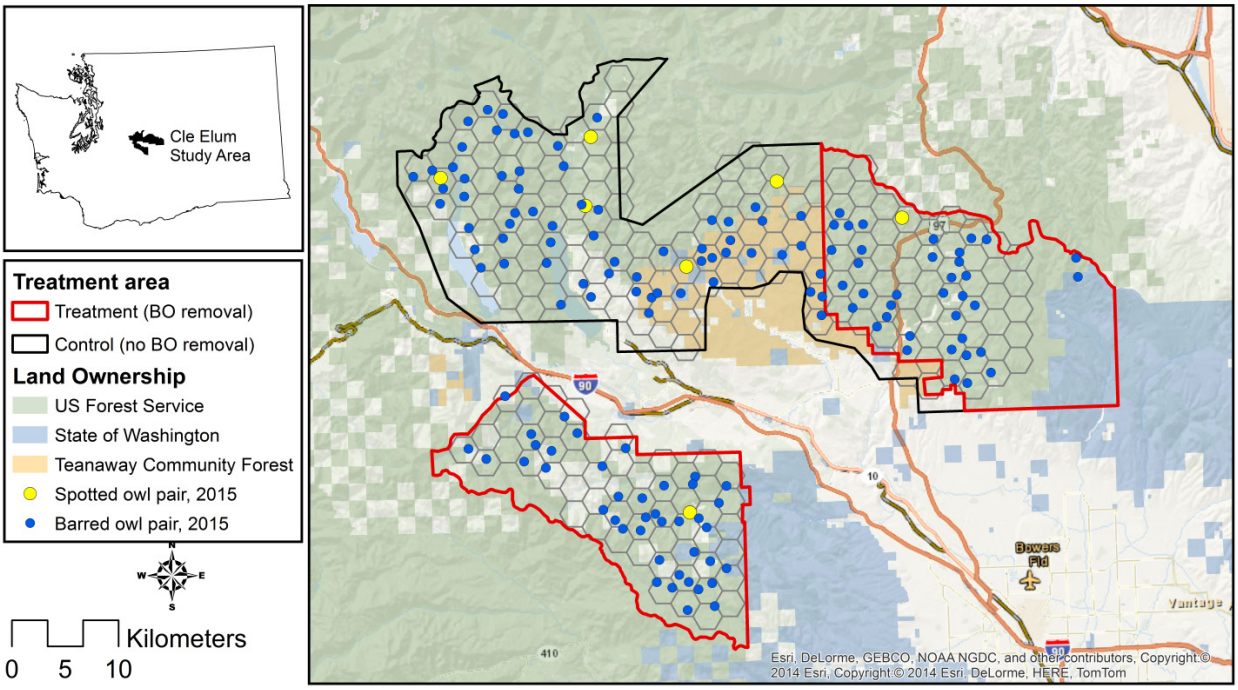
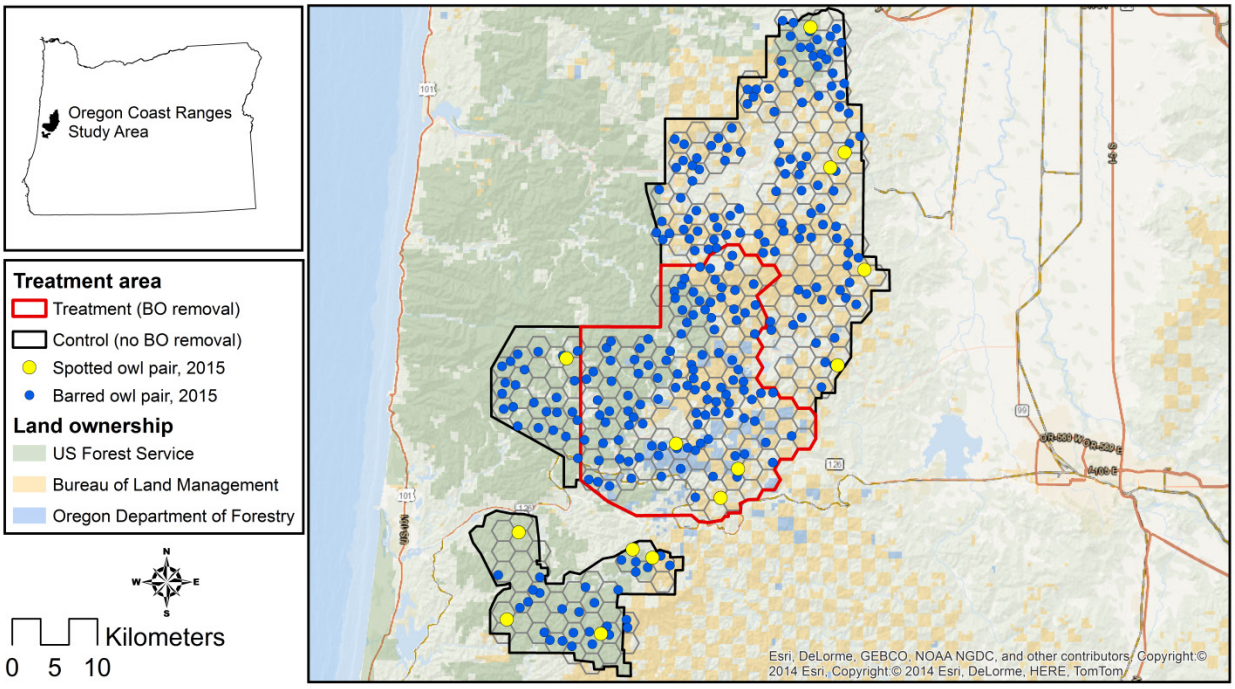
Appendix A. Pre-Treatment Distribution of Territorial Pairs of Northern Spotted Owls and Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015





Appendix B. Model Selection Results for Single-Season Analysis of Proportion of Area Used (ψ) and Detection Probability (p) of Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015

Model parameters defined as: $\boldsymbol{\psi}$ = the probability of ≥1 barred owl using a sampling unit (500-ha hexagon) during the survey season (March–September); $\boldsymbol{p}$ = the probability of detecting ≥1 barred owl at sampling unit *i* during survey occasion *t*, given presence. Models with area effects allow parameter estimates to vary between treatment and control areas. Time effects modeled as constant (.), varying with survey occasion (t), or increasing from the survey Period 1 to Period 3 (T).

Study Area	Model	AIC*c*	Delta AIC*c*	AIC*c* Weights	Num. Par	Deviance
Cle Elum, Washington	{ψ(.) p(t)}	380.068	0.000	0.378	4	-682.838
	{ψ(area) p(t)}	381.026	0.958	0.234	5	-683.973
	{ψ(.) p(T)}	381.224	1.156	0.212	3	-679.608
	{ψ(area) p(T)}	382.608	2.540	0.106	4	-680.298
	{ψ(.) p(.)}	384.765	4.696	0.036	2	-674.012
	{ψ(area) p(.)}	386.520	6.451	0.015	3	-674.313
	{ψ(.) p(g)}	386.801	6.733	0.013	3	-674.031
	{ψ(area) p(area)}	388.589	8.520	0.005	4	-674.317
Coast Ranges, Oregon	{ψ(.) p(t)}	466.206	0.000	0.582	4	-801.462
	{ψ(area) p(t)}	468.226	2.020	0.212	5	-801.516
	{ψ(.) p(.)}	470.773	4.566	0.059	2	-792.792
	{ψ(.) p(g)}	470.799	4.593	0.059	3	-794.810
	{ψ(.) p(T)}	472.184	5.978	0.029	3	-793.425
	{ψ(area) p(.)}	472.479	6.273	0.025	3	-793.130
	{ψ(area) p(area)}	472.857	6.651	0.021	4	-794.811
	{ψ(area) p(T)}	474.007	7.801	0.012	4	-793.661

Appendix C. Model Selection Results for an Analysis of Intensity of Use of Sample Plots (λ) and Unconditional Detection Probability (*r*) of Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015

Model parameters defined as: **λ** = average number of individual barred owls using a sample unit (500-ha hexagon) during the survey season (March–September); ***r*** = the unconditional probability of detecting ≥1 barred owl at sampling unit *i* during the survey season; varadd = additional variance added to **λ** to invoke the Royle/Nichols negative binomial model (all other models assume a Poisson distribution with a mean of **λ**; Royle and Nichols, 2003). Models with group effects (g) allow parameter estimates to vary between treatment and control sites within study areas. Time effects modeled as constant (.), varying with survey occasion (t), or increasing from survey Period 1 to Period 3 (T).

Study Area	Model	AIC*c*	Delta AIC*c*	AIC*c* Weights	Num. Par	Deviance
Cle Elum, Washington	{λ(.) *r*(.)}	384.69	0.00	0.508	2	-674.09
	{λ(g) *r*(.)}	386.52	1.82	0.204	3	-674.32
	{λ(.) *r*(g)}	386.70	2.01	0.186	3	-674.13
	{λ(g) *r*(g)}	388.51	3.82	0.075	4	-674.40
	{λ(g) *r*(g), varadd(.)}	390.48	5.80	0.028	5	-674.52
Coast Ranges, Oregon	{λ(.) *r*(.)}	469.24	0.00	0.32	2	-794.32
	{λ(g) *r*(.)}	469.54	0.29	0.28	3	-796.07
	{λ(.) *r*(g)}	469.56	0.32	0.27	3	-796.05
	{λ(g) *r*(g)}	471.59	2.35	0.10	4	-796.08
	{λ(g) *r*(g), varadd(.)}	473.66	4.42	0.04	5	-796.08

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Marys River Watershed Council
Model Watershed Monitoring Summary
2008 – 2015
Prepared by: Steve Trask / Bio-Surveys, LLC

The following summary includes the data and discussion for three sub-basins of the Marys River (Rock Creek, Woods Creek and Duffy Creek).

Extensive monitoring has been conducted in the Model Watershed sub-basins of the Marys River over the last eight years to better understand the response of cutthroat trout to restoration actions designed to restore system processes.

Cutthroat trout were chosen as a viable indicator species because they represent a high trophic level with the potential to benefit from increases in channel complexity, nutrient storage, primary productivity, access to existing habitats and floodplain connectivity for the provision of winter refuge.

The stated goal for restoration planning in each of the treated sub-basins was to address the primary issues that appeared to limit system function. While the origin and magnitude of dysfunction for each habitat limitation differs from sub-basin to sub-basin, it is safe to say that addressing each of the identified potential limitations was important for achieving the goal of restoring normal system function for a diverse spectrum of both aquatic and terrestrial species with diverse life histories.

All of the treated streams were originally assayed for potential access issues that might affect seasonal habitat linkages. Culverts were replaced, bridges were installed and passage was provided at water intake dams. Care was taken to remove any impediments to access that might impact any life history stage of the cutthroat trout (adult, fry and parr during both summer and winter). An exception existed until the fall of 2013 in Duffy Creek where access for both adult and juvenile cutthroat was seriously compromised (especially during spring and summer) because of a series of man-made barriers that existed on private property where access to work had not been granted (see “Results” for a discussion related to this condition).

The results of project monitoring to date have been mixed with broad variation observed between years (Figure 1). In 2014 there was a significant response in Rock Creek while a continuing decline was being observed in Woods Creek that same year. Comparing initial population abundance (see pre-project years, Figure 1) to that observed in the most recent year (2015) cutthroat populations have declined dramatically in Woods Creek (-78%), moderately in Rock Creek (- 33%) and increased slightly in Duffy Creek (+20%). It is clear that continued monitoring is a necessity for encompassing the types of meta population swings that are likely to be driven by environmental factors on a watershed scale and not at the 7th field scale. We believe that the fluvial life history strategy of Marys River cutthroat plays a powerful role in determining when and where

headwater habitats are utilized for their seasonal habitat attributes (spawning and incubation, summer thermal refugia). Because this migrating component of the meta population may have no affinity for their natal stream, then environmental factors such as water quality (temperature and flow volume) and food resources drive the temporal use of their home waters (Marys River Basin) that can be highly variable from year-to year.

Figure 1

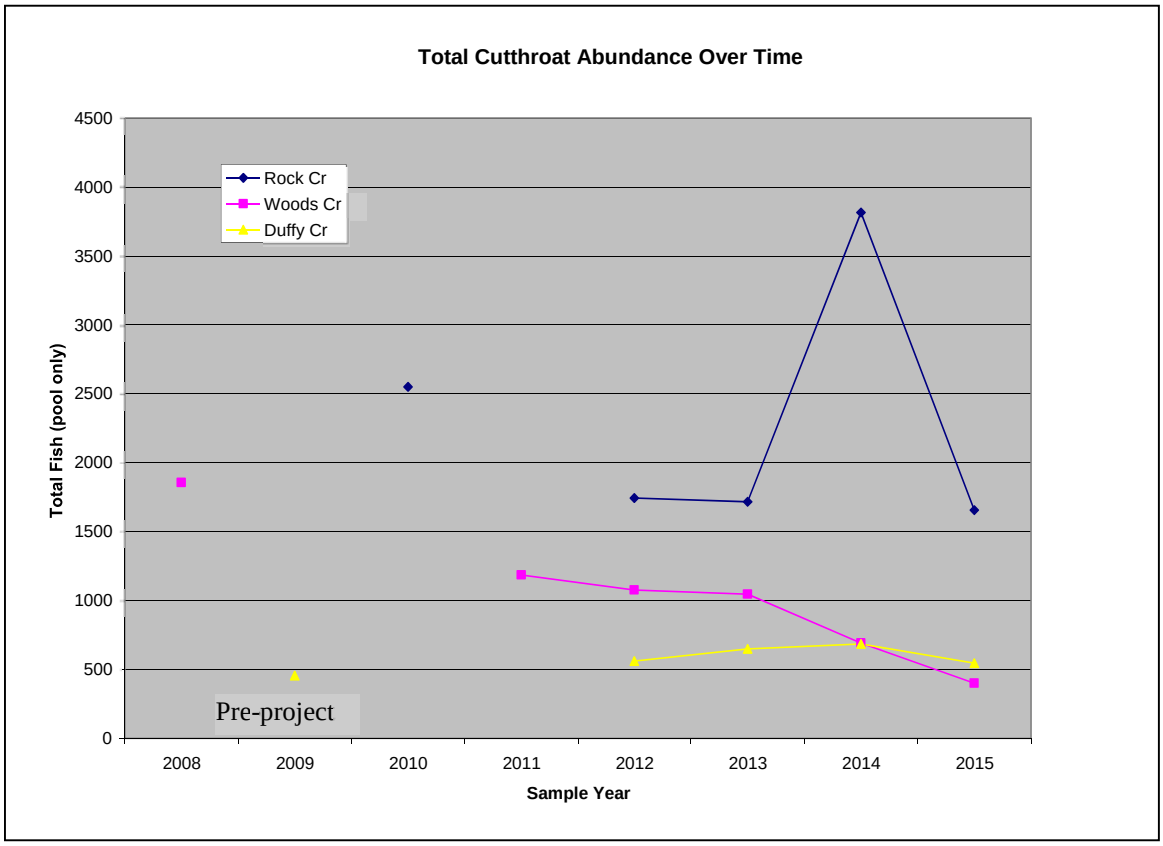


Table 1 Combined Model Watershed Stream Summaries

Rock Cr *

Year	1+	2+ or >	Total Cuts	Sthd	
2010	1,340	605	1,945	0	Post project
2012	985	525	1,510	0	Post project
2013	1,045	415	1,460	0	Post project
2014	2,220	880	3,100	0	Post project
2015			1,385	0	Post project

* Intake dam pool not included in comparison (non representative)

Griffith Cr

Year	1+	2+ or >	Total Cuts	Sthd	
2010	405	55	460	0	Post project
2012	115	25	140	0	Post project
2013	115	15	130	0	Post project
2014	320	180	500	0	Post project
2015			225	0	Post project

* Intake dam pool not included in comparison (non representative)

MF Rock Cr

Year	1+	2+ or >	Total Cuts	Sthd	
2010	145	0	145	0	Post project
2012	80	15	95	0	Post project
2013	115	10	125	0	Post project
2014	185	30	215	0	Post project
2015			105	0	Post project

Rock Combined *Includes Rock - Griffith - MF Rock*

Year	1+	2+ or >	Total Cuts	Sthd	
2010	1,890	660	2,550	0	Post project
2012	1,180	565	1,745	0	Post project
2013	1,275	440	1,715	0	Post project
2014	2,725	1,090	3,815	0	Post project
2015			1,715	0	Post project

Woods Cr

Year	1+	2+ or >	Total Cuts	Sthd	
2008	745	1,110	1,855	10	Pre-Project
2011	575	610	1,185	0	Post project
2012	645	430	1,075	0	Post project
2013	695	350	1,045	50	Post project
2014	465	225	690	30	Post project
2015	260	140	400	0	Post project

Duffy Cr

Year	1+	2+ or >	Total Cuts	Sthd	
2009	315	140	455	0	Pre-Project
2012	340	220	560	0	Post project
2013	490	160	650	0	Post project
2014	450	235	685	0	Post project
2015	360	185	545	0	Post project

Methodology

Protocols involved the Rapid Bio-Assessment (RBA) methodology developed by Bio-Surveys, LLC for snorkel inventory. This is a random sampling strategy designed to gather a 20 percent census of all pool habitats within the current distribution of cutthroat in each of the model watershed sub-basins. The results summarized in Table 1 are expansions of this 20% census. The method also collects pool metrics and classifies variations in habitat complexity.

Modifications were made to the historical data set to normalize the comparison of total cutthroat abundance between years. Unnatural dam pools exist above the City of Corvallis water intake structures that typically hold very high numbers of cutthroat that overestimate total abundance in an expansion of the 20% census. The average number of cutthroat / pool was calculated for each of these stream reaches (Rock Creek and Griffith Creek) and applied to the dam pool in years when these pools were encountered during the random inventory.

Rock Creek

Site specific conditions

The survey was initiated each year at the mouth of Rock Creek (confluence of Greasy Creek) and continued up the mainstem of Rock and its tributaries until increases in gradient diminished the potential of the aquatic habitat to provide significant cutthroat production. The survey included 11.2 miles of contiguous stream habitat. The start and end points of each inventoried stream segment were maintained between years for consistency.

The interannual comparisons of abundance contained in Table 1 have been modified from previous year's analyses to eliminate the sampling bias associated with the random encounter of the dam pool associated with the water intake structures on both South Fork Rock Creek and Griffith Creek. Some years these two pools were encountered in the survey and some years they were not. The issue revolves around the expansion of the 20% sample when utilizing the high numbers of cutthroat observed in these unique man made pools (Rock Creek intake dam pool not sampled in 2012, 159 cutthroat in 2013). Therefore, absolute numbers are higher than reported in Table 1 but interannual comparisons without this pool more accurately represent the actual changes in abundance associated with the basin scale suite of restoration actions completed.

Extremely high water quality (cold summer temperatures) are continually observed in the headwaters of the Rock Creek sub-basin. All the headwater tributaries of Rock Creek originate from high coastal elevations and flow through largely intact Late Successional Reserves (LSR) on USFS property. Canyons are narrow, steep, heavily canopied and exhibit limited solar exposure on aquatic habitats. Wood densities are high,

resulting in deep accumulations of transient bedload (sand, gravel and cobble). These deep bedloads of migratory substrate store summer flows in a hyporheic lens that protects and buffers the stream from exposure to direct sunlight and air.

Each of the major headwater tributaries (North Fork, South Fork, Middle Fork and Griffith Creek) eventually transition onto the City of Corvallis ownership, which is positioned lower in the watershed. The natural geomorphology of the City's ownership is described by wider floodplains and flatter channel gradients. These two natural features predispose the stream corridor to increased thermal impacts from air and solar exposure. Lower stream gradients (<2%) lengthen the window of solar exposure as a result of slower pool turnover rates. This condition is exacerbated by the east / west aspect of significant portions of the Rock Creek mainstem (below confluence of NF Rock). When including the quantifiable decrease in stored bed load on City property (a result of low instream wood densities) to these other morphological differences, the stream begins to exhibit a natural warming trend outside the boundaries of the National Forest.

Results

In 2006, a pre-project RBA snorkel inventory was conducted in the Rock Creek sub-basin and its tributaries to document the abundance and distribution of cutthroat trout prior to any of the contemporary restoration actions implemented by the Marys River Watershed Council (MRWC) and its partners. This 2006 effort (20% census) was conducted in May to coincide with peak adult spawner abundance and the timing was focused on documenting passage conflicts existing in the sub-basin to justify the expenditure of significant resources for rectifying long standing passage barriers (two impassable water intake structures and three perched culverts). Replicates of this census continued until 2010 and post-project inventories were utilized for pre- and post-project comparisons (a full description of these results can be found in Bio-Surveys, Post Restoration Monitoring Summary, 2010, MRWC archives).

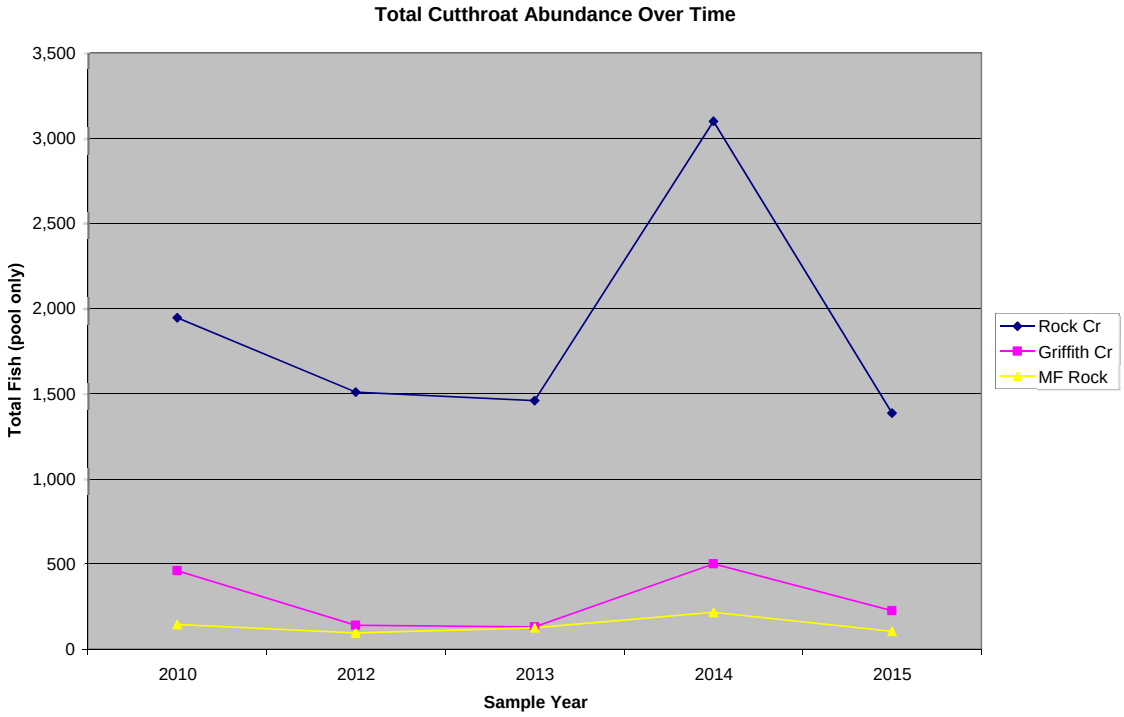
During the summer of 2010, a replicate of the May RBA census was conducted in September that was designed to answer the monitoring question of how will the abundance and distribution of cutthroat in Rock Creek change over time in relation to efforts to address fish passage and elevated summer temperature profiles in both Rock and Greasy Creek (Greasy Creek being a recipient of any cumulative temperature impacts originating in Rock Creek). By necessity this formed a new baseline that no longer is relevant to the pre-project inventory conducted in 2006. Our hypothesis was that improvements in summer stream temperatures resulting from the restoration actions designed to capture bedload, aggrade the active summer channel and recharge floodplain terraces through hyporheic linkage would result in changes in the abundance of cutthroat during pinch period summer flows regimes.

Table 1 summarizes the total abundance of 1+ and older cutthroat observed in the 3 reaches of Rock Creek accessible to fluvial migrants (Rock Creek mainstem, Griffith Creek and MF Rock Creek). When compared to the first post-project summer census conducted in 2010, there was a 31.6% and a 32.7% decrease in abundance on the basin scale (all three stream reaches combined) for the two subsequent sample years of 2012 and 2013. This decline was reversed in 2014 with a 49% increase in abundance when compared to the first post-project year of 2010. However, continued sampling in 2015 resulted in a 33% decline in total cutthroat abundance when compared to the base line abundance observed in 2010. This decline was much more significant (-55%) when compared to the previous summer (2014) inventory that had documented a large increase in abundance. The large fluctuation in abundance between 2014 and 2015 indicates that cutthroat are utilizing Rock Creek habitats seasonally and are not necessarily either full time residents or of Rock Creek origin.

Figure 2 suggests that the increase in total abundance observed in 2014 was observed in each of the three separate reaches of the Rock Creek survey (Rock mainstem, Griffith and MF Rock Creek). Griffith Creek was the highest interannual increase at 285%.

The high interannual variability in abundance observed in Figure 2 suggests that there may be variables in play that extend beyond the physical changes associated with restoration actions. Our original hypothesis was that improvements in basin scale linkages and habitat complexity would show an immediate and continual increase in cutthroat abundance. The declines observed initially in 2012 and 2013 were contrary to our hypothesis suggesting that our observations were being made on a larger and highly mobile population than existed in Rock Creek alone. Essentially we were not sampling a closed system (Rock Creek) but just a portion of the much larger Meta population.

Figure 2



The inventory of 2014 observed a significant interannual increase in abundance when compared to the previous year, but then the 2015 inventory observed a radical decline in cutthroat abundance on the basin scale suggesting again that seasonal abundance may be driven by changes in habitat quality (flow and temperature) and not actual habitat quantity. Cutthroat migrating upstream from the mainstem Marys River or Greasy Creek in search of summer thermal refugia (temps below 64 degrees F) appear to be receiving migration signals that vary from year to year (strong attraction one year, no attraction another). These upstream temperature dependant migrations logically orient migrants at each tributary confluence toward cooler upstream habitats. It would not be intuitive to believe that cutthroat faced with a temperature differential at a tributary confluence would elect to continue migrating up the warmer tributary given equal flow contributions (as is the case at the confluence of Rock Creek and Greasy Creek, equal flow contributions, Rock Creek warmer).

We are uncertain of the actual combination of environmental factors that predispose a migrating population to alter its pathway to summer thermal refuge from year to year. Issues to consider include:

*range of fluvial winter migrations; do they extend into the mainstem Willamette or are they more localized to the mainstem Marys or even just Greasy Creek?

*basin scale temperature profiles; what are the relative contributions of tributary temperatures compared to the mainstem Marys temporally?

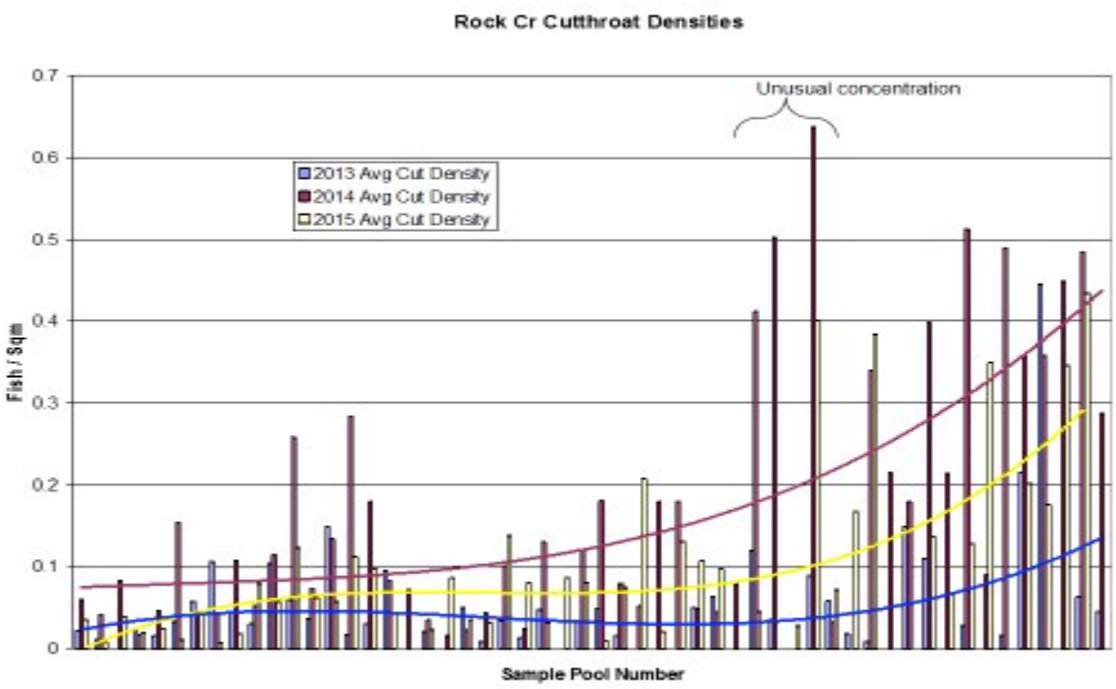
*is the selection of a summer rearing location related to the rate of warming in the mainstem Marys (quick warming selects for a lower basin tributary such as Greasy Creek, slower warming draws those fluvial migrants higher along the

mainstem Marys migration corridor by the time a cooler tributary is selected (Tum Tum).

These are larger basin scale queries that can only be answered with an intensive telemetry study.

Figure 3 compares the differences in abundance and distribution (as described by pool density) of cutthroat in the mainstem of Rock Creek in the last three years. The comparison of the annual trend curve suggests that the uplift in higher abundance years (2014) is experienced in primarily the middle and upper basin (above RM 2). This observation suggests that temperature dependant upstream migrations of cutthroat into Rock Creek from the Greasy Creek mainstem are not terminating in the lower two miles of Rock Creek. This may suggest that summer temperatures in this lower section are inadequate for the provision of thermal refugia at least at higher densities.

Figure 3



The distribution in Figure 3 also reveals an abnormal concentration of cutthroat shortly downstream of the SF Rock Creek water intake dam. At this juncture in time an old bridge abutment has narrowed the active channel and trapped transient woody debris that has formed an impassable debris jam during low summer flow profiles. This is an ephemeral jam and will eventually migrate out of the system. The concentration of older age class cutthroat in the pools below this jam are supplemental verification that upstream temperature dependant migrations are still occurring in SF Rock Creek that extend above the confluence of the NF Rock Creek reservoir outfall.

Discussion

One of the hypotheses being tested in this review was that -Rock Creek's coolest tributary, Griffith Creek, plays a more significant role as summer temperature refugia when stream temperatures in the larger Greasy Creek basin are elevated. Thus we expected to see more fish in Griffith when mainstem Greasy Creek was warmer (2012, 2013, and 2015). However, we actually saw fewer cutthroat in Griffith in 2012, 2013 and 2015 when mainstem Greasy Creek was warmer than observed in 2014. The observed declines in abundance in 2012 and 2013 occurred in years with higher summer water temperatures in the mainstem of Greasy Creek than observed in 2010 and 2015. In 2013 there were 80 days at or above 64 degrees at the mouth of Greasy Creek and 38 days at or above 64 degrees in Greasy Creek above the confluence of Rock Creek. Comparatively, there were only 36 days at or above 64 degrees at the mouth of Greasy Creek in 2010 and 0 days above 64 degrees in Greasy Creek above the confluence of Rock Creek in 2010. The cooler mainstem Greasy
Creek years (2010 and 2014) were the highest observed abundance of cutthroat in Rock Creek and Griffith Creek (53 days above 64 degrees at the mouth of Greasy Creek in 2014). The large declines in abundance observed in 2015 follow this trend. There were 83 days at the mouth of Greasy Creek that exceeded 64 degrees and 63 days of exceedance above the confluence of Rock Creek making it the warmest year recorded with the greatest duration of exceedance both at the mouth and in the headwaters. It is likely that upstream temperature migration triggers are occurring far downstream of the actual terminus of these migrations. This suggests that the cumulative temperature impacts occurring in the headwaters play a critical role in relaying temperature signals to cutthroat making migration choices many miles downstream (confluence of Greasy Creek and the mainstem Marys River).

There may also be other environmental factors at play in the large variation in abundance observed in Rock and Griffith Creek that was not revealed in our monitoring efforts. This leads us to consider the possible role of variable summer flow volumes emanating from both Rock and Griffith Creek as a result of potential differences in withdrawals at the three water intake structures within the system. Summer flow volumes below intake structures have not historically been monitored, but this additional information would be valuable for determining the presence or absence of a correlation to the observed changes in cutthroat abundance between years.

Because the mainstem of Greasy Creek appears to frequently exceed DEQ water quality standards for temperature and this condition can be sustained for long continuous periods between July and September it follows that maintaining or creating a temperature differential in Rock Creek (Rock Creek exhibiting a cooler temperature profile than Greasy Creek) is still a critical restoration objective. MRWC temperature probes have been in place 1,300 ft above the confluence of Rock Creek and 2,000 feet below the confluence of Rock Creek for multiple years. Data collected from these two stations suggest that Rock Creek is generally warmer than the mainstem of Greasy Creek above its confluence. The temperature differential between these sites is consistently one-degree F warmer during the warmest period of the year. MRWC's observation is that this minimal differential suggests that efforts to achieve a reversal of this differential exhibit a very high likelihood of success.

Maintaining Rock Creek as functional temperature refugia has significant survival implications for the larger Meta population (elevated stream temperatures are known to impose stress on salmonids that reduce survival rates directly and indirectly). Therefore, the commonly stated management objective of not exceeding DEQ water quality standards (17.8 C) in the mainstem of Rock Creek is merely a general guideline for evaluating water quality compliance. It does not attempt to consider the relevance of water quality (and its origin) to larger ecosystem processes. To take what we have learned about the basin scale distribution of variable temperature profiles and the resultant impact on cutthroat distribution (our chosen indicator species) to the next level of designing a constructive restoration plan, we should be asking how the larger Greasy Creek sub-basin of the Marys River is functioning as a whole (this extends our focus beyond the confines of Rock Creek) by understanding 5th field limitations to system function, as well as important seasonal services that individual 6th or 7th fields need to contribute so that the whole basin functions as an ecosystem.

Because Rock Creek is the premier source of high water quality for the Marys (volume and temperature), it also represents the greatest opportunity for restoration and aquatic conservation in the Marys River basin. This has played out in Rock Creek in the form of an extensive public investment in restoration planning and restoration actions.

Continuing the search for socially acceptable solutions for improving water quality in Rock Creek and its tributaries remains the highest restoration MRWC priority within the Marys River Basin. The goal is simply to improve water quality (temperature) and quantity (flow).

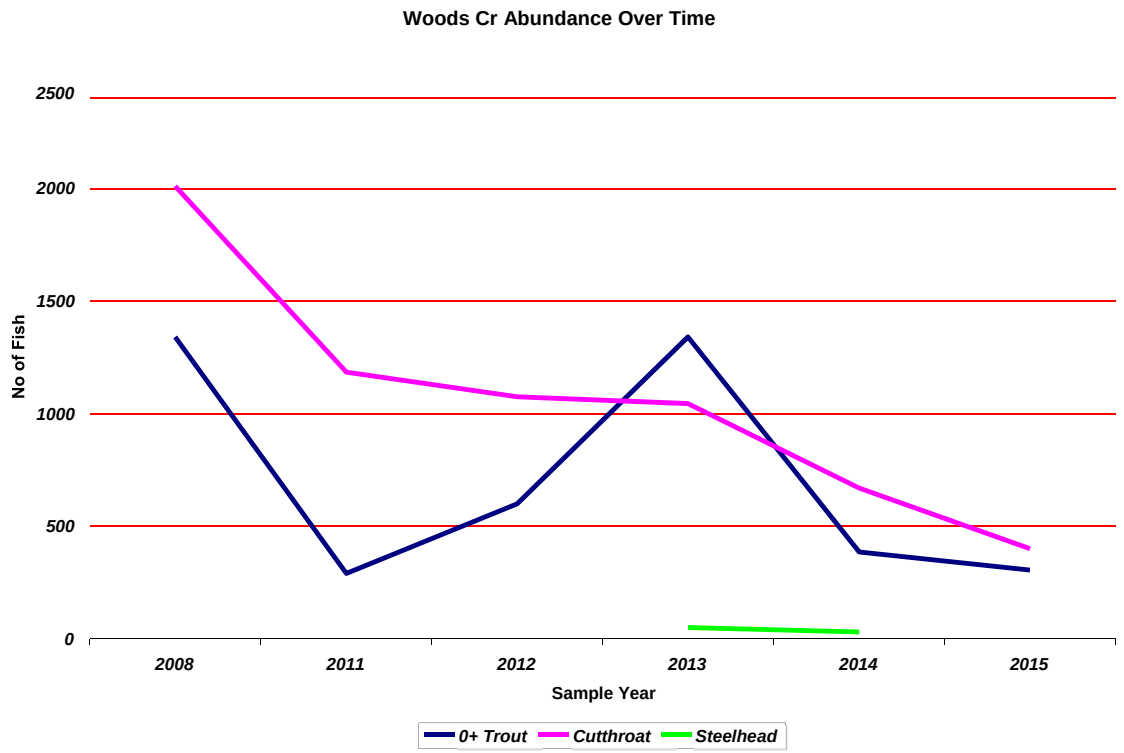
Woods

Site specific conditions

A Rapid Bio-Assessment snorkel inventory was conducted in the Woods Creek sub-basin, a tributary of the Marys River in each of six years (2008, 2011, 2012, 2013,

2014 and 2015). The timing of each survey was kept consistent from year to year with a start date close to August 12th. The 2008 survey represents a pre-project inventory and the subsequent years are each post-restoration reviews of cutthroat abundance and distribution (figure 4).

Figure 4



The survey began at the confluence with the Marys River and extended to RM 6.1. The end point of the inventory can also be described as the stream crossing under a gated Starker Forest road adjacent to the rock quarry on the Woods Creek road.

In 2008, and in each subsequent year, cutthroat trout were the dominant species observed. However, high concentrations of redside shiner were observed in the lower 1,200 ft just above the confluence with the mainstem Marys. Two 1+ age class steelhead were also observed in the lower 1.1 miles of Woods Creek in 2008, 10 in 2013 and six in 2014.

A highly functional and consequently productive stream reach for Cutthroat was observed in 2008 between RM 1.9 and RM 5.4. Consequently, restoration actions that were implemented in 2009 and 2010 focused on small private and industrial forest ownerships within this reach. Subsequent restoration effort was expended in 2014 in the lower 1.9 river miles in an attempt to maintain improvements in summer water quality gained in the earlier upper basin efforts. These additional efforts focused on aggrading bedload to sequester a percentage of summer flow volumes within the hyporheic lens to protect it from the influence of sun and air.

Results

When reviewing the interannual comparisons of abundance in Table 1 a 63% decline in cutthroat abundance can be observed between the initial pre-project year and 2014, and a 78% decline between the pre-project year and 2015. Cutthroat abundance has exhibited a consistent downward trend with major impacts to the population observed six years post-restoration.

No positive response in the abundance of cutthroat associated with the extensive modifications associated with large wood treatment and alcove development has been observed. This has been an unexpected condition especially since the full spanning log jam at RM 0.4 that terminated temperature dependent migrations from the mainstem Marys River washed out in the high winter flows of 2012. The event provided unencumbered summer access to fluvial migrants seeking thermal refugia from the mainstem Marys River during low summer flow regimes.

In 2011 an abnormally high concentration of older age class cutthroat was observed below an impassable full spanning log jam at RM 0.53. This concentration and the absence of pool occupancy below this jam (5 / 7 sample pools below RM 0.53 contained 0 cutthroat) is solid validation that cutthroat were attempting an upstream temperature dependant migration from the mainstem Marys River. This behavior was an expected phenomenon as multiple age classes within the Marys River mainstem are known to seek summer pinch period temperature refugia in cold smaller order tributaries. This condition has complicated the interannual comparison of cutthroat abundance in Woods Creek that was designed to compare post-project responses to the back ground level of cutthroat observed in 2008. Because this concentration of Cutthroat was not observed at the full spanning jam in 2008, we assume that passage occurred for summer migrants seeking cool water refugia that year. A comparison was not possible between 2008 and 2011 because the fluvial component of the summer rearing population was denied access to the cool portions of Woods Creek. The full spanning jam was blown out during the winter of 2012, therefore access to upper Woods Creek should have been available to the fluvial component of the cutthroat population in the mainstem Marys in all 3 post-project summers of 2012, 2013 and 2014. In fact, no cutthroat concentrations similar to those observed in 2011 were present below the remnants of the jam in any of these post-project years.

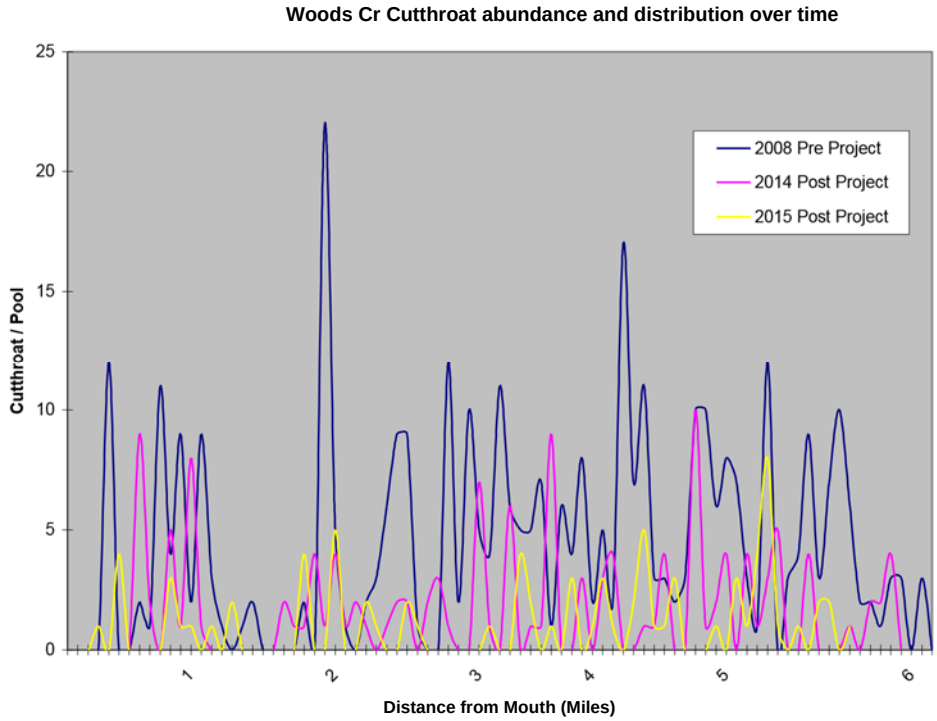
In 2008 two 1+ steelhead parr were documented in the 20% pool survey. This observation was expanded to represent 10 steelhead juveniles for all of Woods Creek. These juveniles were observed only in the lower 1.1 miles of mainstem Woods Creek. In 2011 and 2012, there were no steelhead parr documented in the survey effort. In 2013, 10 steelhead were documented that expanded to an estimate of 50 juvenile steelhead rearing in Woods Creek. (primarily below RM 1.8). 80% of these parr (40) were documented below RM 1.3. Because of the low number of summer parr and their rearing location low in the system it continues to appear that the observed steelhead are not the progeny of a

steelhead spawning event in Woods Creek, but upstream temperature dependant migrants from the mainstem Marys. In 2014 six steelhead parr were observed in the inventory with an expanded estimate of 30 for the entire system. These parr were distributed higher in Woods Creek than previously observed (up to RM 3.2). There were no steelhead observed in the most recent 2015 inventory. The continued low abundance and the concentration of steelhead parr very near the second culvert Crossing at RM 2 continues to suggest that these fish have never been the progeny of an adult spawning event in Woods Creek, but instead are the result of an upstream temperature dependant migration from the mainstem Marys River.

Discussion

Although the abundance of cutthroat declined between 2008 and 2015 (figure 4), the summer distribution pattern remained very similar each year (figure 5). There is no strong signal apparent in the cutthroat distribution profile that might suggest habitat preferences have developed that are related to the suite of restoration actions implemented in the system. It is important to remember that much of the channel roughness and additional habitat complexity that exists in Woods Creek as a result of restoration actions was designed to provide additional winter refugia in the form of connected floodplains with low velocity off-channel habitat. This summer inventory would not be expected to observe significant habitat preferences unless there were measurable differences in water quality (temperature) between the lower and upper reaches of the mainstem. The continuous decline in cutthroat abundance displayed in figure 5 suggests there may be a water quantity issue during summer flow regimes.

Figure 5



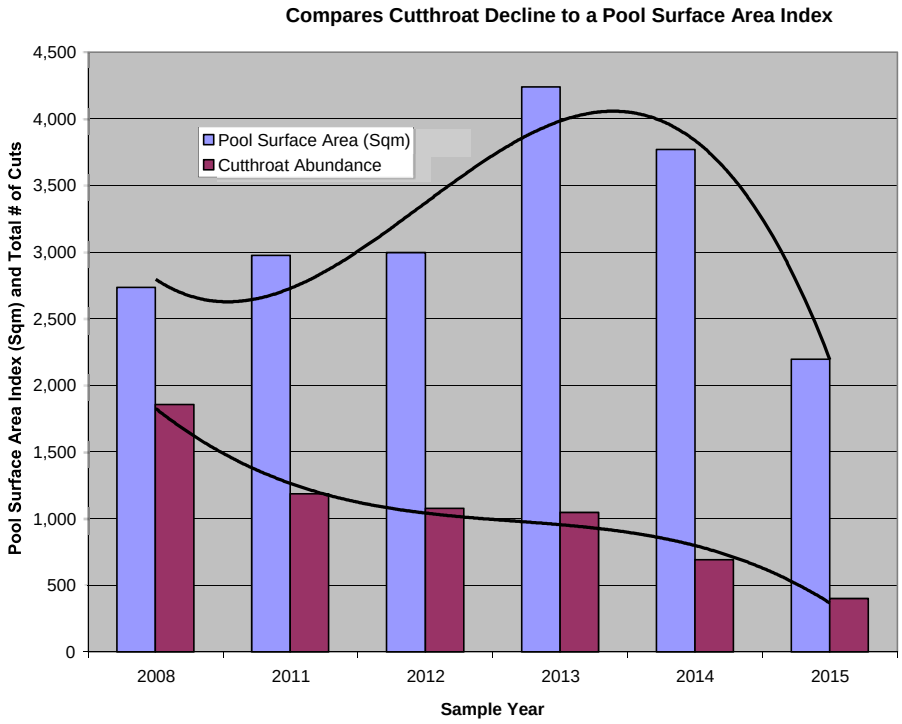
To explore the hypothesis that variations in water quantity over time may have influenced the habitats capacity to rear salmonids, we compared the total pool surface area estimates between all six sampled years to evaluate whether pool volumes were shrinking over time (figure 6). The trends in the two variables (abundance and pool surface area) are dissimilar and suggest a lack of correlation.

An additional hypothesis explored was that declines in water quality (temperature) may be the primary driver in the observed variability over time in the habitats capacity to summer rear older age-class native cutthroat.

Woods Creek at its confluence with the mainstem Marys River exceeded 64 degrees F for 69 days in 2015. The Marys River mainstem directly above the Woods Creek confluence exceeded for 107 days in 2015. The peak daily maximum in 2015 was 82.3 degrees at this location with a diurnal fluctuation only cooling the mainstem to 69.6 degrees at night. The mainstem Marys became inhabitable to cutthroat at the confluence of Woods Creek from approximately May 28 – September 13. This 107-day continuous curtain of warming stream temperatures created a thermal barrier to upstream temperature dependant migrations into Woods Creek from the mainstem Marys River essentially somewhere near the end of May. These excessive temperatures in the mainstem terminate any potential for Woods Creek to be utilized as refugia after the end of May. Migrants encountering the mouth of Woods Creek in the two weeks prior to May 28 would have experienced a range of temperature differentials that may or may not have been a strong enough signal for attraction to Woods Creek (Range = 3.3 – 7.3 degrees f).

Likely the combination of flow volume and temperature both play a role in this migration selection behavior.

Figure 6



The fact that a barrier to migration existed in the first post-project year of 2011 at RM 0.53 suggests that the observed decline in cutthroat abundance that year was expected. The subsequent low abundances of cutthroat observed in 2012, 2013, 2014 and 2015 were not the expected result because there were no impediments to summer migrations from the mainstem Marys River. It is possible that the observed thermal barrier in the mainstem Marys plays a significant role in when and if Woods Creek is utilized as thermal refugia.

Duffy

Site specific conditions

The Duffy Creek snorkel inventory extended 2.5 miles above its confluence with the mainstem of Beaver Creek to a point where the aquatic habitat began to diminish in surface area and the gradients increased (confluence of Cheyenne Creek).

The significant abundance and broad distribution of older age-class (1+ and older) cutthroat observed in the 2009 pre-project inventory suggested that Duffy Creek

functions as a key anchor habitat for both resident and fluvial cutthroat life histories when viewed within the context of the entire Beaver Creek sub-basin of the Marys River.

Focused restoration occurred in 2010, 2011 and 2014. Significant effort was extended by the MRWC and its private land partners on Duffy Creek to boost the complexity of the existing habitat with LWD treatments and encourage the recolonization of legacy beaver colonies with beaver forage prescriptions in the riparian planting plan. In addition, multiple passage barriers were replaced to restore historical access to the full extent of the sub-basin for both resident and fluvial migrants.

Results

The results of the first three post-project monitoring inventories indicated a continuous increase in cutthroat abundance with a 23% increase observed in year 1 (2012), a 16% increase in the following year (2013) and a 5% increase in 2014. In 2015 however, the first post-project decline in abundance was observed with a 20% decline from the abundances observed in 2014 (figure 1). If we compare the current abundance (2015) to the pre-project year (2009), there is still a 20% increase observed over the 6 years inventoried. This is a different response than observed in the other model watershed streams (Rock and Woods) that both exhibited lower abundances in 2015 than their preproject inventory years.

Temperature monitoring in approximately the middle of the sampled reach observed 22 days of exceedance above the 64 degree DEQ water quality standard for salmonids.

Figure 7

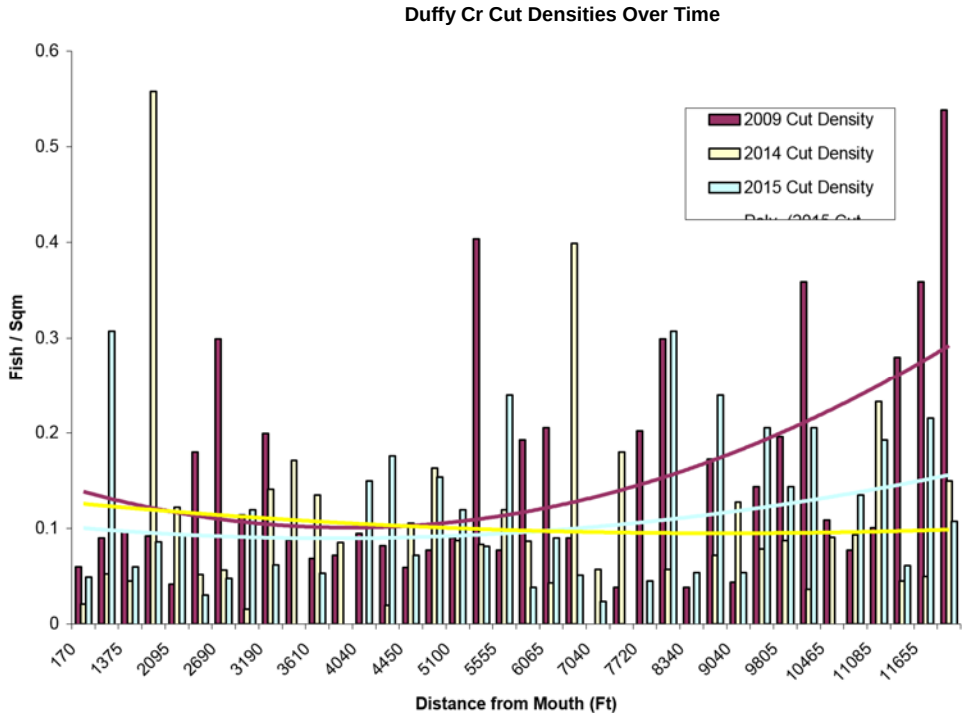


Figure 7 displays the differences in average cutthroat density (trend lines) between sampled years. The pre-project year (2009) exhibited higher average densities in the upper end of the distribution. Subsequent post-project years exhibit a more even distribution of cutthroat throughout the treated reach.

Discussion

The temperature impacts suffered by aquatic organisms in Duffy Creek during the warmest recorded summer in western Oregon could be classified as mild. It is highly likely that the different responses observed in cutthroat abundance (increase in Duffy, decreases in Rock and Woods) over time within all 3 model watershed streams in this review are primarily driven by the limitations caused by the impacts to water quality (temperature) and quantity (flow) during pinch period summer flow regimes.

One of the obvious differences between Duffy Creek and the other 2 model watersheds reviewed in this inventory is the lack of water withdrawals in the summer. It makes intuitive biological sense that water withdrawal during critical peak temperature periods might result in increased stress that influences the survival of some aquatic organisms (in this case we are utilizing the native cutthroat as an indicator species).

The average pool rearing density during the pre-project year (2009) was 0.13 fish /sqm. Because cutthroat trout in Duffy Creek have not had inter specific competition for habitat or food resources (steelhead, coho) then we would expect average summer rearing densities to increase significantly above the level observed in the pre-project inventory as

a result of the restoration plan addressing the existing limiting factors. The average rearing density in 2014 (the highest abundance year) was 0.10 fish / sqm and in 2015 0.11 fish / sqm, all still very similar to pre-project average pool densities. This suggests that there is still significant under utilization of the existing summer habitat with average densities well below what might be expected as fully seeded cutthroat densities (0.7 fish / sqm) in a fully functional stream reach without inter specific competition.

Historically, production was compromised by the seasonal habitat limitation produced by deep channel entrenchment and isolation from the floodplain associated with the loss of legacy beaver colonies and a lack of full spanning large wood. Because floodplain connectivity has been increased dramatically in the sub-basin as a result of LWD placements, we believe that the abundance of low velocity off channel winter habitat has been effectively increased. This should correspond to higher survival rates for each year class of cutthroat and a higher abundance of non-fluvial (resident) fish surviving to spawn. This predicted response was evident in the 2014 inventory with a 51% increase in abundance from the pre-project year. The sub-basin experienced the warmest year on record in 2015 resulting in higher summer water temperatures that appear to have had a significant impact on cutthroat abundance.

Pool frequencies in the reach have changed from approximately 82 pools / mile pre-project to 90 pools / mile post-project. In addition, total pool volume increased by 108%. This was a direct result of wood loading that formed new hydraulic controls that define pool habitat. This had the effect of providing additional summer pool volume for resident fish to expand into thus lowering the average rearing density when compared to pre-project levels. We would suggest that if the winter habitat bottleneck has been significantly improved by restoration actions conducted by the MRWC then we should continue to see these additional summer habitats populated with new year classes and average rearing densities eventually exceed pre-project levels.

The summer temperature profiles in Duffy Creek have been variable over the seven consecutive years of temperature monitoring that has been conducted (2009 – 2015). In summary, summer stream temperatures in Duffy Creek would be classified as good quality, but susceptible to any significant modifications to the existing riparian canopy. In 2009 (pre-project year) there was a 9-day period between July 26 and Aug 3 that exceeded the DEQ standard for salmonids of 64 degrees. The daily periods of elevated temperatures were brief with excellent diurnal recovery. Most of the post-project years have exhibited fewer days in exceedance of the DEQ guideline with only three days in 2012, five days in 2013 and 0 days in both 2010 and 2011. In 2015, the warmest recorded year in western Oregon, stream temperatures in Duffy Creek exceeded the DEQ standard for 22 days. This resulted, however, in just 98 total hours above 64 degrees with a 6.3 degree average diurnal fluctuation during the warmest two-week period of the summer in the last week of June and the first week of July (cooling the system at night to tolerable levels for salmonids). The maximum daily temperature recorded during this two-week window was just 67 degrees. The data supports the MRWC long-range restoration plan that identified Duffy Creek as one of the highest priority zones of action

for the provision of high quality thermal refuge for resident and fluvial cutthroat demes in the Beaver Creek basin.

In relation to this concept of upstream temperature dependant migrations for summer thermal refugia some additional effort was extended in Duffy Creek at a point 780 feet above its confluence with mainstem Beaver Creek in 2013. A series of two backto-back summer barriers to migration were identified that likely terminated the low flow migration of all cutthroat age classes to cool head water habitats in Duffy Creek. Both of these barriers were either modified or removed in 2013 with the cooperation and assistance of a new private land partner (this was conducted after the 2013 snorkel inventory). We expected to observe a significant interannual increase in abundance between 2013 and 2014 because of the new access provided to temperature dependant upstream migrants. This response was not observed in either 2014 or 2015 and may be most recently impacted by thermal barriers developing lower in the Beaver Creek system that truncate the potential of fluvial migrants to reach headwater refugia. All of our monitoring data continues to point back to the need for a comprehensive telemetry study that is capable of describing the seasonal migration routes and rates of both resident and fluvial components of the larger Meta population of Marys River cutthroat.