FOREST PRACTICES BOARD
Regular Board Meeting – August 14, 2019
Natural Resources Building, Room 172, Olympia, WA

Meeting materials and subject presentations are available on Forest Practices Board's website.
https://www.dnr.wa.gov/about/boards-and-councils/forest-practices-board

Members Present
Stephen Bernath, Chair, Department of Natural Resources
Ben Serr, Designee for Director, Department of Commerce
Bob Guenther, General Public Member/Small Forest Landowner
Brent Davies, General Public Member
Carmen Smith, General Public Member/Independent Logging Contractor
Dave Herrera, General Public Member
Jeff Davis, Designee for Director, Department of Fish and Wildlife
Maia Bellon/Rich Doenges, Department of Ecology
Noel Willet, Timber Products Union Representative
Patrick Capper, Designee for Director, Department of Agriculture
Paula Swedeen, General Public Member
Tom Nelson, General Public Member

Staff
Joe Shramek, Forest Practices Division Manager
Marc Engel, Forest Practices Assistant Division Manager
Patricia Anderson, Rules Coordinator
Phil Ferester, Senior Counsel

WELCOME AND INTRODUCTIONS
Chair Bernath called the Forest Practices Board (Board) meeting to order at 9 a.m. Introductions of Board members and staff were made.

APPROVAL OF MINUTES
MOTION: Noel Willet moved the Forest Practices Board approve the May 8-9 and June 4, 2019 meeting minutes.

SECONDED: Bob Guenther

Board Discussion:
None.

ACTION: Motion passed (11 Support / 1 Abstention (Bellon))

TFW RECOMMITMENT UPDATE
Chair Bernath said that Francine Madden, Center for Conservation Peacebuilding, was hired to facilitate and assist in a collaboration building workshop with leadership from the Timber, Fish and Wildlife (TFW) Policy caucuses. The workshop occurred June 12-17, 2019, and was the beginning

of a process for the TFW community to learn how to effectively deal with conflict, re-build relationships and to ultimately recommit to the TFW collaborative model.

The following reflections were shared by some of the participants. Ray Entz, Kalispel Tribe; Elaine Oneil, Washington Farm Forestry Association, (WFFA); Kevin Godbout, Weyerhaeuser; Lisa Remlinger, Washington Environmental Council; Paul Jewel, Washington State Association of Counties; and Jim Peters, Northwest Indian Fisheries Commission (NWIFC):

- Appreciation for the visionary approach for renewed collaboration;
- Appreciation for the encouragement to help solve other's problems;
- Recognition of the tendency to revert to old patterns if significant efforts are not being made to participate in a more collaborative manner;
- No improvements have been seen and not much progress has been made since the meeting;
- A need to support the effort and the leadership to recommit to a more collaborative approach;
- Acknowledged the workshop as an educational opportunity;
- Impressed with the engagement of all attendees;
- Acknowledgment that cultural change takes time;
- Learned some new techniques to resolve problems; and
- The workshop highlighted the need to hold a true TFW principals meeting – not all principals were present at the workshop.

Board Member Bellon said she learned a lot about the TFW process and appreciates the perspectives of everyone in attendance. She said she fully supports the recommitment effort.

Board Member Herrera said he appreciated getting to know those in attendance better.

Board Member Swedeen said she believes a good foundation was set and that more time and work still needs to be accomplished to get to a place that works for everyone.

Board Member Davis said he agrees with everyone's comments and is hopeful that change will come about in a more respectful and collaborative manner.

Chair Bernath thanked Commissioner Franz for making the workshop happen. He also shared the commitment to focus on collaboration moving forward and to continue working with Francine Madden.

REPORT FROM CHAIR

Chair Bernath reported on the following:

- Introduced Mark Hicks as the new Adaptive Management Program Administrator;
- Announced that DNR will be contacting caucus leads to discuss possible proposed agency legislation and to problem solve several issues with the state budget;
- Informed that the tribal cultural resources facilitation effort was completed in July 2019. As a result, DNR has committed to implement three initiatives: (1) change the forest practices application, specifically around how cultural resources are addressed by landowners who contact tribes before submittal of applications; (2) coordinate regional tribal cultural resources trainings; and (3) facilitate several application pilot projects with willing tribes and landowners for identification and protection of cultural resources;

- Announced that DNR's Lenny Young will lead the efforts to complete a programmatic Safe Harbor Agreement for the northern spotted owl;
- Outlined the workgroup's efforts (establishing through Senate Bill 5597) to address concerns regarding the aerial application of herbicides;
- Announced that DNR has contracted with the internal auditor of the Department of Revenue to complete a financial audit of the contracts for the Adaptive Management Program (AMP); and
- Announced that the State Auditor's office will be starting an AMP performance audit.

Chair Bernath thanked Tom Laurie and Lisa Janicki for their service on the Board. Tom has been on the Board for 18 years and Lisa for 3 years.

PUBLIC COMMENT

Vic Musselman, WFFA, said WFFA supports the work of the Board committee, but noted more work needed by the committee and it should not be rushed. He said the identification of PHBs and an anadromous fish floor should be done accurately in order to have an accurate cost/benefit analysis.

Ken Miller, WFFA, provided WFFA's table showing the relative effectiveness of their western Washington Small Forest Landowner Alternate Plan Template proposal compared to the forest practices rules. He also shared a table showing a comparison of riparian functions from each of the proposal prescriptions. He said that he believes the TFW Policy Committee (Policy) workgroup is making significant progress but additional work is needed. He anticipates Policy can provide recommendations to the Board by August 2020.

Ray Entz, Kalispel Tribe, encouraged the Board to provide leadership for maintaining an independent science focused Adaptive Management Program Administrator (AMPA). He asked the Board to evaluate how the AMPA is positioned within DNR to increase independence. He encouraged the Board to ensure that the review of the AMP is consistent with TFW agreements. He asked the Board to fund the potential habitat break (PHB) validation study and the default physical stream characteristics study.

Jim Peters, NWIFC, encouraged everyone to work together to help maintain the tribal way of life by ensuring fish availability and protection of natural resources in general. He informed the Board of an opportunity to testify at an upcoming hearing regarding the clean water standards and encouraged Board members to attend on September 25, 2019.

SMALL FOREST LANDOWNER DEMOGRAPHIC AND FOREST PRACTICES DATA PRESENTATION

Tami Miketa and Marc Engel, DNR provided a presentation on the demographics of Washington's small forest landowners (SFL), a general understanding of their harvest preferences, legislative actions pertaining to SFLs and SFL Program accomplishments.

There are approximately 178,400 SFLs in Washington (owning two acres of forest land or greater), with about 72% of the total occurring in western Washington. Miketa said the best information on how and why they manage their land comes from the USDA Forest Service's National Woodland Owners Survey. A 2013 survey showed that 92% of the landowners owned their land for other reasons besides timber production. A similar survey by the Washington State University Extension

Forestry Program found that SFLs rated ownership for privacy, aesthetics, a place of residence and wildlife habitat quite high, whereas owning land for timber management scored low.

Engel said that the legislature passed several statutes to address the economic effects of the rules. These statutes established the Small Forest Landowner Office as a resource for landowners and established an advisory committee to assist the office in developing policy and recommendations for rules or guidance. He said the Board has adopted rules for long-term applications, alternate plan options and approved guidance for conducting alternate plans.

Engel said the legislature passed, and the Board adopted, the 20-acre exempt riparian buffer rule in recognition of potential disproportionate impact to SFLs owning 20 acre parcels. This rule provides narrower riparian buffers for small forest landowners who own 80 acres or less of forestland, and are harvesting timber on parcels 20 acres or less in size. Roughly 70% of SFLs are eligible to use the 20-acre exempt rule.

Miketa said DNR recently conducted an analysis to better understand SFL harvest choices. She said from 9,211 SFL FPAs approved between 2010 and 2015, a total of 533 landowners opted for an alternate plan. The majority of those plans utilized one of the two templates described in Board Manual Section 21, with the fixed width buffer template being applied 56% of the time. Regular, non-template alternate plans were used approximately 27% of the time. This equates to about 6% of the total SFL FPAs (9,211) contained alternate plans.

Miketa summarized the fiscal year 2017-2019 program accomplishments. For this biennium, the Forestry Riparian Easement Program purchased 34 conservation easements (231 acres) and since its inception, approximately 6,100 acres have been covered. The Family Forest Fish Passage Program eliminated 29 fish passage barriers (60 miles of stream habitat) and since its inception, the program has eliminated 397 barriers and opened up approximately 934 miles of habitat.

TFW POLICY COMMITTEE RESPONSE TO THE BOARD'S JUNE MOTION

Terra Rentz and Curt Veldhuisen, Policy co-chairs, reported on Policy's response to the Board's June meeting motion. Rentz reminded the Board that they had asked Policy to provide recommendations as to whether an anadromous fish floor (AFF) and rule language for water crossing structures should be included in the water typing rule. The Board requested Policy make a formal yes or no vote and report back as soon as possible on each item.

Rentz said Policy, at their July meeting, recognized that each of the three proposed PHB options included an AFF element and as a result, voted to recommend the Board committee consider an anadromous floor as a component for the water typing rule.

Rentz said Policy felt the existing rule provides adequate water crossing management provisions. As a result, Policy voted to not include new language regarding water crossing structures. Policy recommends that an evaluation of potentially affected water crossing structures be considered in the future, but is not a priority at this time.

Rentz said the votes taken by Policy closes the loop for the adaptive management process. She said Policy felt some discomfort with the Board's request. Policy did not consider the requested review as a proposal initiation and as such did not form a workgroup to prepare formal recommendations. She said Policy simply adhered to the Board's request to vote on whether an AFF or language for water crossing structures should be included in rule. She added that Policy did not evaluate the legal bounds of this question.

Chair Bernath acknowledged that an AFF was already part of the draft water typing rule and that the recommendation confirms an AFF should be considered for inclusion in the rule. He acknowledged that Policy's task was to make a recommendation to the Board committee.

Board member Guenther agreed that the Board committee can discuss this further and said he is clear on the recommendations from Policy.

PUBLIC COMMENT

Darin Cramer, Washington Forest Protection Association (WFPA), said their caucus believes the AFF and water crossing rule concepts have not gone through a formal adaptive management process. He said considerable amount of technical and policy work is needed on both the PHB options and the AFF in order to move either forward. He said all three criteria contained in the PHBs need to be fully analyzed and excluding one criteria is improper and may prove to be an inaccurate analysis. He said he is unaware if a detailed discussion has occurred on what the rule is attempting to achieve and encouraged the Board to have this discussion.

Steve Barnowe-Meyer, WFFA, shared his experience at the TFW collaboration building workshop and reminded those involved to focus on the interim steps for success: caucus members should talk with, not at each other; commitment of leadership is needed from all caucuses; commitment to shared problem solving; develop short and long term goals; and focus on relationship building within the AMP. He implored the Board to encourage all who attended the workshop to take these steps seriously and find opportunities for collective wins that solve shared problems.

CMER MEMBERSHIP

Mark Hicks, AMPA, presented Patrick Lizon as Department of Ecology's Cooperative Monitoring, Evaluation, and Research Committee (CMER) nominee. Hicks briefly shared Lizon's current role in Clean Water Act Section 303(d) and nonpoint pollution programs at Ecology and highlighted his past accomplishment in implementing clean water policies at other natural resource agencies.

PUBLIC COMMENT ON CMER MEMBERSHIP

None.

CMER MEMBERSHIP

MOTION: Maia Bellon moved the Forest Practices Board accept Department of Ecology's nominee, Patrick Lizon as a voting member of CMER.

SECONDED: Jeff Davis

Board Discussion:
None.

ACTION: Motion passed unanimously.

WATER TYPING SYSTEM BOARD COMMITTEE STATUS REPORT

Bob Guenther, committee chair, described the topics presented and points discussed during the four committee meetings held in July. Presentations to help clarify the width PHB in option C and the AFF criteria and analysis were given by DNR staff, the industrial forest landowners, with support from small forest landowners, counties, and the western Washington tribes.

The committee discussed various options specific to width-based PHBs including: whether and how tributaries function as habitat breaks; the science team's recommendations regarding tributary streams as reported in the PHB report; the accuracy of the various width-based PHBs; the need to amend the current draft rule language for PHB option C; and options for removing width-based PHBs from the proposals or amending the PHBs altogether.

The committee also discussed the western Washington tribal and landowner's AFF proposals, both the current work being conducted and proposed analysis strategies. In regards to the tribal proposal, the committee recommended that the western Washington tribes continue to facilitate the AFF technical workgroup discussions to develop a charter and to present it to the Board committee.

Board member Swedeen acknowledged that the committee gained clarification regarding the landowner's PHB proposal, but said that some committee members are struggling with how to address tributary streams given the recommendations in the science team's PHB report pertaining to width-based PHBs and tributaries. She recognizes that dropping the width-based PHB from the current proposals might influence the accuracy of the spatial analyses.

Board member Nelson said that the committee and the Board are struggling with a path forward because not only were the objectives of the rule unclear, the objectives for the PHB options and the AFF options are different. He felt that the Board should remand the development of the water typing rule back to the AMP in order for technical folks to arrive at the best possible outcome. He said the Board should secure funding to hire contractors to help provide additional clarification.

Board member Davis expressed concerns about giving it back to a fish habitat technical group. He said the committee is struggling with analyzing the three PHB options systematically. He said that he hoped folks could overcome their defensiveness about specific proposals.

Board member Herrera acknowledged that despite issue complexity, other elements from the Board's June 4 motion were being completed by the committee. He said that the AFF contains a stream gradient, not necessarily a floor, but arrives at the place below which one would not apply electrofishing. The AFF addresses the objective of reducing electrofishing as recommended in the Forest Practices Habitat Conservation Plan. He said the tribe's analysis used the results from a watershed to assess a gradient for the AFF and invited other technical folks to collaborate and further refine that work.

Board member Swedeen said that she believed most Board members agree on the major goals of this rule, specifically delineating Type F waters based on fish habitat and minimizing the use of electrofishing. She expressed hope that the Board could move forward with a rule and to fine-tune the PHB criteria through the completion of a validation study.

Chair Bernath summarized his understanding of the discussion:

- The Board supports continuation of the Board committee;

- Acknowledgement that the fish habitat assessment method seeks to reduce electrofishing;
- The Board supports DNR staff to look for options to secure funding to contract with the science team in order for them to provide clarification on the recommendations in their PHB report; and
- The Board envisions that the AFF workgroup will be accountable to the committee

Board member Davies suggested that one way to avoid confusion is for the Board to emphasize using the default physical stream criteria in the rule instead of using the three PHB proposals.

Board member Swedeen suggested that the committee have the authors of the PHB report and Brian Fransen collectively provide clarification about how and whether they intended tributary stream junctions to function as potential fish habitat breaks.

Chair Bernath expanded his understanding of the discussion:
- The Board requests the AFF workgroup finalize its charter and present it to the Board committee; and
- The Board supports having the science team provide clarity to the Board committee regarding how tributary junctions should be addressed.

Chair Bernath clarified that Policy's recommendation is to consider inclusion of an AFF in the water typing rule and not include rule language for water crossing structures at this time. The Board agreed that formal action was not needed.

WATER TYPING SYSTEM RULE MATERIALS STAFF STATUS REPORT

Marc Engel, DNR, said staff was continuing to develop the guidance for the water typing system rule and envisioned that it may take up to four months to complete a draft of Board Manual Section 23. He acknowledged that the Board committee would continue facilitating discussions with stakeholders on outstanding rule concerns.

Engel said DNR continued to work with the economic advisory workgroup to discuss the elements and the methods used in the draft cost benefit analysis (CBA). In addition, a meeting will be scheduled with Industrial Economics, Incorporated (IEc) to address how the preliminary CBA calculated the expected change in fish populations for each PHB option. He said that additional work was needed by the economic advisory committee to determine how the qualitative analysis would be completed. He added that IEc may need to recalculate the benefits to fish and will need to calculate qualitative values to incorporate into the CBA.

Engel said the primary goals of the rule are to fulfill the four goals identified in the Forests and Fish Report. He said that any significant rule making by the Board must include the goals and objectives of the new rule. He stated that stakeholder requests at past Board meetings and the recent discussions at the Board committee meetings show a need for staff to articulate the goals and objectives for the rulemaking. He presented a draft goals and objectives statement for the Board to consider:

> *This rulemaking was initiated through the Adaptive Management Program in January, 2013 when the U.S. Fish and Wildlife Service, NOAA-Fisheries Service, the Washington Department of Fish*

> *and Wildlife, and the Conservation Caucus raised concerns about continuing the electrofishing practices under the interim water typing system.*
>
> *This rulemaking seeks to better address the Forests and Fish Report foundational goal to protect accessible fish habitat. Additionally, the rulemaking aims to develop a field applied method of reliably identifying accessible fish habitat in an objective and repeatable manner. By maintaining all essential elements of the methodology in rule, this rulemaking will also convert any key long-standing Board guidance into rules where appropriate. See, RCW 34.05.230(1)*
>
> *A sound water typing system ensures that riparian buffers are properly placed at each stream, protecting aquatic resources and their respective habitats. These goals support the statutory objectives endorsed in the Forests and Fish Report and Forest Practices Habitat Conservation Plan.*

Chair Bernath said the draft goals and objectives is being shared so that the general public and the Board can see how DNR is likely to frame the concise explanatory statement.

Board member Nelson expressed concern with the term ‘accessible’ in the presented goals and objectives.

Board member Guenther said the committee can include a discussion about the goals and objectives at their next meeting.

Board member Swedeen asked what the timeline for filing the rule proposal (CR-102) might be if the GIS spatial analysis associated with the CBA needed to be redone.

Engel replied that a contract would first need to be initiated if the Board chose to re-analyze the three rule proposals. He said that late November 2019 would be a probable starting point for re-drafting the economic and environmental analyses.

ADJUSTED ADAPTIVE MANAGEMENT PROGRAM BUDGET AND CMER WORK PLAN

Mark Hicks, AMPA, Curt Veldhuisen and Terra Rentz, Policy co-chairs, presented the adjusted AMP budget. Hicks said that Policy had made several changes to the budget per the Board’s request and found available money to allocate into the water typing line items.

Rentz reminded the Board that they had asked Policy to consider four changes: (1) update revenue to reflect the final legislative budget; (2) correct the estimate for the DNR indirect costs for the Forests and Fish Support Account; (3) create a new line item of $150,000 for the AMP workshops facilitated by the Center for Conservation Peacebuilding; and (4) move any remaining funds into the Board’s water typing rule strategy funding line item. She said that further adjustments would be made later when the job classification for the new administrative assistant was determined.

Hicks said that the position description for the eastside CMER scientist was almost finalized. The next step would be to secure an office space for the position in Spokane.

Rentz said the funding ($35,000) for the deep-seated landslide research project was moved from this biennium to the first of the next biennium. She said that the contingency fund was tapped to move funds into the water typing strategy which resulted in an increase from $40,000 to $68,000 for the first year of the biennium and an increase from $450,000 to $552,000 for the second year of the biennium. This was done to ensure funds would be available for the first two years should the Board need additional funding to complete water typing rule projects.

Board member Swedeen suggested that the Board find a way to fund an adequate validation study.

Rentz encouraged the Board to review the CMER work plan and Master Project Schedule to help clarify and provide feedback to Policy. She said that Policy was aware that project priorities often change and the sooner the Board could determine their plans for water typing, the sooner Policy could make decisions about how to best use the remaining contingency fund.

Hicks said that the 'use it or lose it' concept creates problems for budgetary planning. He added that this was particularly true of projects agreed to at the end of the biennium to use excess funds before they are moved into the fund balance. He said that by the time a decision is made to allocate such funds, there is high risk of not completing projects as planned. This results in projects commonly needing to be finished in the following biennium requiring additional money to be allocated from the next year's funds. He said this happened with last year's surplus fund projects and resulted in reducing this year's contingency balance to approximately $9,000.

Hicks said that accurate budgets with realistic time frames are needed to avoid large under-expenditures at the end of a biennium. He urged the Board to use discretion when considering decisions to allocate funding in the near-term spending plan for studies that have not been scoped.

Board member Bellon suggested for easier tracking that Policy consider providing a budget with two columns showing the prior and new budget values to more clearly show where important adjustments were made.

Rentz confirmed that the revised budget is a consensus budget and requested that the Board accept the revised budget as presented. She also mentioned that all Clean Water Act assurances projects are included in the Master Project Schedule.

PUBLIC COMMENT ON ADJUSTED ADAPTIVE MANAGEMENT PROGRAM BUDGET AND CMER WORK PLAN

None.

ADJUSTED ADAPTIVE MANAGEMENT PROGRAM BUDGET AND CMER WORK PLAN

MOTION: Patrick Capper moved the Forest Practices Board approve the adjusted biennial 2019-2021 Adaptive Management Program budget.

SECONDED: Tom Nelson

Board Discussion:
None.

ACTION: Motion passed unanimously.

TFW POLICY COMMITTEE UPDATE OF TYPE NP WORKGROUP

Curt Veldhuisen and Terra Rentz, Policy co-chairs, provided an update on the Type Np workgroup. Veldhuisen said that the workgroup effort was a result of the Type N Experimental Buffer Treatment Project in Hard Rock Lithologies (hard rock study). He said that Policy had approved a charter to address not only the hard rock study, but also additional Type Np studies that would be forth coming.

Veldhuisen said that the main objective of the charter is to have a technical workgroup develop and recommend potential Np riparian management zone prescriptions. Policy envisioned that the workgroup would be comprised of folks with stream morphology, biology, silvicultural and forestry experience. He said the AMPA would be reaching out to the workgroup to clarify expectations and ensure that they will be committed to the process.

Board member Bellon mentioned that the Clean Water Act assurances expire at the end of 2019. She said the Department of Ecology may consider a short term extension of the assurances given the charter’s important work and anticipated schedule. She asked Curt if Ecology can rely on the timelines within the charter.

Veldhuisen said that he believed the timelines within the charter are realistic, but emphasized that they are not in control of the final delivery dates for when the other Type N studies would be coming to Policy and subsequently to the technical team. Reviewing and acting on the other studies might require adjustments to the overall timeline. He said they are committed to keeping the Board up to date on the progress.

TFW POLICY COMMITTEE PRIORITIES FOR CALENDAR YEAR 2020

Curt Veldhuisen and Terra Rentz, Policy co-chairs, updated the Board on Policy’s priorities for 2020. Veldhuisen said that the highest priorities would be the Type N studies. Other priorities include the master project schedule, annual budgeting, staffing, small forest landowner westside riparian template, a potential audit, hardwood conversion study and the bull trout overlay study. He anticipates a very busy year and said that Policy must work very efficiently and be very careful about taking on new things.

Rentz reminded the Board of the review period for accepting, reviewing and approving studies. She noted the relatively small group of people involved in all the work done by Policy.

Board member Swedeen expressed concern about completing the PHB validation study in light of all the other work.

Rentz agreed that Policy and various workgroup members are stretched thin. She said they have built in necessary safe guards when establishing timelines to address all the work.

Chair Bernath acknowledge that as the new AMPA gets up to speed, he will be able to assess the status of these studies and recommend refinements as needed.

WESTERN GRAY SQUIRREL ANNUAL REPORT

Gary Bell, WDFW, and Teresa-Ann Ciapusci, DNR, provided a status report about the state-threatened western grey squirrel. The update included the current voluntary protection process that takes places between WDFW and forest landowners and a description of the current threats to the squirrel. Bell noted that there were 112 FPAs with a possible nexus to the squirrel in 2018, and that nearly all were in Klickitat County. WDFW's periodic status review for the western grey squirrel is due in 2021.

Board member Willet asked about the lack of information on any changes to the squirrel population.

Bell replied that it is an ongoing challenge for WDFW to determine population changes because there is no dedicated funding for research for the 183 species on the periodic status review list.

Board member Swedeen asked what it would take to know if current management actions are making positive steps for the squirrel.

Bell said a dedicated full time position could perform pre-harvest, post-harvest and habitat restoration work to assess how the current process is working.

Board member Davis asked what it would take to incentivize landowners to grow squirrel habitat.

Bell said WDFW is looking into ways to obtain monies for effectiveness and compliance monitoring, small forest landowner incentives and large landowner conservation opportunities.

STAFF REPORTS

There were no questions on the following reports.

- Adaptive Management Quarterly Report
- Compliance Monitoring
- Small Forest Landowner Office Update
- Upland Wildlife Update

2019 WORK PLAN

Marc Engel, DNR, presented changes to the work plan since the May meeting. Adjustments were also made as a result of today's meeting.

MOTION: Patrick Capper moved the Forest Practices Board approve the work plan as amended.

SECONDED: Carmen Smith

Board Discussion:
None.

ACTION: Motion passed unanimously (Davies absent for vote)

EXECUTIVE SESSION

None.

Meeting adjourned at 4:50 p.m.

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MEMORANDUM

October 18, 2019

TO: Forest Practices Board
FROM: Mark Hicks, Adaptive Management Program Administrator

SUBJECT: Transmittal: Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading Study

At their June 2019 meeting, TFW Policy formally accepted the Findings Report and associated materials for the study entitled Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading study (hereafter: Buffer-Shade Study).

The purpose of the Buffer-Shade Study was to evaluate the effectiveness of different shade levels in maintaining key aquatic conditions and processes affected by Forest Practices in Type N (non-fish-bearing) waters. The investigators created a gradient of stream shade over 50-m (164 ft) study reaches at 25 headwater streams located in northwest Oregon and western Washington.

Post-treatment canopy cover in the reference reaches averaged ≥97% in contrast to the treatment reaches at an average of 77%, 61%, and 40%, in the Intermediate, Low, and No Shade treatments, respectively.

While the study focused on Stream Associated Amphibian (SAA) responses, it also examined resources known to impact SAAs (i.e., shade, water temperature, detritus, and macroinvertebrates).

Some key findings from the study include:

- Stream temperature experienced a small non-significant increase (~0.5ºC) in the mean 7DADM for the Intermediate Shade treatment. However, progressively larger and statistically significant temperature changes were identified in the Low and No Shade treatments. These treatment effects had a magnitude of 2.2ºC and 2.5ºC, respectively.
- Biofilm, which is often viewed as a measure of primary productivity and food availability, increased similarly at all treatments. Reductions in detritus, also a source of food for some species, declined significantly only in the No Shade treatment consistent with the reduction in over story canopy as a supply source.

- Changes in macroinvertebrate drift were highly variable across the metrics examined, but had an overall pattern of less declines occurring in the Intermediate, and Low treatments then in the No Shade treatment.
- Stream-associated amphibian (SAA) response was evaluated at the reach-level, focusing on whether different shade levels met the overall Performance Goals of supporting the long-term viability of SAAs. No consistent patterns in the response were found, however some SAA responses were consistent with expectations linked to shade reductions.
- Considering macroinvertebrates and amphibians collectively, the authors observed more positive and fewer negative responses in the Intermediate Shade treatment than in the No or Low Shade treatments.

After reviewing the study findings, Policy agreed by consensus not to recommend the Board take any formal action in response to this study. Though no action is recommended by the Board, the study findings advances the best available science on the response of Type N streams to reductions in shading. In recognition of this, TFW Policy has asked the study be provided as supporting technical information to the Type Np Prescription Workgroup.

Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading

James G. MacCracken, Marc P. Hayes, Julie A. Tyson,
and Jennifer L. Stebbings

November 2018

CMER #16-1600

STREAM-ASSOCIATED AMPHIBIAN RESPONSE TO MANIPULATION OF FOREST CANOPY SHADING

James G. MacCracken
Marc P. Hayes
Julie A. Tyson
Jennifer L. Stebbings

27 November 2018

Frontispiece Photograph Credits (clockwise from upper left): John P. Clare (Columbia torrent salamander larva); Marc P. Hayes (Coastal giant salamander larva, note bushy gills); Julie A. Tyson (stream enclosure); Marc P. Hayes (Cope’s giant salamander neotene, note reduced gills); Julie A. Tyson (Shade Study field crew from left to right, Amber P. Martens, Kristen D. [Ramsdell] Garrison, and Keith A. Douville); Julie A. Tyson (Keith A. Douville measuring an Olympic torrent salamander); Ryan P. O’Donnell (three Coastal tailed frog life stages: a metamorph [left] and two larvae [center and right]); and Julie A. Tyson (pre-treatment [left panel] and post-treatment [right panel] of a No Shade treatment site; yellow arrow indicates the same tree in both conditions).

Washington State Forest Practices Adaptive Management Program

The Washington State Forest Practices Board (FPB) has established an Adaptive Management Program (AMP) by rule in accordance with the Forests & Fish Report (FFR) and subsequent legislation. The purpose of this program is to:

> *Provide science-based recommendations and technical information to assist the FPB in determining if and when it is necessary or advisable to adjust rules and guidance for aquatic resources to achieve resource goals and objectives. The board may also use this program to adjust other rules and guidance.* (Forest Practices Rules, WAC 222-12-045(1)).

To provide the science needed to support adaptive management, the FPB established the Cooperative Monitoring, Evaluation and Research (CMER) committee as a participant in the program. The FPB empowered CMER to conduct research, effectiveness monitoring, and validation monitoring in accordance with WAC 222-12-045 and Board Manual Section 22.

Report Type and Disclaimer

This technical report contains scientific information from research or monitoring studies designed to evaluate the effectiveness of the forest practices rules in achieving one or more of the Forests and Fish performance goals, resource objectives, and/or performance targets. The document was prepared for the Cooperative Monitoring, Evaluation and Research Committee (CMER) and contains scientific information intended to improve or focus the science underlying the Forests and Fish Adaptive Management program. The project is part of the Type N Amphibian Response Program, and was conducted under the oversight of the Landscape and Wildlife Advisory Group (LWAG).

This document was reviewed by CMER and was assessed through the Adaptive Management Program's Independent Scientific Peer Review process. CMER has approved this document for distribution as an official CMER document. As a CMER document, CMER is in consensus on the scientific merit of the document. However, any conclusions, interpretations, or recommendations contained within this document are those of the authors and may not reflect the views of all CMER members.

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Proprietary Statement

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STREAM-ASSOCIATED AMPHIBIAN RESPONSE TO MANIPULATION OF FOREST CANOPY SHADING

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Executive Summary

We reduced vegetation cover along a 50-m reach on each of 25 headwater streams in northwest Oregon and western Washington. Vegetation removal began directly over the stream and moved outward until 0%, 30%, and 70% overhead cover was attained (hereafter; no-, low-, and intermediate-shade treatments). Each treated reach was paired to an upstream reference reach where cover averaged 92–97%. Using a replicated BACI design, we documented pre- versus post-treatment changes in light levels, water temperature, biofilm, drift of detritus and macroinvertebrates, and the abundance, body condition, and growth rates of six stream-associated amphibian species (one anuran and five salamanders). Quantification of biofilm and drift reflected measurement of basal food resources for higher trophic levels (amphibians). We used the results of mixed models analyses on effect sizes (treatment minus reference, $\alpha = 0.1$) as well as the relative magnitude of effect size (ES) changes (percentage change that exceeded 90% confidence limit

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[CL]) from pre- to post-treatment periods, respectively, to infer important treatment effects and highlight large but statistically non-significant changes implying potential treatment effects.

Treatments resulted in a roughly three-fold gradient (*P* = 0.0001) of photosynthetically active radiation at stream surfaces. At the greatest light levels, heterotrophic streams dominated by allochthonous inputs underwent a shift toward autotrophy as reflected by an increase in biofilm accumulation (*P* <0.1-0.01), declines in coarse particulate organic matter (*P* <0.1-0.01), and a 16-39% decline in all detritus categories. However, we also observed increases in biofilm at low- and intermediate-shade levels (*P* <0.1-0.01). With these changes, we also observed significant (*P* <0.1-0.001) or substantial (≥90% CL) increases in water temperature at all levels of shade reduction, which likely facilitates this shift. We conclude that some shift toward autotrophy is manifest at all levels of shade reduction.

At higher trophic levels, responses to treatments were inconsistent in direction and magnitude, complex, and site-specific. However, many response variables exhibited patterns that agreed with major predictions of the light:nutrient hypothesis: e.g., herbivore growth rates maximized at moderate (low- and intermediate-shading) light levels. The overall pattern was that positive changes in macroinvertebrates occurred only at the intermediate- or low-shade treatments and negative changes generally characterized responses in no-shade treatments. Specifically, drift of macroinvertebrate predators and shredders and total counts of macroinvertebrates declined, respectively, 14-26%, 18-43%, and 22% in the no-shade treatment (*P* <0.1-0.001) along with a substantial decline in gatherers (≥90% CL), whereas gathering collectors increased 38-53% in the low-shade treatment (*P* <0.01-0.001) and scrapers increased 24% in the intermediate-shade treatment (*P* <0.1-0.01). Captures of amphibian species generally increased from pre- to post-treatment periods in all reaches, including references, implying un-sampled ecosystem effects independent of treatments. However, ES estimates for giant salamander (*Dicamptodon* spp.) counts revealed differences among treatment levels (*P* = 0.08), but within treatments, only the 22% increase in the no-shade level was significant (*P* <0.01-0.001), though a 45% increase in the intermediate-shade level implied a positive treatment effect. Effect size estimates for Cascade torrent salamanders (*Rhyacotriton cascadae*) and Olympic torrent salamanders (*R. olympicus*) counts also differed across treatment levels (*P* = 0.06-0.10), but within-treatment patterns revealed an increase (50% and 60%, respectively) pre- to post-treatment for both species at the intermediate-shade level (*P* <0.1-0.01), and a large (833%) decline for Olympic torrent salamanders at the low-shade level (*P* <0.1-0.01). Also, the 1263% pre- to post-treatment increase for tailed frogs (*Ascaphus truei*) at the intermediate-shade level implied a treatment effect (≥90% CL).

Amphibian body condition estimates exhibited fewer patterns among treatments or taxa. Only larval tailed frogs and Cascade torrent salamanders differed across treatments (*P* = 0.04-0.10). Within treatments, estimates of tailed frog larvae and metamorph body condition increased 143% and 520% at the low-shade level (*P* <0.1-0.001), but increases were also seen in giant salamanders and Columbia torrent salamanders (*R. kezeri*) of 50% and 225%, respectively, at the intermediate-shade level, which also implied a treatment effect (≥90% CL). We recorded a decline in body condition only for Cascade torrent salamander in the low-shade reaches (*P* < 0.1-0.01).

Amphibians held in in-stream enclosures had variable growth rates. Only Columbia torrent salamander growth rates differed statistically across all treatments (*P* = 0.10). However, at the intermediate-shade level, we observed two significant changes, a large increase (1150%) in Cascade torrent salamander growth rates and a modest decrease (28%) in tailed frog metamorphs growth rates (*P* <0.1-0.01). Increases of 433% and 800%, respectively, in Olympic torrent salamanders and larval tailed frogs growth rates at the same shade level only implied treatment effects (≥90% CL). At the no-shade level, we observed significant increases in growth rates for larval tailed frogs, and Columbia and Olympic torrent salamanders (*P* <0.1-0.001). At the low shade level, we observed, an 800% increase in growth rate for tailed frog metamorphs and 35% and 200% declines in growth, respectively, for Columbia torrent salamanders and giant salamanders, which all implied a treatment effect (≥90% CL). Patterns obtained from in-stream enclosures must be weighed within the perspective that the complicated temperature data from exclosures (enclosures with tiles [for biofilm accumulation] and temperature dataloggers, but lacking amphibians) implied a partial enclosure effect.

Amphibian responses were taxon-specific and varied among treatments and response variables. Nonetheless, we recorded more positive responses (either significant or implying a treatment effect) and the same number or fewer negative responses at the intermediate-shade level (six of 11 possible responses were positive; one was negative) than in either the low-shade (two positive; two negative) or no-shade levels (one positive; one negative). The intermediate level of shading also displayed the smallest increase in water temperature. These data suggest that incorporating canopy openings similar in size (≈ 0.5 ha) and shade levels created with our intermediate treatments (70% overhead shade) as part of riparian management may benefit stream amphibians as long as other potential stressors (fine sediment delivery or water temperature increases) do not result in negative impacts. Given that we observed water temperature increases over single 50-m reaches at the no and low shade levels, we advise caution in design for both the dimension and shade level of canopy openings. However, the variability observed in this study may have its basis in unmeasured site-specific differences (e.g., groundwater inputs) arising from the relatively small sample of sites used in the overall study, and may aid in understanding the observed response complexity. We recommend further examination of the benefits that may accrue by creating riparian canopy gaps within an adaptive management framework. We expect that some effort to focus on how differences in local groundwater inputs and nutrient sources may influence variability may be revealing.

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Introduction

Worldwide concern about the status of amphibians has increased scrutiny of the effects that many environmental factors have on amphibians (Stuart et al. 2004). One area of concern is forestry practices, which has been the focus of numerous studies over the last four decades (deMaynadier and Hunter 1995, Kroll 2009, Cecala et al. 2014). A number of these studies have examined the effects of timber harvest on a suite of stream-associated amphibians (SAAs) endemic to the Pacific Northwest (PNW); including Coastal tailed frogs (*Ascaphus truei*), giant salamanders (*Dicamptodon* spp.), and torrent salamanders (*Rhyacotriton* spp.) (Murphy and Hall 1981; Bury and Corn 1988; Corn and Bury 1989; Bury et al. 1991; Kelsey 1995; Bull and Carter 1996; Diller and Wallace 1996, 1999; Wilkins and Peterson 2000; Wahbe and Bunnell 2003; Steele et al. 2002, 2003; Russell et al. 2004, 2005; Jackson et al. 2007; Kiffney and Roni 2007; Kroll et al. 2008; Leuthold et al. 2012). Despite this substantial number of studies, their collective results are extremely variable, generating uncertainty (Kroll 2009), and preclude development of harvest guidelines that will retain SAA populations. Though diverse factors contribute to these complex results, the most important are likely: (1) the confounding effects of regional variation in physical features (parent geology, topography, altitude, latitude) and processes because most SAAs have relatively broad distributions, (2) studies were not designed to examine potential interactions between harvest effects and original or harvest-modified abiotic factors, (3) we lack adequate understanding of how much the probability of detecting SAAs varies with diverse habitat conditions and sampling methods (Kroll 2009), and (4) differences in the natural/life history of different SAA taxa may result in fundamentally different responses.

Notwithstanding these complications, these studies agree in that timber harvest has two immediate primary physical effects: (1) reduced vegetation cover and (2) increased fine sediments to streams. Because parent geology, aspect, stream gradient, and the latter's concomitant effects on flow velocity can either diminish or exacerbate these effects, we expect that the relative magnitude of their impact on SAAs will vary with local conditions. For example, Murphy and Hall (1981) and Hawkins et al. (1983) found that the positive effects of removing riparian vegetation (increased primary productivity) could mask a potentially detrimental sedimentation effect; and Murphy and Hall (1981) and Diller and Wallace (1996) found that steep stream gradients also reduced the potential negative effects of increased sediments. However, high flow velocities can also limit periphyton accrual (Warnaars et al. 2007), shift the composition of the flora toward taxa with adnate growth forms, and affect grazing susceptibility (Wellnitz and Poff 2012). Hence, to quantify physical effects on SAAs, it is essential to examine the changes in vegetation cover and sedimentation independently, i.e., under conditions where one or the other are absent or nearly so. In this study, we examine the impacts of reducing vegetation cover on SAAs while keeping sediment influx to a minimum.

In forested ecosystems of the PNW, autochthonous (within-stream) productivity in headwater streams is limited due primarily to interception of sunlight by dense cover of vegetation from the low-shrub layer to the forest canopy (Gregory et al. 1987, Hetrick et al. 1998, Murphy 1998, Kiffney et al. 2004). In general, energy inputs to these streams are from allochthonous sources (outside the stream), and hence, the streams are labeled heterotrophic (Lagrue et al. 2011, Marcarelli et al. 2011). The relative importance of allochthonous versus autochthonous inputs shapes stream communities at all trophic levels (Hall et al. 2000, Baxter et al. 2005, Lagrue et al. 2011, Wootton 2012). Reductions in vegetation cover can alter these basic relationships by shifting stream segments from heterotrophy to autotrophy as autochthonous energy sources become more dominant and stream assemblages or structures change (Feminella and Hawkins 1995, Lagrue et al. 2011; Hill et al. 2010, 2011a, 2011b; Lange et al. 2011, Ohta et al. 2011).

Many studies have shown that reduced canopy cover has positive effects on abundance, species richness, survival, growth, and development of several species of pond-breeding anurans and some caudates (see review in Earl et al. 2011 and references therein). However, Earl et al. (2011) found a differential response to pond shading between two ambystomatid salamanders and three anurans as well as among the anuran species they studied. Although that study was conducted in lentic environments and with different taxa, such a dichotomy may be frequent based on the energy subsidies of shaded vs. open waters, macroinvertebrate species differences, and the trophic position of anuran (grazer) and caudate (predator) larvae. These fundamental relationships may also apply to headwater stream communities in the PNW.

A number of studies in the PNW have indicated that a reduction in vegetation cover increases stream primary productivity (Hansmann and Phinney 1973, Wootton 2012), often translating to greater production at higher trophic levels (Murphy and Hall 1981, Hawkins et al. 1983, Bisson and Sedell 1984, Bilby and Bisson 1987, Holtby and Scrivener 1989, Keith et al. 1998, Kiffney et al. 2004, Wilzbach et al. 2005, Mallory and Richardson 2005, Wootton 2012). Inconsistent conversion of the increase in primary production to higher trophic levels may reflect the confounding and negative effects of increased sedimentation (e.g., Murphy and Hall 1981), temperatures (e.g., Leach et al. 2012), discharge and weather (Hetrick et al. 1998), and site-specific conditions (Richardson and Béraud 2014). Importantly, site-specific conditions may include complex biotic effects, such as those involving the behavioral or morphological traits of prey that limit their vulnerability to predators and limit the flow of energy to higher trophic levels, which can substantially weaken top-down effects on primary consumer biomass (Ruetz et al. 2002, McNeely et al. 2007). Hence, effective translation to higher trophic levels reflects the relative importance of bottom-up (production) versus top-down (predator) regulation, and may be manifest as increased production at alternating trophic levels below the highest level as empirically established aspects of food-chain theory predict (Fretwell 1987). Inconsistencies may also arise because light saturation for algal production occurs at less than full sunlight (Murphy 1998), which suggests a threshold at which further reductions in shade will not increase productivity, a pattern that may vary with latitude. Furthermore, the light:nutrient hypothesis predicts that herbivore growth rates are maximized at moderate light levels (e.g., low- to intermediate-shade in this study) because greater structural carbon (cellulose and lignin) in algae at high light levels reduces the quality of algae to grazers, and at low light levels herbivores are limited by available algal mass, not its digestibility (Sterner et al. 1997). Another causal mechanism can be found in the bioenergetics hypothesis (Brett and Groves 1979), i.e., increased solar radiation can increase stream temperatures, which increases metabolic rates of aquatic organisms and at some point metabolic demands cannot be met by available resources and growth and body condition exhibit a roughly inverse quadratic response to light and temperature gradients (Huey and Stevenson 1979; **Fig. 1**). These relationships may affect secondary consumers because herbivores experiencing optimum growth rates should translate to greater foraging efficiency by predators (Charnov 1976) under favorable habitat conditions.

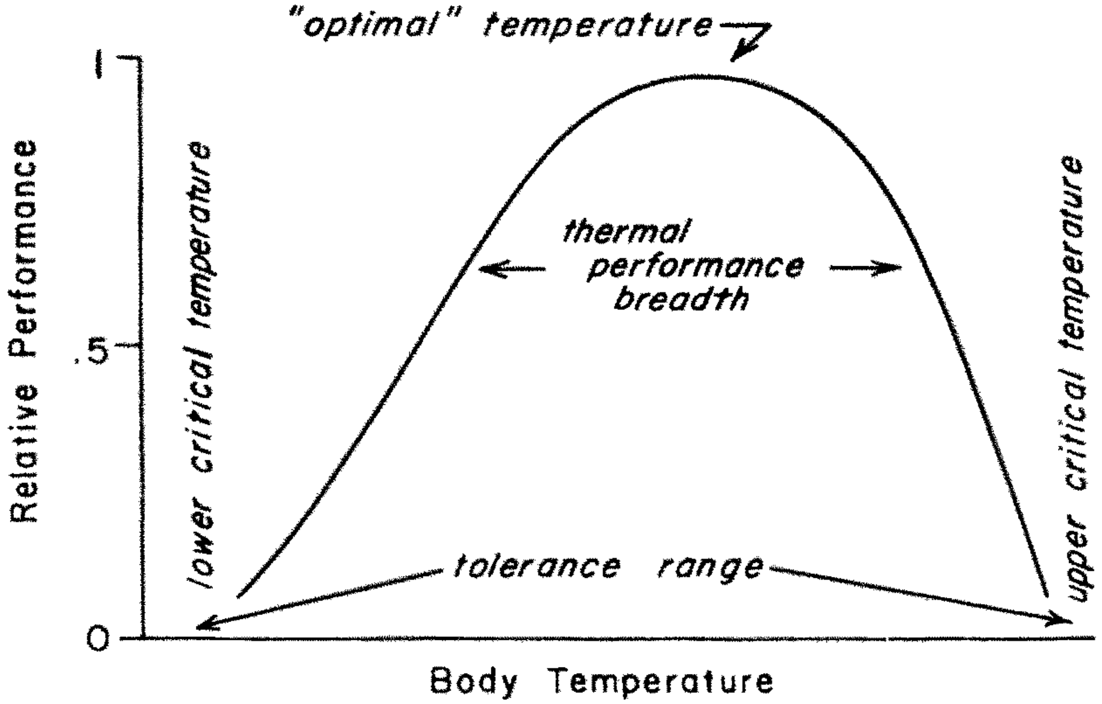

Figure 1. Hypothetical ectotherm temperature performance curve (adapted from Huey and Stevenson 1979).

Of the studies that have examined higher trophic level responses to shading, few have addressed SAAs (Hawkins et al. 1983, MacCracken 2002, Kiffney et al. 2004, Mallory and Richardson 2005, Kiffney and Roni 2007). Hawkins et al. (1983) detected no differences in the density and overall mass (g m^{-2}) of Coastal giant salamanders (*D. tenebrosus*) in stream reaches between adjacent or paired clearcut and unharvested stands in western Oregon, but Kiffney and Roni (2007) found that the interaction between light and stream gradient best explained *D. tenebrosus* abundance at their coastal Oregon sites. In a riparian hardwood conversion study (thinning of hardwoods and under-planting with conifers) in southwestern Washington, MacCracken (2002) found body condition (based on the residuals index) of Columbia torrent salamanders (*R. kezeri*) to be greater, albeit at lower densities, in streams where the surrounding tree canopy was reduced by 30-50%. In addition, though Wahbe and Bunnell (2003) found no statistically significant differences in density or mass of Coastal tailed frog larvae among streams in clearcut, second-growth, and old-growth stands; average larval mass was highest in clearcuts, suggesting a biologically significant effect in terms of better foraging in those streams for this algae grazer. In addition, two manipulative experiments have demonstrated that *A. truei* larvae can show marked responses to variation in light levels. Using experimental channels that were artificially shaded to create four levels of photosynthetically active radiation (PAR) reaching streams (2%, 10%, 22%, and 100% of full exposure), Kiffney et al. (2004) found that larvae lost mass in the two treatments with the lowest light levels, whereas larval growth rates were seven-times greater in the 100% versus the 22% treatment. Light level was also strongly related (R^2 = 0.96) to the proportion of larvae surviving at the end of the study. Using in-stream experimental enclosures, Mallory and Richardson (2005) showed that *A. truei* larvae had relative growth rates that were 14% higher in the less shaded treatments, which presumably reflected the 30-40% greater periphyton mass in those treatments when contrasted with the more shaded treatments. Collectively, these studies imply that shade reductions produce a bottom-up response that is manifest as improved body condition, growth or survival of primary consumers (e.g., tailed frog larvae) and increased body condition and population density of secondary consumers (e.g., salamanders). However, dynamics of energy transfer to SAA consumers can be influenced by differences in susceptibility to predation of invertebrate prey taxa (Atlas and Palen 2014), intra-SAA guild predation or aggression and/or predator hunting behavior (Parker 1994, Feminella and Hawkins 1995). As previously noted in discussing site-specific conditions, such influences can dampen bottom-up responses. Further, confidence in the applicability of previous SAA study results is limited due to the retrospective and correlative nature of all studies except those of Kiffney et al. (2004) and Mallory and Richardson (2005). Moreover, how the pattern that the latter studies found might change with latitude (e.g., Liess et al. 2013) or influence SAA secondary consumers is not known; tailed frog was the only SAA addressed in their experiments and they worked in a system lacking SAA secondary consumers. Furthermore, the response to reduced shade appears to be linear, contrary to the light:nutrient and bioenergetics hypotheses, but few of these studies sampled along a complete gradient of light intensity and thus have limited utility in assessing the predictions of those hypotheses.

The combination of the limited scope of past studies in terms of the SAA community, the light levels examined, and geographic extent led us to undertake a reach-level manipulative experiment to examine SAA response. The overarching objective of this experiment was to assess the effects of shade reductions on SAAs, and examine some possible causal mechanisms as well as the applicability of both the bioenergetics and light:nutrient hypotheses at primary and secondary consumer levels. Another objective of the study was to insure that the results had widespread application by having study sites encompass three ecoregions or provinces (Bailey et al. 1994) of coastal Oregon and Washington (i.e., Coast Range, Puget Trough, and West Cascade Range).

We studied six SAA species, one of which (*A. truei*) is a primary consumer during its larval stage and the remaining species, all salamanders (*D. tenebrosus*, *D. copei*, *R. cascadae*, *R. kezeri*, and *R. olympicus*), are secondary consumers during their in-stream larval stages (Nussbaum et al. 1983). Coastal tailed frogs and the torrent salamanders were part of the seven target SAAs considered during the development of headwater stream protection strategies for private and state lands managed for timber production in Washington (Forests and Fish Report 2000) and later adopted under the Forest Practices Habitat Conservation Plan (Washington Department of Natural Resources 2005). We focused on SAA abundance, body condition, and growth rates as response variables based on their use in previous studies and our belief that a change in body condition or growth rate would likely be the most rapid response evident from shade manipulations. We also measured water temperature and light, and estimated biofilm accumulation and macroinvertebrate abundance to enable linking SAA responses to any treatment effects on those key variables. The conceptual model upon which our study was based showing the major energy and process pathways is shown in Figure 2.

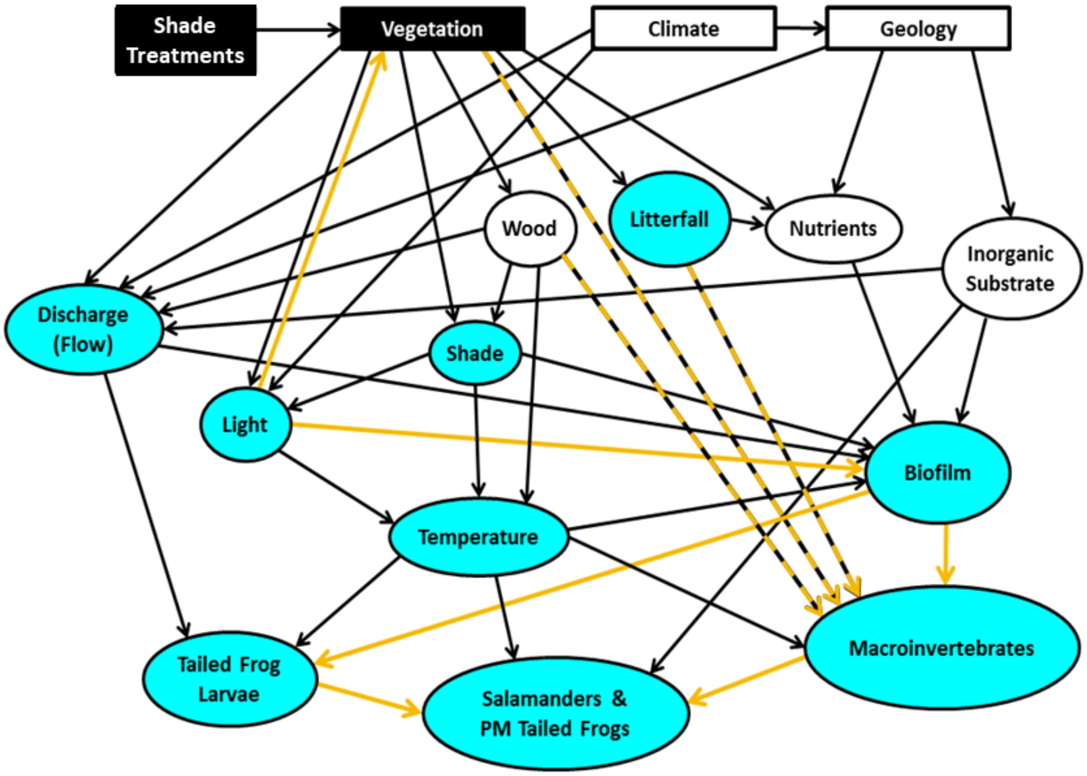

Figure 2. Conceptual model of energy and process pathways in study streams. Energy (gold), process (black), and hybrid energy/process (black and gold) pathways are shown. Measured elements are blue. Boxes show manipulated (black) and uncontrolled (white) elements. PM refers to “post-metamorphic”.

To evaluate the applicability of the bioenergetics and light:nutrient hypotheses effectively, we examined testable predictions for each. For both hypotheses, less shade is expected to result in greater biofilm accumulation and increased macroinvertebrate abundance. Biofilm, a mix of algae, bacteria, and selected other microorganisms, may accumulate faster if its light-responsive fraction dominates. Further, increased macroinvertebrate abundance resulting in an increase in scrapers may result in biofilm being grazed to the degree that biofilm does not accumulate. Abundance of macroinvertebrate functional feeding groups should also shift to greater dominance by scrapers or collectors (filterers and gatherers). This reflects the dependence of these groups on biofilm and reduced dominance by shredders because of their close association with leaf litter inputs (Hawkins et al. 1982, Cummins et al. 1989, Quinn et al. 1997, Kiffney et al. 2003, 2004, Leberfinger et al. 2011, Richardson and Béraud 2014). However, the extent to which this shift takes place depends on both how much leaf litter input is actually reduced and the degree to which biofilm production is increased. We also hypothesized that larval *A. truei*, will show a positive response to less shade (Kiffney et al. 2004, Mallory and Richardson 2005), which assumes an increase in biofilm production. Lastly, we expect the salamanders will respond positively to less shade if their prey is part of the instream assemblage that increases with changes in light regimes. However, subsidies of terrestrial prey may be substantial (Atlas and Palen 2014), especially in headwater streams (Wipfli 1997, Richardson and Danehy 2007), so the degree to which terrestrial prey input is tied to harvested canopy may influence salamander response. For example, small reductions in forest cover can weaken terrestrial-aquatic linkages (England and Rosemond 2004). Further, if salamanders and/or post-metamorphic tailed frogs are particularly effective predators, they might consume the increased production of invertebrate prey, which could result in the standing stock of invertebrate prey not changing. Based on the aforementioned suite of original assumptions, the light:nutrient and bioenergetics hypotheses each predict that intermediate shading is optimal (Sterner et al. 1997, Murphy 1998, Brett and Groves 1979), and we would expect SAAs to exhibit a non-linear response to shade levels. That non-linear relationship could either be an asymptote with a response plateau, or quadratic, where the response declines beyond an optimum level. The latter may depend either on whether high light levels actually decrease biofilm quality as food for both tailed frog larvae and macroinvertebrates eaten by salamanders (based on the light:nutrient hypothesis), or whether higher water temperatures that may occur at high light levels result in food deficiencies (quantity, quality, or both) due to increased SAA metabolic demands (bioenergetics hypothesis, Brett et al. 1969, Railsback and Rose, 1999, Leach et al. 2012), or both.

Methods

Site Selection and Description

We selected small SAA-occupied, non-fish-bearing streams with a mostly south-facing aspect (135˚-235˚) because we anticipated the effect of shade removal due to increased solar radiation to be greatest in such streams (Risley 2003, Moore et al. 2005). We also constrained sites to competent lithologies (igneous and metamorphic) because the greater SAA abundance reported from such lithologies (versus sedimentary; Wilkins and Peterson 2000, Jackson et al. 2007) increases the likelihood of identifying a shade-reduction effect. Lastly, we selected sites from over a relatively broad area where target SAA genera co-occur, namely from northwest Oregon to the Olympic Peninsula and from the Coast Ranges to the Cascade Mountains (Jones et al. 2005). This greatly increased the geographic and ecoregion scope of inference for our results.

We used 25 streams located in two general areas: an east-west-oriented area defined by the Columbia River and a second area along the east Olympic Peninsula (Fig. 3, Appendix 1). Fifteen of the 18 streams near the Columbia River were on Longview Timberlands LLC ownership (now owned by Weyerhaeuser Company) in Clatsop County, Oregon; and Cowlitz, Skamania, and Wahkiakum Counties in Washington. The remaining three sites near the Columbia River included a stream in Wahkiakum County on The Campbell Group ownership and two in Skamania County

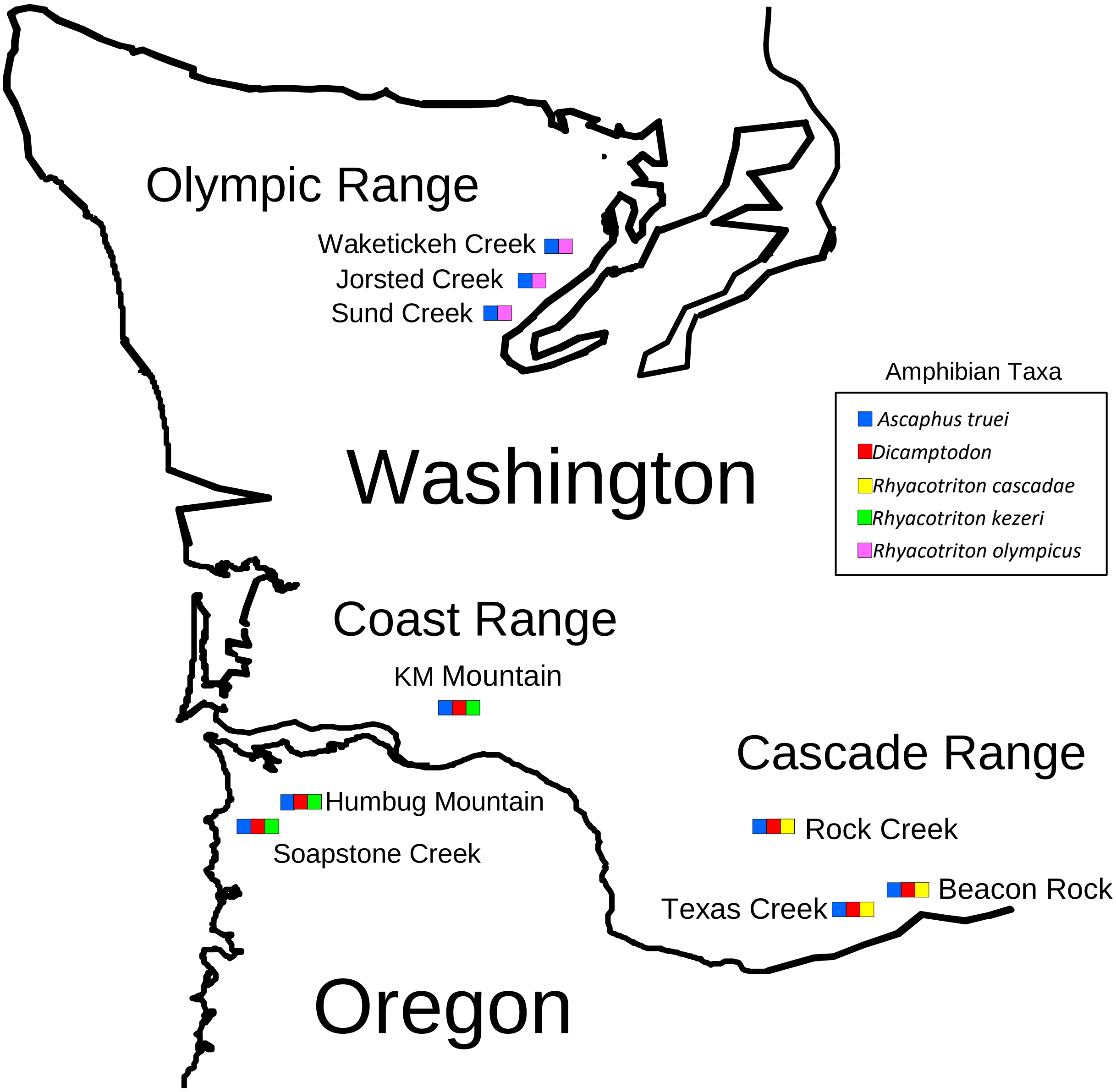

Figure 3. Location of study sites within three ecoregions of western Washington and northwest Oregon. Dicamptodon reflects a composite of two species: D. copei and D. tenebrosus.

on Washington Department of Natural Resources (DNR) lands. All seven streams on the Olympic Peninsula were on DNR lands in Mason County **(**Fig. 3). All streams were on lands intensively managed for timber production within second-growth coniferous forest. Variation existed in managed stand composition; managed forest at most sites was primarily Douglas-fir (*Pseudotsuga menziesii*) and Western hemlock (*Tsuga heterophylla*), but three mid-elevation sites in Skamania County were dominated by Noble fir (*Abies procera*).

Riparian stands bordering streams varied as well; Red alder (*Alnus rubra*) and Western hemlock were often dominant, and Douglas-fir, Western red cedar (*Thuja plicata*) and Big-leaf maple (*Acer macrophyllum*) were regularly to infrequently important (Appendix 1). Understory was dominated by one or more of Vine maple (*Acer circinatum*), Salmonberry (*Rubus spectabilis*), Stink currant (*Ribes bracteosum*), and Devil's club (*Oplopanax horridus*) in the shrub layer, and diverse forbs and mosses in the ground layer. Combined canopy and shrub layers often resulted in pre-treatment vegetation cover over streams in excess of 100%.

General silviculture on all ownerships involved clearcut logging and one of three modes of site preparation (broadcast burning of slash, piling and burning of slash, or piling with or without burning and chemical treatment) followed by planting of site-adapted seedlings. However, a mix of clearcut logging and selective logging was used at the mid-elevation sites.

Study streams were located either in rotation-age second-growth stands or had a $\geq$30-m buffer left on both sides of the stream during the most recent harvest that occurred four and 10 years prior to initiation of the study. At one site, adjacent stands were harvested during the fall after treatment implementation. In that case, we worked closely with the harvest operators to ensure that the treatment specified (no-shade) for this study site was maintained and the reference reach was not impacted.

The study design included eight blocks (Fig. 3), each of which had three streams; one additional stream in the Olympics was also included (Jorsted Cr., low-shade retention). Streams within blocks were located within the same 3rd- or 4th-order watershed (*sensu* Strahler 1957) except in the Olympics, where five of the seven streams were located in adjacent 3rd- or 4th-order watersheds. Due to availability, actual study reaches were 1st- or 2nd-order except for one 3rd-order stream in the Olympics. Basin size averaged 40.5 ha (± 6.5 ha SE) and the basin size range varied by an order of magnitude: the two largest basins were somewhat over 100 ha, whereas the two smallest basins were 1-2 ha (Appendix 1). Reference (control) reaches were always located upstream of treatment reaches (see Treatment section), so basin size to the drainage point of the reference reach was 54-99% of the basin area encompassing the treatment reach. Two of the three SAA genera, *Ascaphus* and *Rhyacotriton*, were represented in all streams, but *Dicamptodon* occurred only in the six blocks in northwest Oregon and southwest Washington (Fig. 3). Tailed frogs were represented by one species, Coastal tailed frog. In contrast, *Dicamptodon* and *Rhyacotriton* were represented, respectively, by two and three species. The two *Dicamptodon* species – Cope's giant salamanders (*D. copei*) and Coastal giant salamanders (*D. tenebrosus*) – co-occurred in all streams in northwest Oregon and southwest Washington. Cope's giant salamanders occur on the Olympic Peninsula (Adams and Bury 2002), but its range on the Peninsula was just outside our study blocks (M. Hayes, J. Tyson, unpubl. data). In this study, we treated the two species of giant salamanders collectively because they cannot be unambiguously identified exclusively based on external morphology. Columbia torrent salamanders occurred in the Coast Range of northwest Oregon and southwest Washington, Cascade torrent salamanders (*R. cascadae*) in the south Cascade Range, and Olympic torrent salamanders (*R. olympicus*) in the Olympic Range (Fig. 3).

Treatments

We used a replicated, before-after control-impact (BACI) paired design (Underwood 1994, Smith 2002), with two years each of pre- and post-treatment data collection. Each stream was divided into a 50-m treatment (downstream) and a 50-m reference (upstream) reach separated by 50‒94 m (Fig. 4). With paired treatment and reference reaches, we were better able to control for possible confounding factors such as substrate composition and competency, gradient, aspect, and elevation (Hawkins et al. 1983), all of which can influence SAA abundance. We spaced treatment and reference reaches at least 50-m apart to maintain relative independence between reaches in terms of intra-seasonal SAA movement patterns of instream life stages (Nussbaum and Tait 1977, Ferguson 2000, Wahbe and Bunnell 2001) and other biotic and abiotic characteristics (e.g., water temperature, stream drift, stream flow). We recognize that the seasonal movement scale of postmetamorphic Coastal tailed frogs likely exceeds the dimension of our reaches (Hayes et al. 2006, Hayes and Quinn 2015), but this life stage was not a study focus. Thus, it was unlikely that individual SAAs inhabiting one reach would move to another reach during the assessment intervals of this study each year. Variability in length of the intervening (non-sampled) reach reflected limitations of local topography (e.g., areas too steep for access) and other stream characteristics in order to match treatment and reference reaches as closely as possible. Our choice of study reach length represented a compromise among a desire to minimize reach variation in aspect, gradient, and substrate; feasibility of treatment application; and enough length to ensure a treatment effect.

One of three shade retention treatments (≈ 0%, 30%, and 70% overhead canopy cover; hereafter no-, low-, and intermediate-shade; respectively) was randomly assigned to a treatment reach in each block. We reduced shade to specified treatment levels by removing vegetation based on readings of the middle two rows of a convex spherical densiometer, which restricted the view to vegetation directly over and adjacent to the stream channel. Multiple densiometer readings were taken from the mid-channel position at the bottom, middle, and top of each treatment reach. Shade reductions were achieved by iteratively removing shrubs and trees that provided shade directly over the channel and then, as needed, by removing vegetation further into the riparian area based on the two middle rows of the densiometer (about 10-20 m). We considered only the two middle rows of the densiometer to reduce the angle of view of the densiometer, and avoid removing vegetation far from the stream channel that did not shade the stream or provided shade only at very

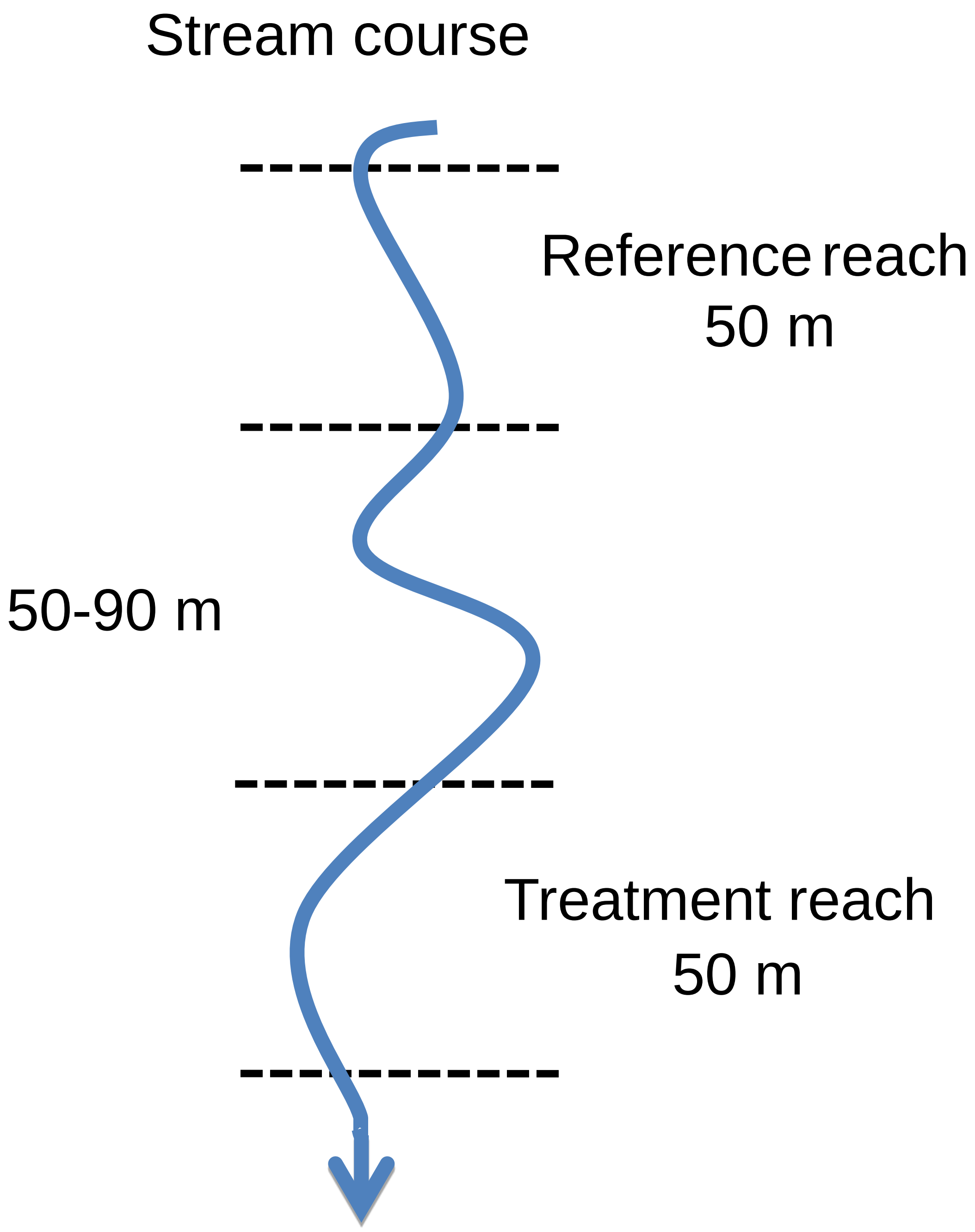

Figure 4. Schematic of typical study reaches configuration for a stream.

low sun angles. We also implemented vegetation removal in a manner that resulted in cover that was roughly evenly distributed along treatment reaches. Thus, full densiometer readings (all rows) exceeded those of the treatment targets, i.e., mean canopy cover based on full densiometer readings were 40%, 61%, and 77% for the no-, low-, and intermediate-shade treatments, respectively, due to trees and shrubs that appeared in the outer rows. In each post-treatment sample year, we also took periodic densiometer readings (middle two rows only) to determine whether vegetation regrowth required touch-up removals to maintain assigned shade levels. To ensure that we did not increase sediment input to treatment reaches, we reduced vegetation cover by directional felling of trees with chainsaws and clearing of brush with chainsaws or pruning loppers, with all material left onsite. Material that fell into the stream we immediately moved to the bank and placed it to avoid contributing to shade.

Study chronology and treatment application was staggered among blocks. Study reaches in each block in the northwest Oregon and southwest Washington were sampled during summers 2004 and 2005 (pre-treatment), and 2006 and 2007 (post-treatment). Treatment application in those blocks occurred during fall–spring 2005–2006. We originally added streams in the Olympic block in 2005. However, six streams on U.S. Forest Service lands (comprising two of the three blocks) were lost because we were denied approval for implementation of the no- and low-shade treatments. Replacements for four of the streams were found on DNR lands early in 2006, resulting in two complete blocks and an extra intermediate-shade treatment. Pre-treatment sampling on all seven streams occurred in 2006 and 2007, treatment application took place in fall-spring 2007–2008, and post-treatment sampling occurred in 2008−2009.

Response Variables

Cover and light

We estimated vegetation cover and light (PAR) reaching the streams for each stream reach every 2–4 weeks from May–October of each year. Percent canopy cover or density (Jennings et al. 1999) and PAR estimates (μmols m^{-2} sec^{-1}) were taken at 10-m intervals along each reach starting at the downstream end (a total of six per reach). We made cover estimates using the entire grid of a convex spherical densiometer held at the stream surface facing the four major compass directions (in contrast to the way in which densiometers were used for treatment implementation as described above); and dominant canopy species were identified. PAR estimates were taken at the stream surface with an LI-190SA quantum sensor and LI-250A light meter (LI-COR, PO Box 4425, Lincoln, NE 68504). The light meter averaged PAR readings over a 15-sec interval and we took three averaged readings at each point. We averaged PAR readings over each stream reach for each year.

Water temperature

We monitored water temperature in each reach from June–September each year using Onset Stowaway™ or Tidbit™ data loggers (Onset Computer Corporation, Bourne, MA 02532) programmed to record water temperature every 30 min. Data loggers, housed in PVC pipe with numerous 12 mm holes, were placed at the bottom of each treatment and reference reach. At each stream visit, we checked the data loggers and adjusted them as needed to ensure they were completely submerged. We calibrated data loggers following Schuett-Hames et al. (1999) or the manufacturer's instructions.

We examined the data to identify the seasonal maximum water temperature during the entire time series for each reach each year. We also calculated the seven-day moving average of the maximum daily water temperature for each reach each year. The data logger manufacturer indicated a $\pm 0.2^{o}$ C error rate, so we rounded estimates to the nearest 0.5^{o} C.

Stream productivity

We estimated productivity by placing five 15 × 15-cm unglazed quarry or clay tiles in all reaches in May–June at 10-m intervals. We collected the tiles approximately four months later (late September–early October), placed in plastic storage bags, and frozen until processed in the lab. We standardized for the precise time interval tiles were in the stream post-processing. In the lab, we scraped the tiles of biofilm after removal of macroinvertebrates and coarse debris. The scrapings of the five tiles per reach were combined and then filtered, oven-dried, and weighed. Subsequently, the scraped material was placed in a muffle furnace at 500° C for 15 min, and reweighed (Hauer and Lamberti 1996). We estimated biofilm accumulation on the tiles as g cm^{-2} ash-free dry mass (AFDM) $reach^{-1}$ $year^{-1}$.

Stream drift

To index stream productivity, potential macroinvertebrate prey for salamanders, assess treatment effects on litter inputs, and assist in interpretation of our results, we collected drift samples from each reach in the spring, summer, and fall each year (Wipfli and Gregovich 2002, Wipfli and Musselwhite 2004, Wipfli 2005). The primary assumption in using this metric is that drift rates are an index of the abundance of each component (sediment, detritus, and macroinvertebrates) in each reach. This assumption likely holds for sediment and detritus (Wipfli 2005), but macroinvertebrates may drift for a number of reasons including passively or to increase fitness (Hammock and Wetzel 2013) requiring cautious acceptance of drift sampling results (Wipfli and Musselwhite 2004).

For each sampling period, we established a sandbag weir across the bottom of each reach with a 10-cm plastic pipe set flush with the stream bottom for outflow. The pipe extended about 4 cm upstream of the weir and another 50 cm below the weir and we positioned it to capture most of the surface flow of the reach. We attached a fine mesh (250 µm) nylon bag (≈4 cm × 50 cm) to the downstream end of the pipe to capture material that flowed through the pipe. To ensure that contributions of drift originated exclusively from the length of study reaches, we established the same weir and pipe system at the top of each reach. We left these apparatuses overnight, retrieving them the next day (18–30 hours later, Danehy et al. 2011), which captured both the evening and morning pulse of drifting macroinvertebrates. We transferred the contents of the nylon bags to large plastic storage bags in the field, and filled them with 70% ethanol adequate to cover the contents. We then placed the plastic bags in a freezer until processing.

We measured stream discharge (ml sec^{-1}) for each reach in association with drift sampling either immediately prior to attaching the nylon bag to the pipe or the next day, when the bag was removed by recording the time needed to fill a 1000-ml beaker with water coming through the pipe three times. The three measurements were averaged to estimate discharge for that sampling period for each reach. In addition, we visually estimated the portion of surface flow not captured by the pipe and used it to calculate total discharge. Following each sampling period, we dismantled the weir and pipe assemblies. We measured discharge to standardize drift by stream flow; we did not expect shade reductions over a 50-m stream reach to affect stream discharge.

In the lab, we rinsed the contents of each bag through a series of stacked sieves (5-mm, 2-mm, and 250-µm mesh). We then sorted the contents of the two larger mesh sieves by hand with the aid of a 10× dissecting microscope into the following components: deciduous leaves, conifer needles, wood, other vegetation (bark, cone fragments, florets), insects, and inorganic material (rocks and pebbles). Following sorting, we oven-dried organic matter, excluding insects, collected from these sieves for 24–48 h at 60^{o} C, depending on the amount of material, and weighed to the nearest 0.0001 g. For analyses, we combined these samples and labeled them coarse particulate organic matter (CPOM).

We also separated the contents of the 250-µm mesh sieve into material identifiable as vegetation and remaining fine material; the latter included inorganic material (dirt particles and sand) as well as organic material too small to identify. We added the material identifiable as vegetation, primarily small pieces, to the CPOM organic matter pile for drying as indicated above. Remaining fine material was removed from the sieve, oven-dried at 60^{o} C for 24–48 h, weighed to the nearest 0.0001 g, baked in a muffle furnace at 500^{o} C until all the organic material was ashed, and then reweighed. The difference between the two weights was determined and labeled fine particulate organic matter (FPOM).

We identified aquatic macroinvertebrates to the lowest taxonomic level necessary to assign them to a functional feeding group (filterers, gatherers, scrapers, shredders, and predators) and the number of individuals of each taxon recorded. We then composited aquatic macroinvertebrates by functional group, dried them to a constant weight in an oven at 60^{o} C, then weighed to the nearest 0.0001 g.

Our analyses of the drift samples followed the procedures of Wipfli and Gregovich (2002) and Wipfli (2005). All drift components (CPOM, FPOM, macroinvertebrate functional groups) were quantified as g m^{-3} of stream flow and g day^{-1} (24 hr). We also quantified individual macroinvertebrates captured as number m^{-3} of flow and number day^{-1}. We processed and analyzed spring, summer, and fall samples separately.

Amphibian abundance

We estimated amphibian abundance in each reach during low flow periods (late July–early October) each year. We sampled five 2-m long plots with a width equivalent to the wetted channel in each reach by randomly assigning the first plot within the first 10-m segment then locating the other four plots at successive 10-m intervals. We sampled each plot by blocking its lower margin with a fine-mesh screen and removing all wood and cobble, then raking the gravel and fines while holding a dip net below the area searched. We checked the blocking screen for amphibians as the plot was searched and when the plot search was finished. We identified each amphibian captured to species (except individuals of *Dicamptodon*), life stage (larvae, metamorph, juvenile or adult) and sex, whenever possible. We also weighed (to the nearest 0.1 g) and measured (total and snout-vent or urostyle length to the nearest 0.1 mm) either all individuals or a maximum of 10 individuals of each species plot^{-1} to estimate body condition. For plots with more than 10 individuals of each species, we held animals in a plastic bag or bucket until the plot search was completed and then 10 were randomly selected for measurement.

We estimated the probability of detecting amphibians (p) in the plots by a repeat sample of a randomly selected plot in each reach each year. Such methods have been shown to reduce unwanted variability in population estimation (Schmidt 2003). After the initial search of the plot, we established a block screen along the upper edge of the plot. We held the amphibians captured during the initial search temporarily in plastic bags. Block screens remained in place until the plot was re-visited 2−24 hours later. We replaced all material removed from the stream after plot searches. We estimated detection probabilities as $p = C_i/C_t$ where C_i is the number of initial captures and C_t is all captures from the two searches. We then summed amphibian counts for each species, age, and stage over all plots, reach, and year and adjusted by p estimates.

Amphibian body condition

We estimated the body condition (energy stores) of individual amphibians captured during abundance surveys using the scaled mass index (SMI) of Peig and Green (2009, 2010). We used total length as the body structure measure for larval tailed frogs and the salamanders and snout-urostyle length for tailed frog metamorphs and post-metamorphs. We used an ordinary least squares regression to estimate the coefficient of the SMI power function. MacCracken and Stebbings (2012) tested this procedure with American bullfrog (*Rana [Lithobates] catesbeiana*) larvae and post-metamorphic juveniles and Roughskin newts (*Taricha granulosa*) and found a high correlation ($r \geq 0.8$) among energy stores and SMI estimates. We averaged the SMI for each individual for each species and stage (*A. truei* only) by stream reach and year.

Amphibian growth rates

Growth rates (g week^{-1}) were estimated by stocking species-specific in-stream enclosures with four giant salamander or six individuals of the other species (all larvae) in both treatment and reference reaches of each stream. We stocked exclusively larvae, but some tailed frogs metamorphosed in late summer, so we also obtained limited growth data on metamorphs during this period. We based stocking levels on both sample size considerations and densities of these species reported in the literature (Russell et al. 2004). We took animals for introduction to the enclosures from each stream either below the treatment reach, $\geq$ 50 m above the reference reach, or from the nearest stream not used in the study. All reaches had one enclosure with *A. truei*, and one with the local species of *Rhyacotriton*. All reaches except those on the Olympic Peninsula also had enclosures with *Dicamptodon* spp.

Enclosures were semi-transparent plastic boxes (0.17–0.26 m^2 bottom surface area, 13–16 cm tall) placed in the streams in May. Within each study reach, we placed enclosures at 12-m intervals, starting at the 12-m mark from the downstream end. We maintained water flow and some drift into enclosures by cutting three 8-cm holes in the upstream and downstream ends of the enclosures that were covered with 3-mm mesh screen. We modified the enclosure in two ways to ensure adequate flow: 1) we drilled numerous 1-mm diameter holes in the bottom and sides of each enclosure; and 2) we inserted two lengths of 2.5-cm diameter PVC pipe through the top of the upstream side of the enclosure and placed the opposite ends of these pipes in the stream. Six-mm mesh screens covered the pipe ends, which prevented amphibians and crayfish (Astacidae) from entering the enclosure but allowed the passage of smaller invertebrates as well as FPOM. We also cut out the center of the lid for each enclosure so that a 6−8-cm lip remained when attached to minimize shading and enable litterfall and volant invertebrates to drop into enclosures as well as to keep amphibians from escaping.

We filled each enclosure with about 6-cm of sand to cobble-sized rock from the adjacent stream location. We established the enclosures two to four weeks prior to placing amphibians in them. We weighed and measured each amphibian when it were introduced to an enclosure, and marked each with one or more injections of colored fluorescent elastomer under the skin in a pattern unique to each individual. We visited enclosures every 7−14 days. On each visit, we cleaned the screens and adjusted enclosures as necessary to maintain water flow. On every other visit, we weighed amphibians, noted the development stage for *A. truei*, and recorded the location of each amphibian within the enclosure. If individuals were missing, we occasionally found them nearby and returned them to the enclosure; alternatively, we captured new ones and added them at that time or within a week to maintain at minimum of four animals in the enclosures. We calculated growth rates of marked individuals as the change in mass between their initial introduction to an enclosure and each subsequent weighing. We then averaged these estimates and standardized them by the number of weeks in the enclosure. To be used in the analysis, individuals had to be in the enclosures for at least four, but no longer than 16 weeks. We truncated the interval at 16 weeks because the sample size of individuals extending beyond that time interval was too small for analysis.

We also established a separate but similar plastic box in each reach to estimate a possible enclosure effect (Mallory and Richardson 2005) by assessing biofilm accrual and water temperature. We labeled these boxes exclosures because they lacked amphibians. Exclosures also had minimal stream substrate, and three clay tiles. We also added a water temperature data logger to one exclosure in either the reference or treatment reach of each stream, based on a random draw. This allowed us to determine whether exclosures differed from the stream in water temperature and biofilm accumulation, and whether enclosures differed from the stream, the latter imperfectly because of differences in their contained stream substrate, clay tile, and dataloggers.

Data Quality Control

We took several steps to ensure data quality. In the field, we recorded data with hand-held computers (Dell Axim PDAs) directly into Excel spreadsheets. This insured that all observers consistently collected the complete set of data at each site for each sample, assisted in the recognition of incorrectly entered information, and eliminated the transfer of data from data sheets to a spreadsheet program that can also add transcription errors. We also checked data daily for errors and consistency. In addition, we also created backups by printing copies of spreadsheets or by creating backup files on a desktop computer in the office. Each spreadsheet contained a column for observers to enter notes on unusual conditions that might have affected estimates, such as minor adjustments to sampling protocols.

We also captured and corrected errors as we summarized and formatted data for analyses. The pivot table feature of Excel was often used to average subsamples (see below) of the various metrics measured, which was useful in quickly identifying outliers, inconsistent sample sizes, mislabeled sample units, and other miscellaneous problems. In addition, the results of data analyses routines (see below) contained diagnostic graphs (e.g., plots of residuals), degrees of freedom, etc. that could also signal data errors. Finally, if we found the results of data analyses inconsistent with expectations and unusual, that would trigger examination of data matrices for errors. In this study, this process revealed two major errors that were the inadvertent consequence of data handling: (1) the SUM and AVERAGE functions in Excel were excluding some cells in the calculations, and (2) errors occurred when importing Excel files into SYSTAT, e.g., some cells were left blank and incorrect numbers appeared in others.

Data Analyses

The study design contrasted a treatment reach (reduced shade) with a paired reference reach (un-manipulated control) on each stream. Thus, the basic metric for analysis of each response variable was the difference between the treatment and reference reaches for each stream, i.e., the raw effect size (Di Stefano 2004). Over 60 measures of effect size (ES) exist in the statistical literature (Jaccard and Guilamo-Ramos 2002). We used the raw ES (treatment minus reference) as the metric for analyses because it maintains the original units of the response variables and is generally easier to interpret (Di Stefano 2004); as original units are maintained, scaling to references is analysis-specific. This approach has the advantages of normalizing data, and reducing both variance and heteroskedasticity (as detected by patterns in model residuals). The base data matrix for the analysis of each response variable consisted of the raw ES estimate for each shade level in each block each year (years were further assigned to pre- and post-treatment periods). We also assigned each block to an ecoregion (Coast Range, Cascade Mountains, and Olympic Peninsula). For reference reaches, a dummy variable (a row of zeros) was required in data matrices to contrast shade treatments and their respective references directly. This was needed because reference reaches were paired to treatment reaches (i.e., located upstream of reference reaches in the same streams), and instream comparisons involved treatment-reference reach contrasts.

We analyzed the ES data with linear mixed effects models (McDonald et al. 2000, Zuur et al. 2009) with period (pre- and post-treatment), shade (no, low, intermediate, reference), and the period × shade interaction as fixed effects. We modeled year, block, and ecoregion as random effects, and included year and block in all models. Only tailed frogs, giant salamanders and macroinvertebrate groups occurred in multiple ecoregions; for models including those taxa, we nested block within ecoregion as a random effect. Model parameters were estimated with restricted maximum likelihood procedures (Bolker et al. 2008). We assessed model fit by examination of residual plots (Zuur et al. 2009). For models producing strong patterns in the residuals (e.g., funnel-shaped, see Zuur et al. 2009), the raw ES estimates were rank-transformed (Iman and Conover 1979, Conover and Iman 1981) across the four years of sampling then model fit was reassessed. Log-transformations were not possible as the ES data consisted of negative numbers and zeros and the log of those quantities is undefined. We identify the response variables where ESs were rank-transformed in the text, tables, and figures.

We placed emphasis on the period × treatment interaction term (hereafter interaction) in a BACI design (Underwood 1994, McDonald et al. 2000), the pivotal term to examine in the results of the analysis. However, contrasts between each combination of period and shade level were also of interest because they could help to explain interactions. We were most concerned about guarding against a Type II statistical error (i.e., declaring no treatment effect when one exists) in this study, an approach used in ecological studies with relatively few replicates (Toft and Shea 1983, Toft 1991, Schrader-Frechette and McCoy 1993). This is because we expected the power of the statistical tests to be low due to the broad geographic coverage of the study and the high likelihood of site-specific effects (Richardson and Béraud 2014). To that end, we made pair-wise contrasts with the more liberal (i.e., lower *P*-value estimates) Fisher's Least Significant Difference test, emphasizing the interaction terms and individual contrasts with *P*-values ≤ 0.1. We performed these analyses with SYSTAT v.12 or 13. We also considered the relative magnitude of ES estimates in making inferences about treatment effects. Large ESs that are not statistically significant could be biologically important (Yoccoz 1991, McGill 2013) and should not be entirely dismissed simply because hypothesis tests generate *P*-values that exceed an arbitrary cutoff (Johnson 1999, Anderson et al. 2000, Murtaugh 2014, Stanton-Geddes et al. 2014). To that end, we calculated the percent ES change from pre-to post-treatment periods for each treatment level and the 90% confidence limit (CL) across treatments based on those percent changes for each response variable. We used these to assist in interpreting responses for which the results of the mixed effects models were not statistically significant, but where relatively large changes in ESs potentially indicated a response that might require further consideration, especially in future work. Specifically, we regarded percent changes in treatment means that fell outside the CLs to be potentially biologically meaningful.

We used the same mixed model approach to examine variation in detection probabilities (p) for each amphibian species that may be attributable to the same fixed and random effects as for the primary response variables. We also used Spearman correlations to examine the relationships between estimates of p and amphibian abundance as well as the elapsed time (hours) between the initial search of a plot and the resampling of the same plot.

Results

We made the following comparisons were made for each response variable for both the original data (before subtracting reference from treatment estimates, presented in the Tables) and ES estimates (presented in the Figures and Appendix 2). We first compare the percent difference among stream reaches (shade levels) for the pre-treatment period, the post-treatment period, then percent differences for each reach pre- to post-treatment contrast for the original data. For ES estimates, we present P-values from the mixed models for those comparisons as well as for the interaction term. We present the ES estimates in figures showing both the pre- and post-treatment mean ES estimates and standard errors (SE) for each variable for each treatment. We also present the mean post- minus the mean pre-treatment ES and 90% CL for each variable and treatment in Appendix 2 as well as the percent change in ES estimates from pre- to post-treatment and associated 90% CL. We discuss large percent changes in ES that fall outside the 90% CLs that may be biologically meaningful regardless of the outcome of the mixed models analysis.

Canopy Cover

Original Data

Pre-treatment differences in canopy cover among streams and treatment and reference reaches within streams were low (0-5%) with cover estimates, based on the entire densiometer grid, ranging from 92% (references)–97% (no- and low-shade) (Table 1). We needed substantial effort ($\geq$ 8 person-days reach^{-1}) to reach the assigned shade retention levels. We based canopy cover estimates in Table 1 on readings of the entire grid resulting in post-treatment cover estimates that were greater than the treatment target levels.

Effect Size

Mean ES estimates for canopy cover were small and relatively consistent pre-treatment. Effect size estimates changed by more than an order of magnitude for all reaches post-treatment (Table 1).

Photosynthetically Active Radiation

Original Data

Mean PAR estimates varied $\leq$74% (20 μmols m^{-2} sec^{-1}) among reaches pre-treatment with the largest estimates for the intermediate- and no-shade reaches (Table 1). Treatments resulted in monotonically increasing amounts of PAR reaching the streams as a function of declining canopy cover, meeting the primary study objective of creating a nearly complete gradient in light levels. Post-treatment mean PAR estimates for the treatment reaches were an order of magnitude greater than pre-treatment estimates. Post-treatment estimates for the no- shade reaches were 34% greater than the low-shade reaches, 155% greater than the intermediate-shade reaches, and 10-fold greater than reference reaches. The low-shade treatment had mean PAR estimates 91% greater than the intermediate-shade treatment, and 649% greater than reference reaches. The intermediate-shade treatment had mean estimates 293% greater than the reference reaches. In addition, PAR estimates for reference reaches increased by 43% between pre- and post-treatment periods due to storm blowdown, flooding, and channel meander that affected canopy cover. Nevertheless, this increase in PAR was less than one-sixth the magnitude of the smallest post-treatment difference (the intermediate-shade level) between any treatment reach and its paired reference reach.

Effect Size

Pre-treatment mean PAR ES estimates ranged from -10 to 0 (Fig. 5) and contrasts among reaches were not statistically significant ($P = 0.8$–1.0). Post-treatment ES estimates were over two orders of magnitude greater than pre-treatment estimates and all were positive resulting in a significant ($P = 0.0001$) interaction term, indicative of a large treatment effect at all shade levels. Trends in mean ES among reaches post-treatment were similar to those for the original data, monotonically declining with increasing shade and all contrasts were significant ($P < 0.001$, Appendix 2).

Table 1. Mean percent canopy cover, cover effect size (ES; treatment minus reference), and photosynthetically active radiation (PAR, μmols m^{-2} sec^{-1}) at stream surfaces along 50-m stream segments for pre- and post-treatment periods and four experimental shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington, May-October, 2004-2009. Values in parentheses following mean canopy cover and PAR values are standard errors of the mean.

Period and shade level	Sample Size	Canopy cover[a]	ES	PAR
Pre-treatment				
No	8	97 (1)	2	41 (16)
Low	9	97 (2)	-1	27 (4)
Intermediate	8	96 (<1)	-2	47 (14)
Reference	25	92 (5)		39 (4)
Post-treatment				
No	8	40 (4)	-53	682 (75)
Low	9	61 (3)	-33	509 (52)
Intermediate	8	77 (3)	-18	267 (35)
Reference	25	97 (2)		68 (9)

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[a] estimated with a convex spherical densiometer; includes full view of the densiometer where treatment targets (0%, 30%, and 70% overhead cover, i.e., no-, low-, and intermediate-shade levels) were based on vegetation obscuring only the middle two rows of the densiometer.

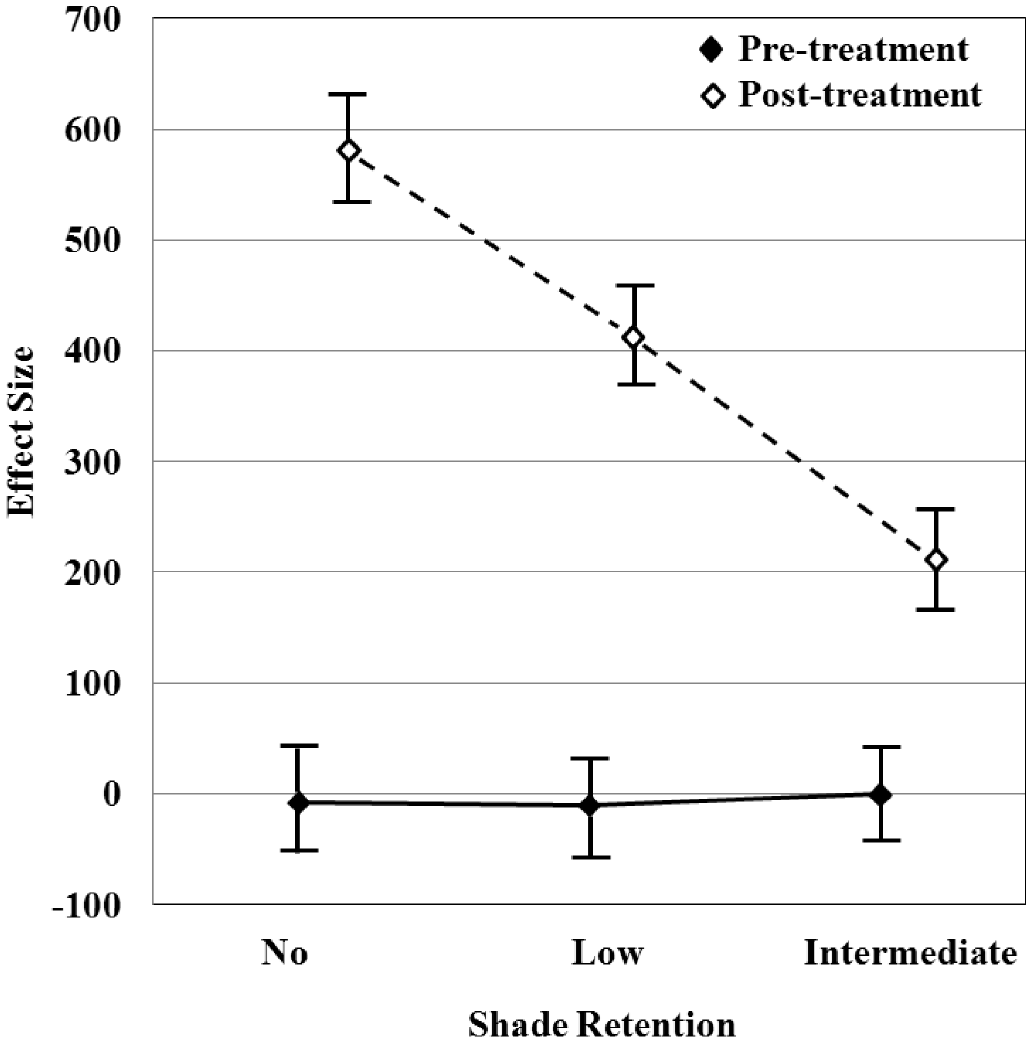

Figure 5. Effect size (treatment-reference) for estimates of net change in photosynthetically active radiation (μmols m^{-2} sec^{-1}) along stream reaches randomly assigned three levels of shade retention for pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted values means; whiskers are standard errors of the means.

Water temperatures

Original Data

Streams

Prior to treatment implementation, mean maximum daily water temperature and seven-day moving average differed from 0–7% across stream reaches, with the greatest temperatures in the no- and low-shade reaches (Table 2). In stream reaches, we recorded progressive increases in mean seasonal maximum (0–24%) and the maximum seven-day moving average (4–22%) pre- to post- treatment with decreasing shade levels (Table 2). In particular, the intermediate-shade level change by ≤0.5° C, the low-shade level by 2.0° C, and the no-shade level had the greatest change at 3.0–3.5° C. In contrast, in reference reaches both metrics showed almost no change (≤0.5° C) pre-to-post-treatment in the stream.

Exclosures

Prior to treatment implementation, mean maximum daily water temperature and seven-day moving average differed from 0–15% among exclosures in treatment and reference reaches with the largest estimates in the low and intermediate reaches (Table 2). All exclosures in treatment reaches had increases in temperature pre- to post-treatment for both metrics; in contrast, in reference reaches, both metrics decreased 1.0–1.5° C (Table 2). In particular, the no-shade level showed the smallest change (1.5–2.5°C), the low-shade level a larger change (2.0° C), and the intermediate-shade level had the greatest change (2.0–4.0° C). However, in context of absolute temperatures, exclosures in the low-shade treatment reaches had water temperatures for both metrics greater than most of the other stream treatment reaches in both pre- and post-treatment (1.0–2.0° C) years. The low-shade treatment was also higher than reference exclosures for both metrics (<1.0–4.0° C) except for the pre-treatment seasonal maximum where it was identical to the reference.

Table 2. Mean maximum water temperature (^{o} C) recorded (MAX) and seven-day moving average maximum daily water temperature (7-DAY) for streams and exclosures for pre- and post-treatment periods at four shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind mean values are the standard errors of the means. Temperatures were sampled during June-October, 2004-2009 at one-half hour intervals.

Shade level	Pre-treatment		Post-treatment	
(stream or exclosure)	MAX	7-DAY	MAX	7-DAY
No				
Stream	14.5 (0.5)	13.5 (0.5)	18.0 (0.9)	16.5 (0.8)
Exclosure	14.5 (0.4)	13.5 (0.6)	17.0 (1.2)	15.0 (0.8)
Low				
Stream	15.0 (0.7)	14.0 (0.6)	17.0 (0.5)	16.0 (0.4)
Exclosure	16.0 (1.7)	15.0 (1.3)	18.0 (0.8)	17.0 (0.7)
Intermediate				
Stream	15.0 (0.8)	13.5 (0.6)	15.0 (0.6)	14.0 (0.6)
Exclosure	14.0 (0.7)	13.0 (0.5)	18.0 (1.7)	15.0 (0.9)
Reference				
Stream	14.0 (0.3)	13.0 (0.3)	14.0 (0.3)	13.5 (0.3)
Exclosure	16.0 (0.7)	14.0 (0.6)	14.5 (0.5)	13.0 (0.5)

Effect Size

Streams

Mean raw ES estimates for seasonal maxima (Fig. 6a) ranged from 0.5–0.8 among stream reaches pre-treatment (*P* = 0.60–0.93) and from 0.9–3.6 post-treatment (*P* = 0.0001–0.04). The greatest increases from pre- to post-treatment were in the no- (*P* = 0.0001) and low-shade (*P* = 0.03) reaches (Fig. 6a, Appendix 2), which resulted in a significant (*P* = 0.001) interaction term. Trends in pre-to-post-treatment ES estimates for the maximum seven-day moving average were 0.5, 2.0, and 2.5C, respectively, in the intermediate-, low-, and no-shade reaches. This was similar to trends in seasonal maximum ES estimates (Fig. 6b, Appendix 2), also resulting in a significant (*P* = 0.0001) interaction term.

Exclosures

For exclosures, ES estimates for both measures of water temperature resulted in a funnel-shaped pattern for model residuals (implying heteroskedasticity). Rank-transformations resulted in better dispersion of the residuals for both metrics. Ranked ES for seasonal maxima differed by 5–18% (*P* = 0.56–78) among reaches pre-treatment (Fig. 6c). Post-treatment ranked ES differed by 2–69% among treatments with the mean of the no-shade reaches smaller than the low- and intermediate-shade treatments (*P* = 0.05). Ranked ES estimates declined 99% pre- to post-treatment in the no-shade reaches (*P* = 0.24) but increased 122-558% pre- to post-treatment for the low- and intermediate-shade reaches (*P* = 0.54 and 0.22), respectively, resulting in a significant (*P* = 0.03) interaction term (Appendix 2).

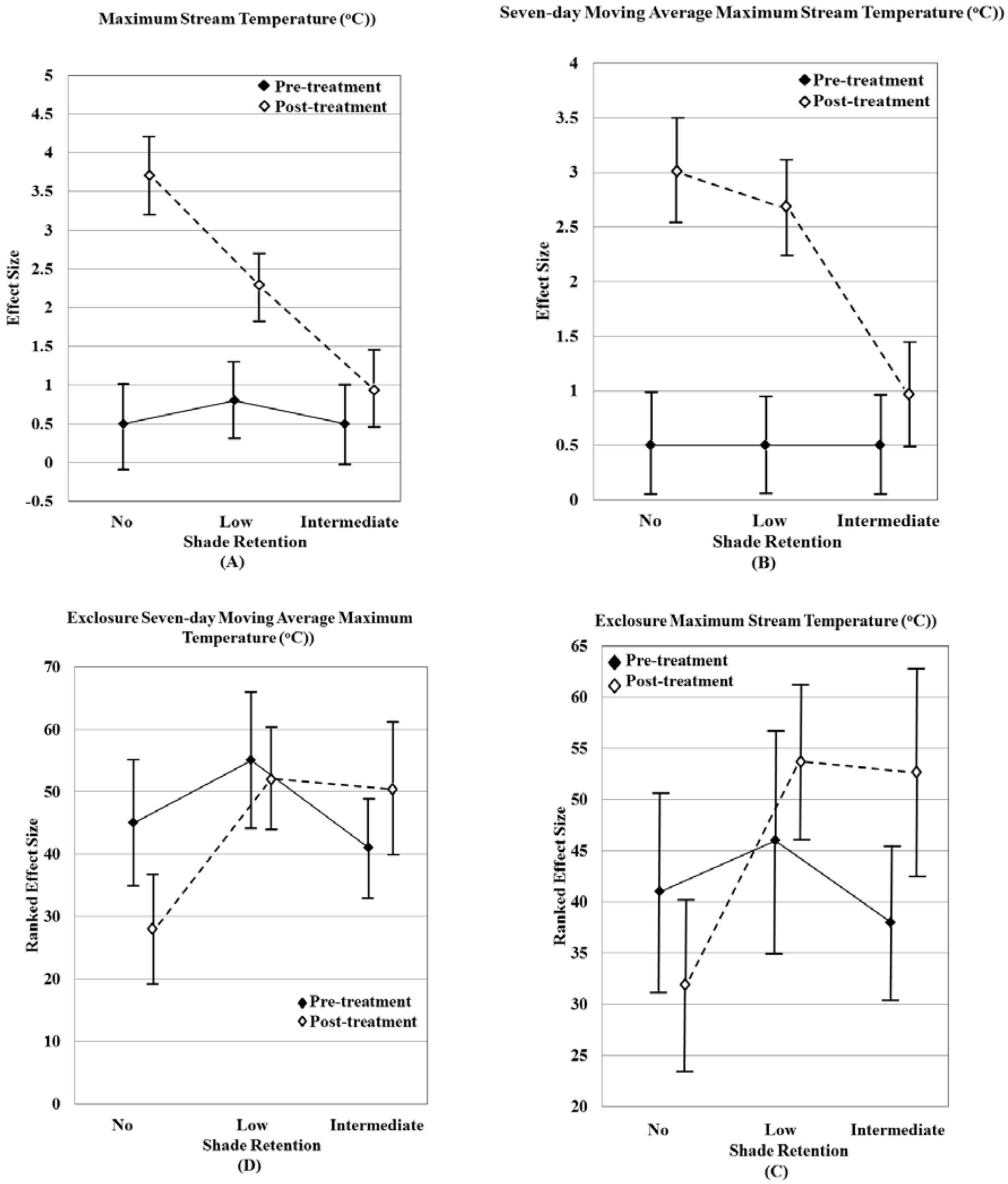

Figure 6. Effect sizes (treatment-reference) for seasonal maximum water temperature (°C) for stream reaches (A and B) or exclosures (effect sizes were ranked-transformed for analyses) in streams (C and D) randomly assigned to one of three levels of shade retention for pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted values are means or ranked means of effect sizes; whiskers are standard errors of the means.

Mean ranked ES estimates of the maximum seven-day moving average for the exclosures differed by 10–34% pre-treatment (*P* = 0.31–0.80) (Fig. 6d). Post-treatment ranked ES estimates differed by 4–86% (*P* = 0.02–0.88), with the no-shade reaches lower than both the low- and intermediate- reaches (*P* = 0.02, 0.07, respectively). These trends resulted in an interaction term with a *P*-value of 0.11 (Appendix 2), but a relatively large decrease (589%) in ES at the low-shade level, which fell below the lower 90% confidence limit (CL) implying a treatment effect.

In summary, maximum stream temperatures responded to different levels of shade retention in an approximately negative linear fashion. Overall, we observed post-treatment temperature increases of 1.5–4.0°C in the streams across treatments, and slightly less of an increase in the exclosures (0.0–3.5°C, Table 2). Treatment interactions were significant for both stream temperature metrics and the seasonal maximum metric for exclosures (*P* = 0.03-0.0001). In stream reaches, maximum seven-day moving average temperatures exceeded 16.0° C in the no- and low-shade levels post-treatment. Maximum water temperature changes in the exclosures were more variable and greater than reach temperatures, non-parallel during both periods, and did not track any expected pattern relative to shade levels, generally being greatest in both low-and intermediate-shaded reaches, post-treatment.

Biofilm Accrual

Original Data

Streams

Pre-treatment mean estimates of biofilm accrual (g AFDM m^{-2}) among the different shade levels differed by 3–21% and estimates were greatest in the low-shade and reference reaches; treatment implementation increased variability as differences among reaches were 18–105% (Table 3) with the largest amounts in the low- and no-shade reaches. Biofilm accrual increased in all treatment reaches by 2–105% (greatest in no-shade reaches, least in low-reaches) pre- to post-treatment, but declined by 13% in references reaches. Post-treatment estimates differed by only 4% between the low-and intermediate-shade retention reaches, but were 67 and 74% greater in the no-shade reaches than in the low- and intermediate- reaches, respectively.

Exclosures

Mean biofilm accrual in the exclosures varied by 2–35% pre-treatment (largest in the no-shade reaches followed by the low, intermediate, and reference reaches) and 1–84% post-treatment, increasing in all reaches, most notably at the no- (greatest mass) and intermediate-shade levels (3rd greatest mass) (Table 3).

Effect Size

Effect size estimates produced a strong funnel-shaped pattern in model residuals (heteroskedasticity) for both stream and enclosure biofilm estimates, which improved following rank-order transformation.

Streams

Mean ranked ES for stream biofilm accrual differed by 2–30% pre- treatment and mean ranked ES for the no-shade reaches (most mass) was greater (*P* = 0.05) than that for the low-shade reaches (least mass) (Fig. 7a). Differences in ranked ES among stream reaches post-treatment ranged from 1–23% (*P* = 0.0001–0.96) with the largest differences between the no-shade (greatest mass) and low and intermediate levels (least mass). Estimates increased 39–48% across shade levels pre- to post-treatment (*P* = 0.002), the percentage change for the no-shade treatment level fell below the lower 90% CL and the interaction term was not significant (*P* = 0.23, Appendix 2).

Exclosures

Patterns of biofilm accrual on tiles in the exclosures compared to those in the streams followed the same general trends, pre-treatment (Table 3). However, for the post-treatment period tiles in the exclosures tended to have a larger amount of biofilm (24–123%) than tiles in the stream (Table 3).

Table 3. Mean biofilm accumulation (g ash-free dry mass $m^{-2}yr^{-1}$) on unglazed quarry tiles along 50-m stream segments and exclosures for pre- and post-treatment periods and four experimental shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind the means are the standard error of the means. Streams were sampled during May-October, 2004-2009.

Period and shade level	Sample Size	Stream	Exclosure
Pre-treatment			
No	8	0.39 (0.15)	0.46 (0.18)
Low	9	0.47 (0.14)	0.54 (0.21)
Intermediate	8	0.40 (0.15)	0.40 (0.15)
Reference	25	0.44 (0.13)	0.45 (0.11)
Post-treatment			
No	8	0.80 (0.32)	1.03 (0.44)
Low	9	0.48 (0.17)	0.68 (0.16)
Intermediate	8	0.46 (0.14)	0.67 (0.22)
Reference	25	0.39 (0.12)	0.56 (0.13)

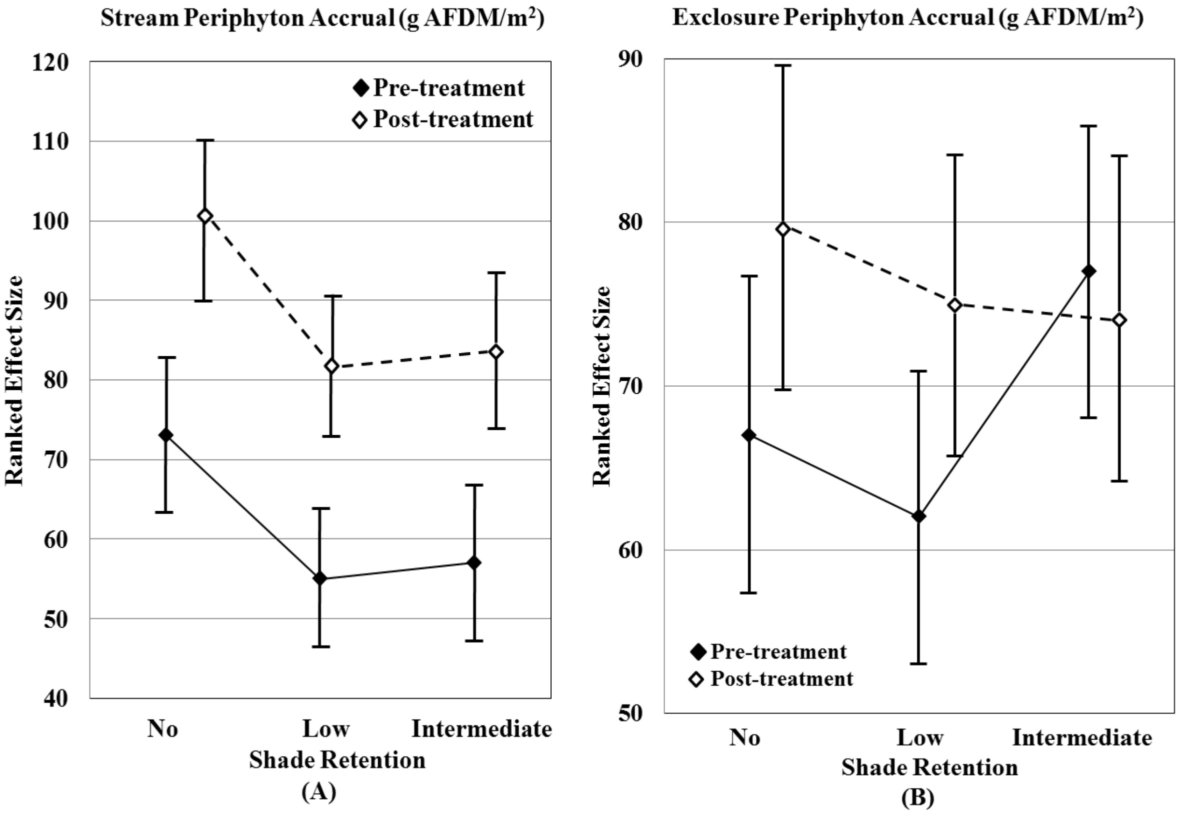

Figure 7. Effect sizes (treatment-reference) for estimates of biofilm accrual (g ash-free dry mass m^{-2} yr^{-1}) on tiles placed in stream reaches (A) or exclosures in streams (B) randomly assigned to one of three levels of shade retention for pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted are mean ranked effect sizes; whiskers are the standard errors of the mean ranked effect sizes.

Ranked ES estimates of biofilm on the tiles in the exclosures differed by 8–24% pre-treatment (*P* = 0.70–0.26; greatest mass in the intermediate and least in the low reaches), but only 1–8% post-treatment (*P* = 0.97–0.66), where the largest amount was in the no-shade reaches, followed by the low-shade reaches (Fig. 7b). Pre-to post-treatment, ranked ES increased 18% and 19% in the no- (*P* = 0.38) and low- (*P* = 0.37) shade reaches, respectively, but declined by 5% (*P* = 0.79) in the intermediate- reaches (Fig. 7b). The interaction term was not significant (*P* = 0.78,

Appendix 2) but the mean percent change for the intermediate level of shade fell below the lower 90% confidence limit (CL).

Stream Drift

The mass of the various components of stream drift (CPOM, FPOM, aquatic macroinvertebrates) and associated ES estimates were variable. The data contained outliers resulting in heteroskedasticity in model residuals. Effect sizes were rank-transformed for analysis, which improved dispersion of model residuals.

CPOM

Original Data

In general, mean CPOM drift (mass m^{-3}) differed among reaches by 5–179% pre-treatment which increased by 179–564% post-treatment (Table 4). CPOM drift was greatest in the intermediate- and no-shade reaches pre-treatment and the reference and low-shade reaches post-treatment. CPOM declined 329% in the no-shade reaches, pre- to post- treatment, but increased 79% in the low-shade reaches and 19,690% in the reference reaches.

In contrast, mean mass of CPOM day^{-1} varied by 0–17% among reaches pre-treatment, whereas post-treatment differences ranged from 50–917%. When quantified as mass day^{-1}, CPOM was nearly equal among reaches pre-treatment, followed the same pattern as mass m^{-3} post-treatment, and also declined (100–200%) in the low and intermediate reaches, but increased by 13,014% in the reference reaches.

Table 4. Mean mass or counts of stream drift components (detritus and macroinvertebrate functional class) per m^3 of stream flow and per day (24 h) for pre- and post-treatment periods at four shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values behind each mean value are the standard errors of those means. Streams were sampled during May-September 2004-2009.

	Pre-treatment Shade Level				Post-treatment Shade Level			
Drift Component	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference
Detritus								
CPOM[a] m^{-3} (kg)	31 (19)	19 (7)	53 (41)	20 (7)	7 (2)	34 (10)	19 (2)	3958 (3935)
CPOM[a] day^{-1} (kg)	6 (3)	6 (3)	6 (3)	7 (4)	1 (<1)	3 (<1)	2 (1)	918 (915)
FPOM[b] m^{-3} (kg)	40 (34)	9 (3)	147 (138)	20 (15)	7 (3)	16 (9)	14 (8)	10 (3)
FPOM[b] day^{-1} (g)	3 (2)	2 (1)	8 (7)	13 (12)	1 (<1)	1 (<1)	1 (1)	1 (<1)
Macroinvertebrate Functional Class								
Scrapers m^{-3} (g)	39 (30)	26 (8)	43 (24)	46 (23)	11 (4)	54 (19)	37 (18)	22 (6)
Scrapers day^{-1} (mg)	35 (13)	83 (32)	77 (44)	125 (62)	23 (9)	63 (26)	70 (44)	44 (6)
Shredders m^{-3} (g)	24 (8)	50 (36)	58 (43)	52 (19)	6 (3)	28 (9)	43 (12)	18 (4)
Shredders day^{-1} (mg)	45 (9)	34 (14)	33 (9)	66 (26)	13 (5)	46 (21)	25 (6)	20 (4)
Filterers m^{-3} (g)	7 (4)	7 (2)	10 (7)	6 (2)	6 (2)	32 (15)	3 (1)	6 (1)
Filterers day^{-1} (mg)	20 (13)	17 (6)	9 (4)	13 (5)	13 (4)	49 (18)	5 (2)	12 (5)

Table 4. Continued. Mean(SE) mass or counts of stream drift components (detritus and macroinvertebrate functional class) per m^3 of stream flow and per day (24 h) for pre- and post-treatment periods (2 years each) at four shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Streams were sampled during May-September 2004-2009.

	Pre-treatment Shade Level				Post-treatment Shade Level			
Drift Component	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference
Gatherers m^{-3} (g)	23 (8)	5 (1)	11 (3)	10 (1)	23 (6)	47 (30)	38 (20)	20 (10)
Gatherers day^{-1} (mg)	53 (17)	13 (5)	17 (8)	23 (6)	33 (9)	129 (111)	46 (26)	15 (2)
Predators m^{-3} (g)	233 (155)	105 (50)	62 (26)	46 (23)	16 (6)	36 (8)	26 (11)	30 (8)
Predators day^{-1} (mg)	212 (<1)	197 (<1)	165 (<1)	131 (<1)	22 (8)	26 (5)	23 (7)	33 (10)
Total m^{-3} (g)	346 (204)	201 (71)	198 (51)	173 (50)	98 (33)	208 (57)	154 (38)	108 (11)
Total day^{-1} (mg)	390 (165)	359 (188)	17 (152)	93 (102)	175 (69)	25 (170)	73 (30)	58 (28)
Total Count $m^{-3}x10^3$	46 (22)	47 (26)	25 (12)	63 (34)	287 (148)	269 (111)	123 (18)	183 (40)
Total Count day^{-1}	10 (2)	7 (2)	5 (2)	8 (2)	117 (54)	105 (62)	102 (60)	88 (46)

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[a] coarse particulate organic matter; leaves, needles, twigs, wood, stems, etc. between >2 mm.
[b] fine particulate organic matter, <2 mm and >250 µm.

Effect Size

Mean ES estimates of kg CPOM m^{-3} varied 0–9% (P = 0.38–0.98) pre-treatment, were greatest for the no-shade reaches, and nearly equal for the others. Drift of CPOM was 2–22% lower (P = 0.16–0.12) in the no-shade reaches than the low- and intermediate- reaches post-treatment, respectively, and the interaction term was not significant (P = 0.19) despite the relatively large (39%) decline in the no-shade reaches (P = 0.008; Fig. 8a, Appendix 2). Low-and intermediate-shade reaches had progressively lesser declines; respectively, 5% (P = 0.65) and 3% (P = 0.78). Mean ES of CPOM day^{-1} followed the same patterns as CPOM m^{-3} and its interaction term was also not statistically significant (P = 0.75, Appendix 2), but the percent decline in the no-shade (17%) reach fell below the lower 90% CL.

FPOM

Original Data

Trends in drift of FPOM (mass m^{-3}) differed among reaches pre-treatment by 100–1533%, but only 14–129%, post-treatment (Table 4). Pre- to post-treatment declines in FPOM (mass m^{-3}) occurred in the no-shade (471%), intermediate- (950%), and reference (100%) treatments; but increased 78% in the low-shade reaches.

FPOM (mass day^{-1}) declined 100–1200% in all reaches pre- to post treatment, with the greatest declines in the reference and intermediate-shade reaches, respectively.

Effect Size

Mean ranked ES based on mass m^{-3} varied 4–10% (P = 0.42–0.72) among reaches pre-treatment and 2–24% (P = 0.05–0.86) post-treatment with trends mirroring those of untransformed mass m^{-3} estimates (Fig. 8b). The interaction term for this metric was not significant (P = 0.43, Appendix 2), and the declines did not fall outside of the 90% CL (Appendix 2).

However, mean ES for mass of FPOM day^{-1} increased in the low- (largest estimate) and intermediate- (2nd largest) reaches by 7% and 8%, respectively from pre- to post-treatment periods (P = 0.53 and 0.50, respectively) and declined in the no-shade reach by 16% (P = 0.16), resulting in a P-value of 0.42 for the interaction term (Appendix 2) despite the fact that the 16% decline in the no-shade reaches fell below the lower 90% CL.

In summary, estimates of detrital drift among treatment reaches were highly variable, with estimates based on mass m^{-3} of flow more variable than estimates based on mass day^{-1}, particularly post-treatment. Inputs of allochthonous materials to streams, as measured by drift, declined in the no-shade reaches following shade reductions, but the non-significant interaction terms appear to make the overall pattern statistically ambiguous. Nonetheless, the significant declines in mass m^{-3} ($P \leq$0.01-0.001) combined with declines for the no-shade reach falling below the lower 90% CL for both variables (CPOM and FPOM) for either one or both metrics, seems to indicate detritus was primarily reduced in the no-shade treatment. Drift quantification based on mass adjusted for flow and sampling duration did not always agree in direction (+, –) or magnitude of change.

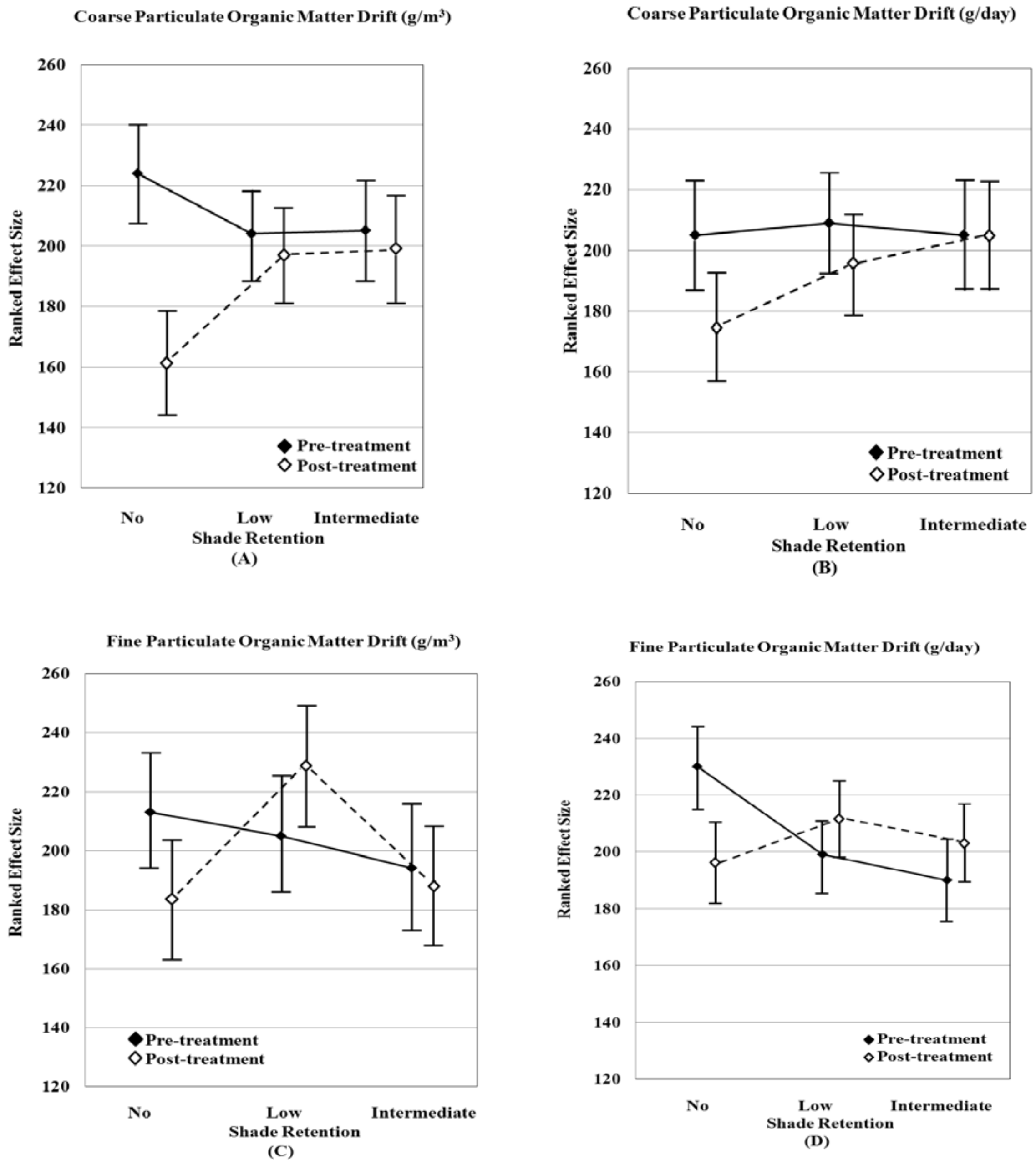
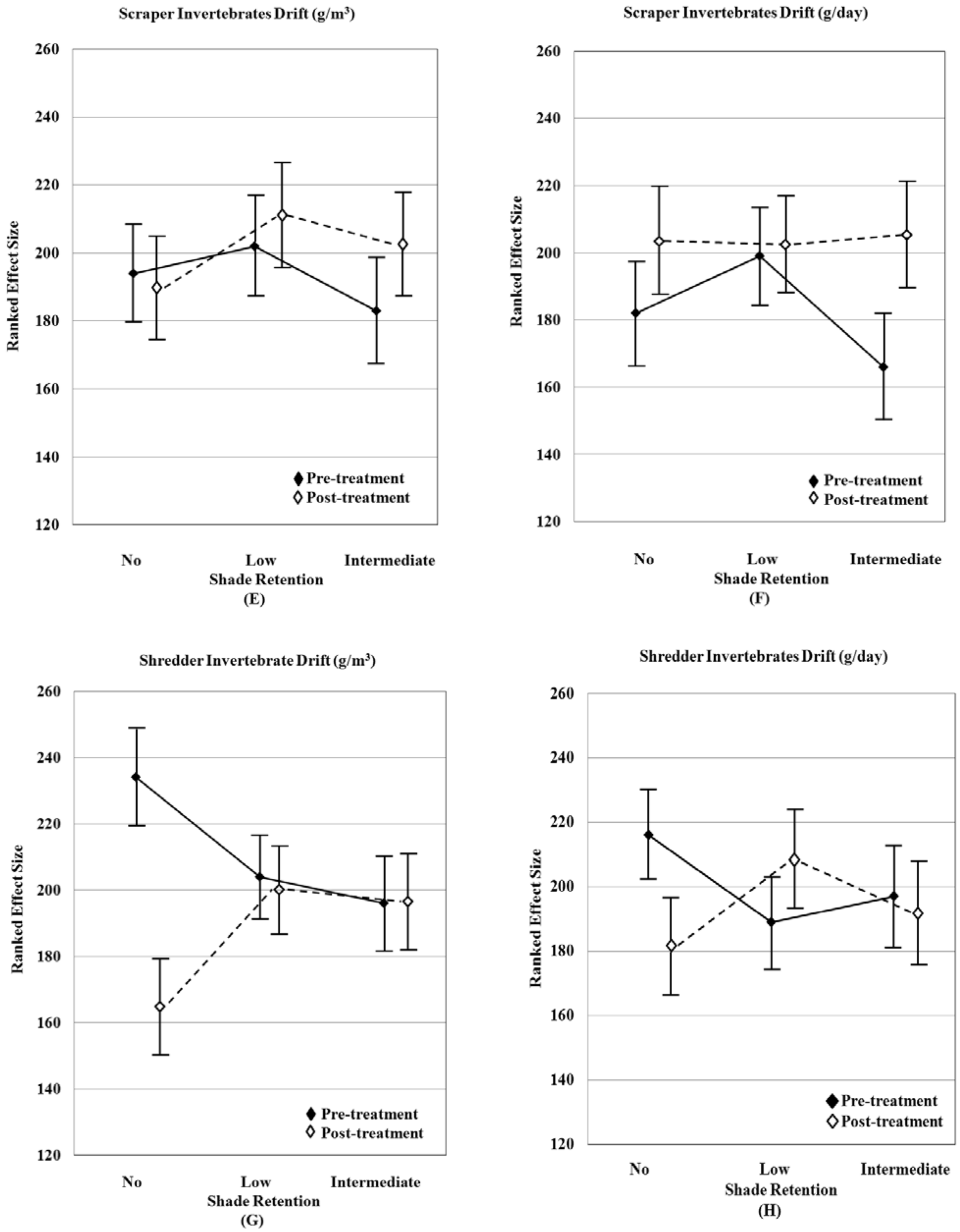


Figure 8. Effect sizes (treatment-reference) for drift components (coarse particulate organic matter [A-B], fine particulate organic matter [C-D] and aquatic macroinvertebrate functional classes [E-R]) quantified as mass m^{-3} and day^{-1}, and counts for stream reaches randomly assigned to one of three levels of shade retention for pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted are the means of ranked effect sizes; whiskers are the standard errors of the means.



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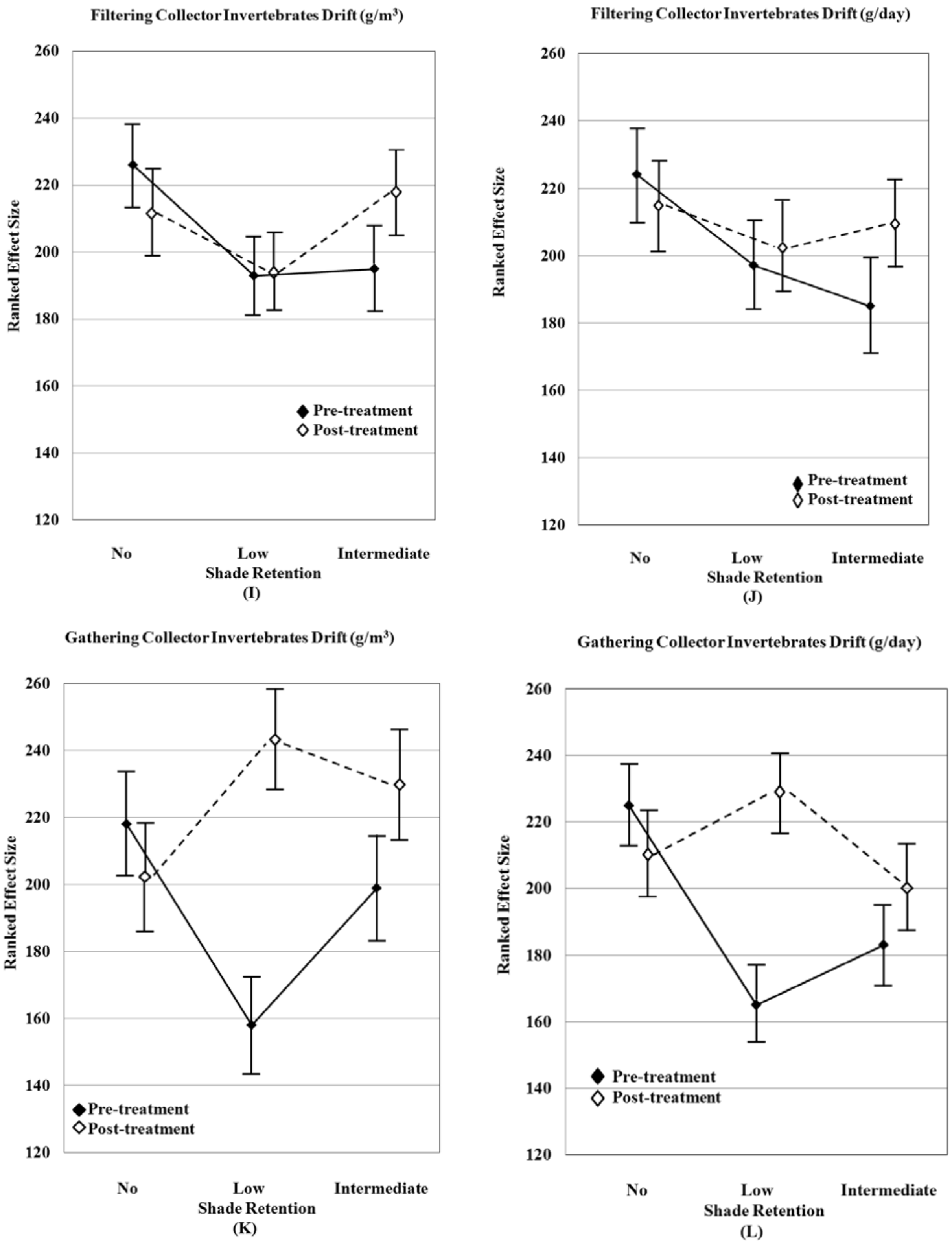

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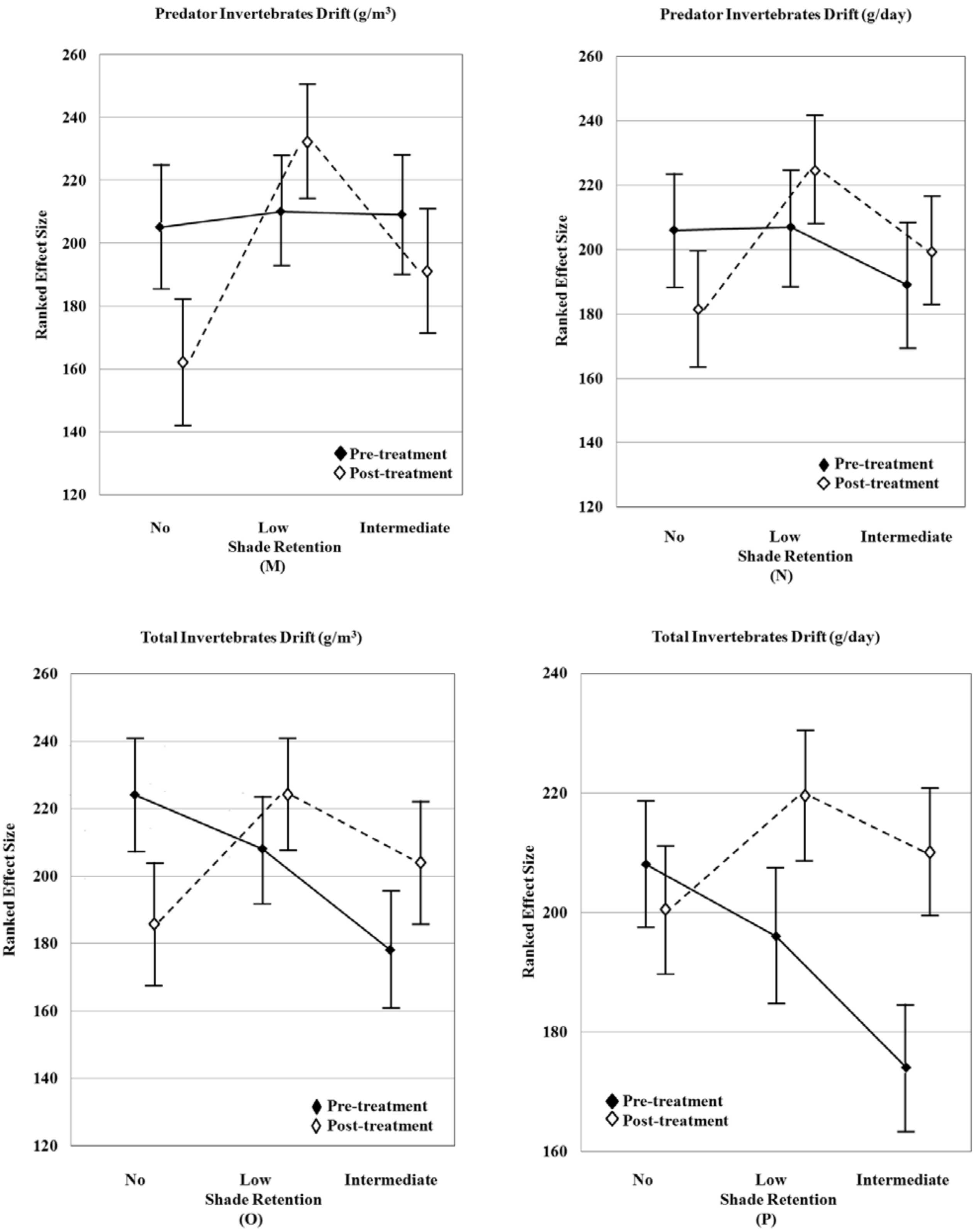

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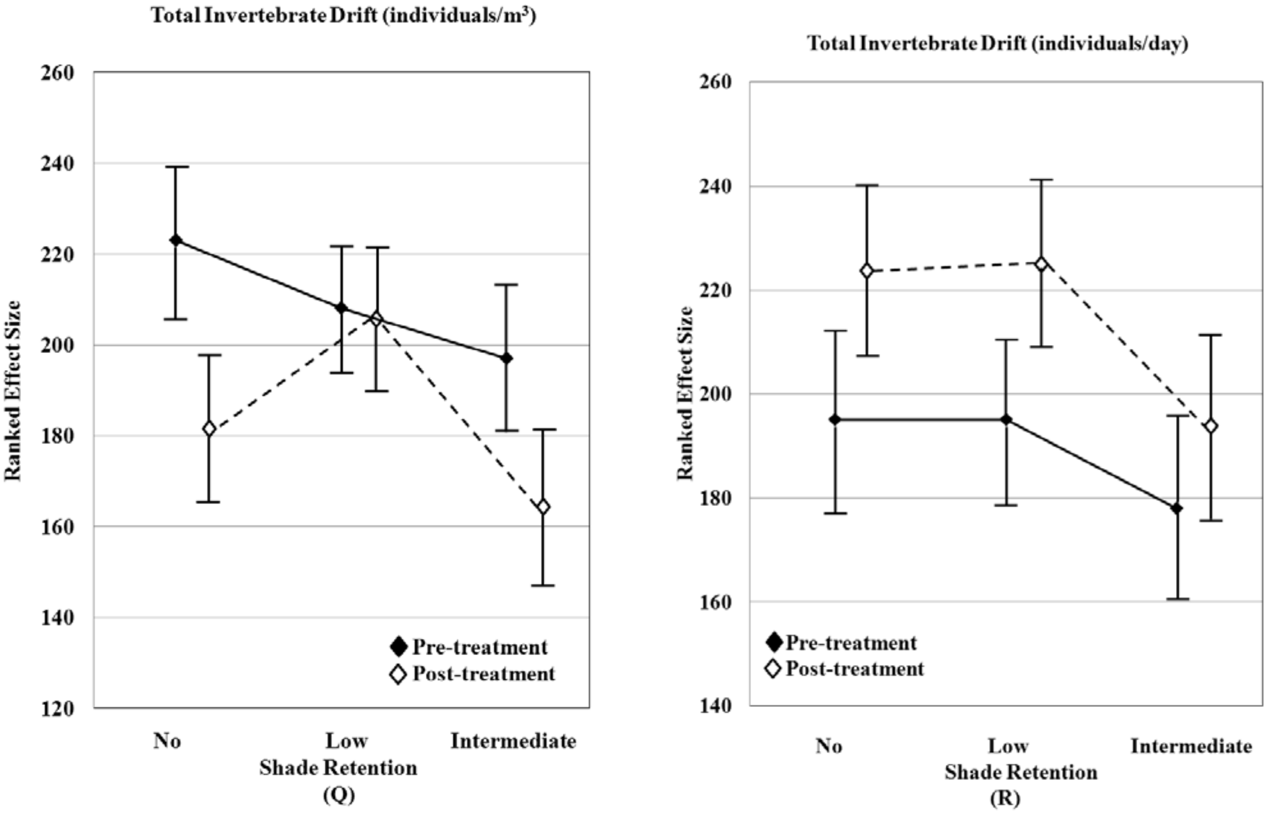


Figure 8. Continued.

Macroinvertebrate Drift

Macroinvertebrate drift among periods, treatments, and metrics was highly variable even though taxa were combined into functional classes (Table 4, Fig. 8e-r).

Scrapers

Original Data

Drift (mass m^{-3}) of scrapers differed 7–77% pre-treatment and was greatest in reference and intermediate reaches (Table 4). Scraper drift was greatest in the low- and intermediate- reaches and differed 46–391% post-treatment, declining in all reaches pre- to post-treatment (16-255%), except the low-shade reaches (108% increase, Table 4). Quantified as mass day^{-1}, mean drift of scrapers was greatest in reference and low- reaches and differed by 8–257% pre-treatment. Drift was also greatest in low- and intermediate- reaches post-treatment, differed 11–204% across reaches, and declined (10–184%) in all reaches pre- to post-treatment.

Effect Size

Mean ranked ES of scrapers (mass m^{-3}) differed by 4–10% among all reaches pre-treatment (*P* = 0.42-0.73) and was greatest in low- and no-shade reaches. Drift was greatest in low and intermediate reaches and differed 4–9% (*P* = 0.43–0.72) post-treatment (Fig. 8e). Mean ES based on mass m^{-3} increased 5% (*P* = 0.69) in the low-shade reaches and 11% (*P* = 0.42) in the intermediate-reaches pre- to post-treatment. However, ES of scrapers based on mass m^{-3} declined 1% in the no-shade reaches (*P* = 0.96), and the interaction term was not significant (*P* = 0.91; Appendix 2). None of those percent changes fell outside the 90% CL. In contrast, when quantified as mass day^{-1}, (Fig. 8f) ES increased 2–24% for all reaches pre- to post- treatment and was greatest in intermediate reaches (*P* = 0.09) and smallest in the low-shade reaches (*P* = 0.85) also resulting in a non-significant interaction term (*P* = 0.56, Appendix 2). The relatively large (24%) increase in the intermediate-shade reaches (*P* = 0.088) also exceeded the upper 90% CL.

Overall, original estimates of the mass of scrapers (Table 4) declined in all treatments except for the low-shade level (mass m^{-3}), and declines were greatest in the no-shade treatment, but non-significant interaction terms indicate that these changes are driven by something other than treatments alone. Scrapers also declined in the references at levels greater than or equal to the no-shade treatment. After accounting for the post-treatment decline in reference reaches, ES estimates increased in all treatments except at the no-shade level (mass m^{-3}). At the intermediate-shade level, the combination of the statistically significant increase in the scraper ES estimate in g day^{-1}, which also exceeded the upper 90% CL suggest a treatment-dominated effect at that level.

Shredders

Original Data

Drift (mass m^{-3}) of shredders differed among reaches by 4–142% pre-treatment, and was greatest in the intermediate and reference reaches. Drift of shredders post-treatment differed among reaches by 56–616% and was also greatest in the intermediate reaches, but second in the low reaches. Shredders m^{-3} declined by 35–300% pre- to post-treatment, the decline being greatest in the no-shade and reference reaches (Table 4).

Shredder drift (mass day^{-1}) differed by 3-100% among reaches and was greatest in the reference and no-shade reaches, pre-treatment. Post-treatment estimates differed by 25-254% among reaches and were greatest in the low- and intermediate-shade reaches. Shredder drift day^{-1} varied by 32-230% from pre- to post-treatment periods, with the greatest declines in the no-shade and reference reaches (Table 4).

Effect Size

Mean ranked ES (mass m^{-3}) of shredder drift differed by 4−19% (P = 0.10–0.72) among reaches pre-treatment and was greatest in the no- and low-shade reaches. Post-treatment, the no-shade reaches had the least amount of shredder drift followed by the intermediate-shade reaches and differences among all reaches were 2–21% (P = 0.12–0.89; Fig. 8g). Shredder drift m^{-3} declined pre- to post-treatment about 43% (P = 0.003) in the no-shade reaches, but changed little at the other shade levels (-2–0%, P = 0.87–0.96), resulting in a significant interaction term (P = 0.09, Appendix 2). The level of decline in the no-shade reaches also fell below the lower 90% CL.

Mean ES based on mass day^{-1} (Fig. 8h) of shredders followed similar patterns as mass m^{-3} when contrasting reaches (pre- and post- values ranged from 4–14% differences, P = 0.25–0.70). All pre- to post-treatment ES estimates were statistically non-significant; declines of 18% and 2%

occurred in the no-shade (*P* = 0.16) and intermediate-shade (*P* = 0.85) reaches, respectively; with an increase of 10% in the low-shade reaches (*P* = 0.41); and an interaction term with *P* = 0.46 (Appendix 2). The level of change within the no-shade reaches fell below the lower 90% CL.

In summary, drift of shredders (original data) differed more among reaches post- than pre-treatment for both metrics and declined from pre- to post-treatment periods at the lowest levels of shade retention. Ranked ES estimates were less variable among reaches during both pre- and post-treatment periods for both metrics and only no-shade reaches exhibited an unambiguous decline.

Filtering Collectors

Original Data

Average mass m^{-3} of drift of filtering collectors (filterers) differed by 0–67% among reaches pre-treatment, was greatest in the intermediate- reach, and equal in the no- and low-shade reaches (Table 4). Drift differed among reaches 0–967% post-treatment and was greatest in the low-shade and least in the intermediate- reaches (Table 4). Mean mass m^{-3} of filterers did not change in the reference reaches and declined by 17% in the no-shade reaches, but increased by 357% in the low-reaches and declined by 233% in the intermediate- reaches pre- to post-treatment.

Mean mass day^{-1} of filterers differed 18–54% among reaches pre-treatment and was greatest in the no- and low-shade reaches. Drift varied among reaches 8–880% post-treatment, was greatest amount in the low- and no-shade reaches, and followed similar patterns as mass m^{-3} in terms of relative magnitude and direction of change between periods. In general, mass of filterers for both metrics declined pre- to post-treatment, except in the low-shade reaches where increases occurred.

Effect Size

Mean ranked ES for mass m^{-3} of filterers differed 1–18% pre-treatment (*P* = 0.10–0.90) with the no-shade reaches larger than both the low- and intermediate- reaches (Fig. 8i). Mean ES varied 3–13% across reaches post-treatment (*P* = 0.27–0.76) being largest for the intermediate- and no-shade reaches (Fig. 8i). Mean ES of mass m^{-3} declined 1–8% pre- to post-treatment (*P* = 0.90–0.46) in the low- and no-shade reaches, respectively, but increased (*P* = 0.40) 10% in the intermediate-reaches (Appendix 2). The interaction term was not statistically significant (*P* = 0.72) but the increase in the intermediate-shade treatment fell above the upper 90% CL.

The interaction term was also not statistically significant (*P* = 0.66) for the ES analysis based on mass day^{-1} of filterers. Mean ES differed (*P* = 0.10–0.88) 6–21% among reaches pre-treatment with the greatest difference between the no-shade (largest estimate) and intermediate- (smallest estimate) reaches (Fig. 8h). In contrast, ES estimates differed by only 1–6% post-treatment (*P* = 0.20–0.92), and increased pre- to post-treatment by 2% (*P* = 0.86) and 15% (*P* = 0.23) in the low- (smallest estimate) and intermediate-shade (largest estimate) reaches, respectively, but declined 6% (*P* = 0.60) in the no-shade reaches (Appendix 2). The relatively large percent increase in the intermediate reaches exceeded the upper 90% CL.

In summary, relatively large differences existed in the drift of filterers among some reaches pre-treatment. Changes in filterer drift due to shade reductions were generally relatively small (10-15%) and consistent among treatments, metrics (m^{-3} or day^{-1}), and data type (original or ES). However, values falling outside the 90% CLs for both metrics imply support for increases in the intermediate-shade treatment, but lack of a significant treatment interaction suggests a complicated response.

Gathering Collectors

Original Data

Drift (mass m^{-3}) of gathering collectors (gatherers) differed 10–360% among reaches, pre-treatment and was greatest for the no- and intermediate-shade levels. Drift was greatest in the low and intermediate reaches post-treatment and differed by 15–135% among reaches. Gatherer drift increased pre- to post-treatment in the low- (840%), intermediate- (245%), and reference reaches (100%), but did not change in the no-shade reaches (Table 4).

Gatherer drift, quantified as mass day^{-1}, differed 31–308% among reaches pre-treatment and was greatest in no-shade and references. Post-treatment drift was largest in the low and intermediate reaches and differed 39–760% among all reaches. Pre- and post-treatment comparisons mirrored trends in mass m^{-3}, with increases of 892% in the low- reaches and 171% in the intermediate- reaches, but declines of 61% and 53% in the no-shade and reference reaches, respectively.

Effect Size

Pre-treatment mean ranked ES (mass m^{-3}) of gatherers was greatest in the no- and intermediate-reaches and differed 11–36% (P = 0.008–0.41) among reaches with the largest difference between the no- and low-shade reaches. Post-treatment variation was relatively less (6–19%, P = 0.09–0.56) with the greatest estimates for the low and intermediate levels. Mean ES increased (P = 0.0001–0.19) by 53% and 15% in the low- and intermediate-shaded reaches, respectively, pre- to post-treatment, and declined by 7% in the no-shade reaches (P = 0.54) (Fig. 8k), resulting in a significant interaction term (P = 0.008, Appendix 2). The low-shade value (mass m^{-3}) increase was also above the upper 90% CL. The same pattern (Fig. 8l) was observed for mass of gatherers day^{-1}, a significant interaction term (P = 0.06); but the decline for the no-shade reaches was below the lower 90% CL (Appendix 2).

In summary, gatherer abundance differed among reaches pre-treatment and displayed large statistically significant increases following shade reductions at the low-shade level, but statistically non-significant changes at the no-shade (declines) and intermediate-shade (increases) levels. However, significant interaction terms and values falling outside the 90% CLs provide support for asserting that declines occurred in the no-shade treatment and increases occurred in the low-shade reaches. Both metrics and data types resulted in similar patterns.

Predators

Original data

Drift of predators expressed as mean mass m^{-3} of flow differed among reaches by 35–456% pre-treatment, with the largest amounts in the no- and low-shade reaches. Post-treatment drift was greatest in the low and intermediate reaches and differed 15–125% among reaches. Drift declined pre- to post-treatment in all reaches by 53–1,356%; most notably at the no- and low-shade levels (Table 4).

Drift of predators in mass day^{-1} was relatively more uniform among the reaches for both pre- and post-treatment periods, and declined by approximately an order of magnitude in all reaches. Patterns among reaches pre- and post-treatment mirrored those for m^{-3} estimates.

Effect Size

Mean ranked ES of predators based on m^3 of flow differed by <1–2% among reaches pre-treatment ($P = 0.81$–0.95) with the greatest amounts in the low and intermediate levels. Post-treatment predator drift was greatest in the same reaches and estimates differed 18–43% ($P = 0.002$–0.18) among reaches (Fig. 8m). ES based on mass m^{-3} declined pre- to post-treatment 8 and 26% ($P = 0.53$, 0.08) in the intermediate- and no-shade reaches, respectively, but increased 11% ($P = 0.32$) in the low-shade reaches (Appendix 2). These trends resulted in a statistically non-significant ($P = 0.22$) interaction term, despite the decline in the no-shade reaches and increase in the low-shade reaches falling outside the 90% CL.

Ranked ES for predators based on mass day^{-1} followed a somewhat similar pattern as mass m^{-3} (Fig. 8n), but differences among reaches within and between periods were more subtle (5%, *P* = 0.70). The interaction term for mass day^{-1} was also not statistically significant (*P* = 0.59, Appendix 2), but the 14% decline in the no-shade reaches fell below the lower 90% CL.

In summary, regardless of metric examined, shade reductions significantly reduced predator drift in no-shade reaches and imply a treatment effect at this shade level, but the statistically insignificant interaction makes the overall pattern ambiguous. In particular, mean ranked ES estimates revealed non-significant increases at low-shade levels for both metrics, with only mass m^{-3} extending above the upper 90% CL.

Total Macroinvertebrate Mass

Original Data

Mean drift (mass m^{-3}) of all macroinvertebrates combined differed by 2–100% among reaches pre-treatment being greatest in the no- and low-shade reaches and differed 10–112%, post-treatment with the greatest estimates in the low- and intermediate- reaches (Table 4). Total drift declined 29–253% from pre- to post-treatment periods in all reaches but the low-shade reaches where it increased 3%.

Pre-treatment total mass day^{-1} of macroinvertebrate drift differed by 8–33% with progressively smaller estimates from the no-shade to intermediate- reaches with reference reaches greater than the intermediate (Table 4). In contrast, differences among reaches ranged from 1–106% post-treatment with the largest estimates in the no-shade, followed in declining order by intermediate-, reference, and low-shade reaches. Pre- to post-treatment declines of 10–123% occurred across all reaches with the largest decline in the low-shade treatments.

Effect Size

Mean ranked ES for total drift (mass m^{-3}) differed 8–26% pre-treatment (*P* = 0.05–0.48), with the no-shade reaches greater than the other reaches (Fig. 8o). Post-treatment ES based on mass m^{-3} differed 8–21% among reaches (*P* = 0.09–0.45) with the intermediate-shade reaches greater than other reaches. A pre- to post-treatment decline of 21% occurred in the no-shade reaches (*P* = 0.12), but increases of 8–16% occurred in the other reaches (*P* = 0.24–0.50), resulting in a non-significant interaction term (*P* = 0.20, Appendix 2). However, the percent decline for the no -shade levels fell below the 90% CL.

Trends in ranked ES for mass day^{-1} of total macroinvertebrate drift differed 6–20% pre-treatment (*P* = 0.16–0.60), declining progressively from the no-shade to the intermediate-shade treatment (Fig. 8p). Post-treatment ES varied 4–8% across all shade levels (*P* = 0.38–0.73), being greatest in the low and intermediate reaches. Pre- to post-treatment ES declined in the no-shade reaches (3%, *P* = 0.78), but increased 11–21% (*P* = 0.14-0.34) in the other reaches, resulting in a non-significant interaction term (*P* = 0.55, Appendix 2), despite the 3% decline in no-shade reaches, which fell below the lower 90% CL.

In summary, total mass of macroinvertebrates revealed no significant trends for either metric (mass m^{-3} or mass day^{-1}), either for the interaction term or the individual shade levels. However, the no shade level had declines that fell below the lower 90% CL for both metrics, suggesting support for a negative response at this shade level.

Total Macroinvertebrate Counts

Original Data

Counts of individual macroinvertebrates m^{-3} of flow varied from 25,000–63,000 (2–152%) among reaches pre-treatment and were largest in the reference reaches followed by the low-, no-, and intermediate-shade reaches (Table 4). Post-treatment, counts differed 7–133% among reaches and were greatest in the no-shade reaches followed by the low-shade, reference, and then the intermediate-shade reaches. Counts increased inversely with the amount of shade reduced from pre- to post-treatment periods from 190–524%. Counts of individual macroinvertebrates captured day^{-1} varied 14–100% among reaches, pre-treatment, and were greatest for the no-shade reaches

(Table 4). Post-treatment totals varied 3–33% with the no-shade reaches maintaining the greatest counts. Pre- to post-treatment differences ranged from 1000–1940%, with all reaches including the reference having large increases.

Effect Size

Mean ranked ES for total number of macroinvertebrates m^{-3} of flow differed 6–13% among reaches pre-treatment ($P = 0.26$–0.63) and 10–24% post-treatment ($P = 0.07$–0.46) with the ES estimate for low-shade reaches greater than the intermediate- reaches (Fig. 8q). Pre- to post-treatment estimates decreased from 1–22% ($P = 0.10$) with a decline in the no-shade reaches ($P = 0.08$) that also fell below the lower 90% CL ($P = 0.17$). In addition, the 19% decrease in the intermediate reaches exceeded the upper 90% CL. However, the interaction term was not significant ($P = 0.47$; Appendix 2).

Trends in mean ranked ES for numbers of individuals day^{-1} (Fig. 8r) followed similar patterns except that pre- to post-treatment estimates increased 7-16% ($P = 0.11$) for all reaches with the greatest increase (16%) in the low-shade reaches ($P = 0.16$) followed by a 15% increase in the no-shade reaches ($P = 0.22$). The interaction term was also not significant ($P = 0.82$, Appendix 2) but the 7% increase in the intermediate-shade reaches was above the upper 90% CL.

In summary, numbers of macroinvertebrates revealed no significant interaction term for either metric (number m^{-3} or number day^{-1}), but the no-shade level showed a significant decline in numbers m^{-3}, but not in numbers day^{-1}. Hence, the pattern in macroinvertebrate numbers was parallel, but less robust than the metrics for total mass of macroinvertebrates.

Overall Summary – Macroinvertebrate Data

Macroinvertebrate drift by functional class or totals was variable pre- and post-treatment. In general, estimates based on stream flow were more variable than estimates of amount day^{-1} in the no-shade treatment, less variable than estimates of amount day^{-1} in the intermediate-shade treatment, and a mix in the low-shade treatment. Overall, macroinvertebrate response to the treatments was generally limited in magnitude. However, despite response complexity, the overall pattern was consistent with the light-nutrient hypothesis. Gatherers, scrapers, and to a lesser degree filterers increased in either the low- or the intermediate-shade levels, but shredders and predators generally decreased in the no-shade treatment. However, values below the lower 90% CL for each of gatherers, predators, shredders, total mass, and total individuals also suggest support for decreases in the no-shade treatment. Significant interaction terms for gatherers and shredders indicate the changes are attributable to treatments. In general, near uniformity of negative responses at the no--shade level contrasts with the handful of positive responses or lack of discernable response in the low- and intermediate-shade levels. Mean ES estimates did not parallel the original data trends, largely due to simultaneous changes in reference reaches.

Amphibian Detection Probability and Counts

Detection probabilities (*p*) ranged from 0.65–1.00 (Table 5). We found no significant interaction among *p* estimates for any species. However, some large differences existed in estimates for tailed frogs, giant salamanders, and Cascade torrent salamanders in both pre- and post-treatment periods. For tailed frogs, the estimate for the low-shade reaches pre-treatment was 28–43% smaller (*P* = 0.004–0.07) than the intermediate- and reference reaches pre-treatment, respectively, and the no-shade, low-, and references reaches post-treatment. Differences for giant salamanders between reaches (*P* = 0.05–0.09) were due to the lower estimates for the intermediate-reaches pre-treatment and the low- reaches, post-treatment. In contrast, the *p* estimate for Cascade torrent salamanders was lower (*P* = 0.07–0.09) for the intermediate-shade reaches compared to the no-shade and references reaches post-treatment. No differences in *p* were found for the other taxa.

Given the differences in *p* described above, we adjusted counts for tailed frogs in the low-shade reaches pre-treatment by 0.65, giant salamanders by 0.72 for the intermediate-shade reaches pre-treatment and 0.76 for the low-shade reaches post-treatment, and Cascade torrent salamanders by 0.79 for the intermediate-shade reaches post-treatment. For all other reaches, counts were adjusted by the overall mean (0.87–0.99) for each species (Table 5), prior to analyses. Effect sizes for counts of each species were approximately normally distributed and did not result in outliers or heteroskedasticity in model residuals.

Tailed Frogs

Original Data

Mean tailed frog counts (all development stages) varied 43–333% among reaches, pre-treatment, and were greatest in the low-shade reaches, followed in order by the no-shade, reference, and intermediate-shade reaches (Table 6). Post-treatment differences in counts ranged from 8–33% with the smallest difference between the intermediate-shade reaches and both the reference and no-shade reaches, and with the greatest difference between the low- and reference reaches. A 23–333% increase was found in tailed frog numbers in all reaches, pre- to post-treatment, with the smallest increase in the low-shade reaches and greatest in the intermediate reaches.

Effect Size

Mean ES for tailed frog counts differed 100–200% pre-treatment (*P* = 0.37–0.67), being greatest for the no-shade reaches, and differed by 0–200% post-treatment (*P* = 0.56–0.93), being greatest for the intermediate-shade level (Fig. 9a). Mean ES declined 154% pre- to post-treatment in the no-shade reaches (*P* = 0.37), did not change for the low-reaches (*P* = 0.98), but increased 1263% in the intermediate-shade reaches (*P* = 0.37), resulting in a non-significant (*P* = 0.74) interaction term (Appendix 2). However, the relatively large increase in the intermediate-shade reaches fell above the 90% CL.

Giant Salamanders

Original Data

Counts of giant salamanders differed by 0–27% among reaches pre-treatment with counts in both the no- and low-shade reaches being greater than the reference reaches (Table 6). Post-treatment variation was similar (4–35%) with the greatest counts in the low-shade reaches and lowest in the reference reaches. Counts increased in all reaches by 37–63% pre- to post- treatment, with the greatest increase in the low-shade reaches, followed by the intermediate- and reference, and then the no-shade reaches (Table 6).

Effect Size

Mean ES estimates for giant salamanders differed 340–800% (P = 0.001–0.27) pre-treatment with the largest difference between the no-and low-shade reaches (Fig. 9b). ES estimates differed 50–512 % (P = 0.002–0.29) post-treatment. Mean ES estimates increased 22% in the no-shade reaches (P = 0.002), 20% in the low- reaches (P = 0.42), and 45% in the intermediate-shade reaches (P = 0.88), resulting in a significant interaction term (P = 0.08) Appendix 2.

Cascade Torrent Salamanders

Original Data

Cascade torrent salamander counts differed from 0–350% across stream reaches, pre-treatment and were greatest in the no-shade and reference reaches followed by the low- and intermediate-shade reaches, respectively (Table 6). Post-treatment torrent salamander counts differed by 0–30%; in descending order from the highest were low-shade, intermediate-shade, reference, and no-shade. Mean counts also increased (11–450%) pre- to post-treatment in all treatments, with the greatest increases in the intermediate- and low-shade reaches.

Table 5. Mean probability of detecting stream-associated amphibians sampled in 2-m long in-stream plots for pre- and post-treatment periods and four experimental shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind each mean are the standard errors of those means. Streams were sampled during July-September 2004-2009. Estimates followed by the same symbol across rows were significantly different ($P \leq 0.1$).

	Pre-treatment Shade level				Post-treatment Shade level				
Species	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference	Mean[a]
Ascaphus truei	0.82(0.14)	$0.65(0.11)^{\psi,\pi,\varphi,\tau,\omega}$	$0.87(0.13)^{\psi}$	$0.83(0.11)^{\pi}$	$0.87(0.11)^{\varphi}$	$0.92(0.11)^{\tau}$	0.82(0.12)	$0.93(0.09)^{\omega}$	0.87(0.02)
Dicamptodon spp.	$0.94(0.09)^{\psi}$	0.95(0.10)	$0.72(0.10)^{\psi,\pi,\varphi}$	$0.92(0.07)^{\varsigma}$	$0.92(0.11)^{\varphi,\tau}$	$0.76(0.08)^{\pi,\varsigma,\tau,\omega}$	0.85(0.08)	$0.88(0.06)^{\omega}$	0.91(0.01)
Rhyacotriton cascadae	1.00(0.00)	1.00(0.14)	no data	0.78(0.05)	$1.00(0.07)^{\psi}$	1.00(0.10)	$0.79(0.08)^{\psi,\pi}$	$0.96(0.05)^{\pi}$	0.99(0.01)
R. kezeri	no data	no data	0.83(0.2)	1.00(0.19)	1.00(0.08)	1.00(0.10)	1.00(0.10)	0.83(0.07)	0.97(0.03)
R. olympicus	1.00(0.21)	0.90(0.13)	1.00(0.17)	0.77(0.12)	no data	no data	0.98(0.28)	0.88(0.23)	0.92(0.04)

[a] Average of estimates that did not differ from each other across periods and shade levels. Those means were used to adjust amphibian counts for incomplete detections where significant differences among shade levels did not occur ($P \leq 0.1$). For periods and shade levels that were significantly different, the detection probability for each was used to adjust amphibian counts.

Table 6. Mean number (corrected for detection probability) of stream associated amphibians in 50-m stream reaches for pre- and post-treatment periods and four experimental shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind each mean are standard errors of those means. Streams were sampled during July-September 2004-2009. Mean counts represent all life stages combined.

	Pre-treatment shade level				Post-treatment shade level			
Species	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference
Ascaphus truei	10 (3)	13 (5)	3 (1)	7 (1)	14 (4)	16 (6)	13 (4)	12 (2)
Sample size (n =)	8	9	8	25	8	9	8	25
Dicamptodon spp.	19 (3)	19 (3)	16 (4)	15 (2)	26 (5)	31 (5)	25 (5)	23 (2)
Sample size (n =)	6	6	6	25	6	6	6	18
Rhyacotriton cascadae	9 (6)	5 (3)	2 (1)	9 (3)	10 (4)	13 (6)	11 (6)	11 (3)
Sample size (n =)	3	3	3	9	3	3	3	9
R. kezeri	1 (1)	1 (<1)	2 (1)	2 (1)	5 (3)	5 (1)	5 (3)	6 (2)
Sample size (n =)	3	3	3	9	3	3	3	9
R. olympicus	4 (1)	3 (2)	1 (<1)	2 (1)	<1 (<1)	1 (1)	3 (2)	2 (1)
Sample size (n =)	2	3	2	7	2	3	2	7

Effect Size

Mean ES estimates differed from 100−300% among reaches pre-treatment (*P* = 0.24−0.56) and 50−313% post-treatment (*P* = 0.0001−0.65). Pre-treatment, the largest differences were between the no-shade reaches (lowest estimate) and the intermediate- and low-shade reaches, whereas post-treatment low- and intermediate-shade reaches (highest estimates) differed from no-shade reaches (Fig. 9c).

Mean ES estimates for Cascade torrent salamanders declined by 50% pre- to post-treatment in the no-shade reaches (*P* = 0.50), but increased by 100% in the low-shade reaches (*P* = 0.12) and 50% in the intermediate-shade reaches (*P* = 0.01), resulting in a statistically significant (*P* = 0.10) interaction term (Appendix 2). In addition, the relatively large decline in the no-shade reaches fell below the lower 90% CL (Appendix 2).

Columbia Torrent Salamanders

Original Data

Mean counts of Columbia torrent salamanders were relatively low (ranging from 1−2) and differed from 0−100% among reaches pre-treatment (greatest in intermediate and reference reaches), with the largest difference between both the no- and low-shade reaches compared to the intermediate- and reference reaches (Table 6). Differences among reaches post-treatment (mean counts of 5 and 6, largest in reference reaches) were not as great ranging from 0–20%, but were greatest between all the treatment reaches and the references. Counts increased 150−400% pre- to post-treatment, with the largest increase in the no- and low-shade reaches followed by the reference (Table 6).

Effect Size

Mean ES estimates for Columbia torrent salamanders differed from 0−200% pre-treatment (*P* = 0.29−1.00), with the smallest estimate for the no- and low-shade reaches and the largest for the intermediate reaches (Fig. 9d). Post-treatment ES estimates differed from 0−100% (*P* = 0.51−0.80) with the smallest estimate for both the low- and intermediate-shade reaches. Mean ES increased 71% and 25% in the no-shade (*P* = 0.83) and low-shade reaches (*P* = 0.89), and decreased 100% (*P* = 0.21) in the intermediate-shade reaches, pre- to post-treatment (overall period effect – *P* = 0.6), resulting in a non-significant (*P* = 0.61) interaction term (Appendix 2). However, the large decrease in the intermediate reaches fell below the lower 90% CL.

Olympic Torrent Salamanders

Original Data

Similar to Columbia torrent salamanders, mean counts of Olympic torrent salamanders were relatively low and varied 33−300% among reaches pre-treatment with the largest counts in the no- and low-shade reaches. Post-treatment counts were largest in the intermediate and reference reaches and varied by 0−200% across all reaches. In contrast to the other SAAs studied, Olympic torrent salamander counts declined 200−400% pre- to post-treatment except in the intermediate-shade reaches where they increased by 200%; we observed no change in the reference reaches (Table 6). Declines were greatest in the no-shade followed by the low-shade reaches.

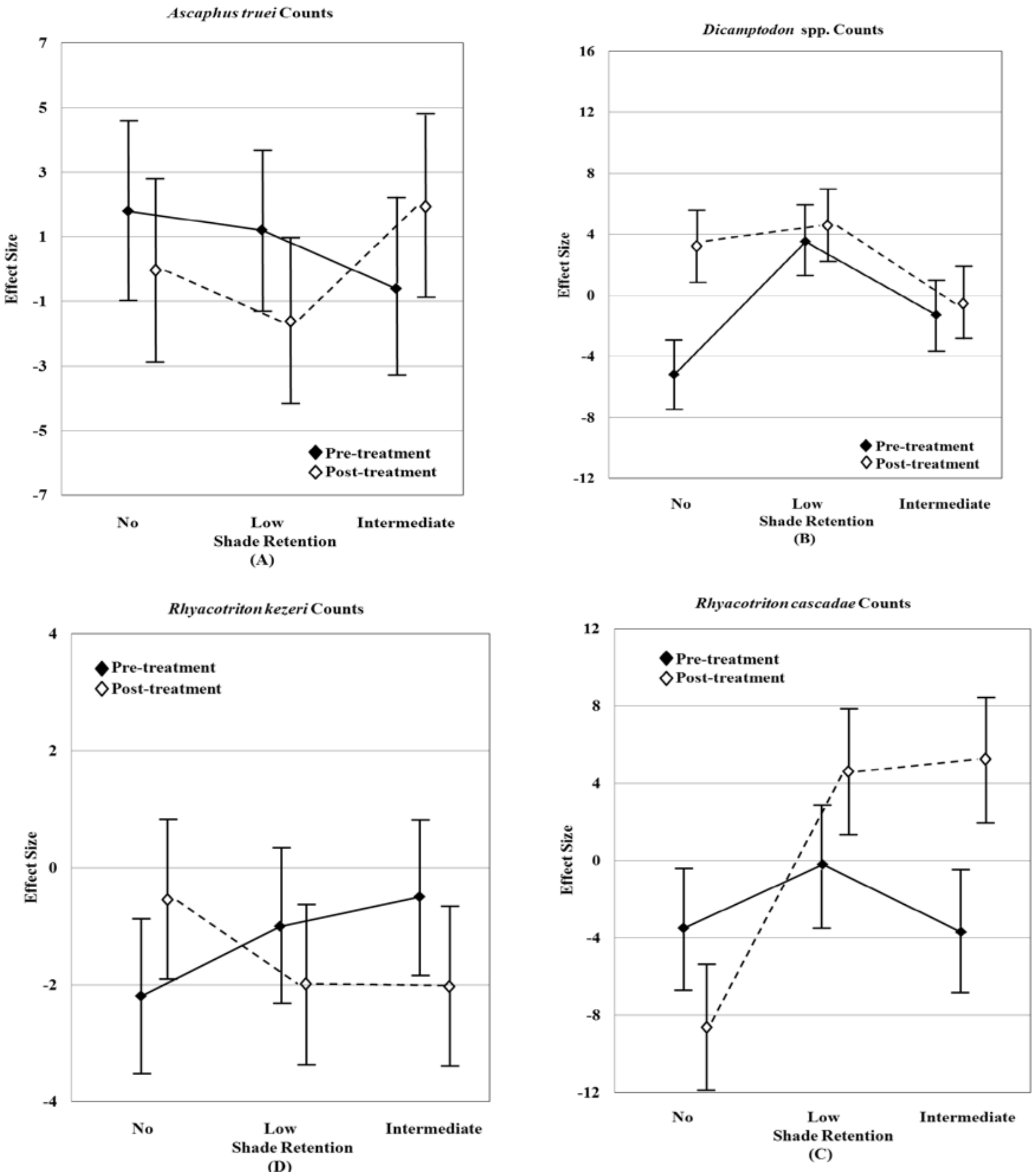


Figure 9. Effect sizes (treatment-reference) of counts of tailed frogs (*Ascaphus truei*; A) giant salamanders (*Dicamptodon* spp.; B), and torrent salamanders (*Rhyacotriton* spp.; C-E), corrected for detection probabilities, for pre- and post-treatment periods in each of 25 stream reaches in northwest Oregon and western Washington randomly assigned to three shade retention levels, 2004-2009. Plotted are the mean effect sizes; whiskers are the standards errors of the means. Sample sizes for tailed frog were eight in each treatment except for the low, which was nine; and giant and each torrent salamander species were, respectively, six and three in every treatment. Data represent all life stages combined.

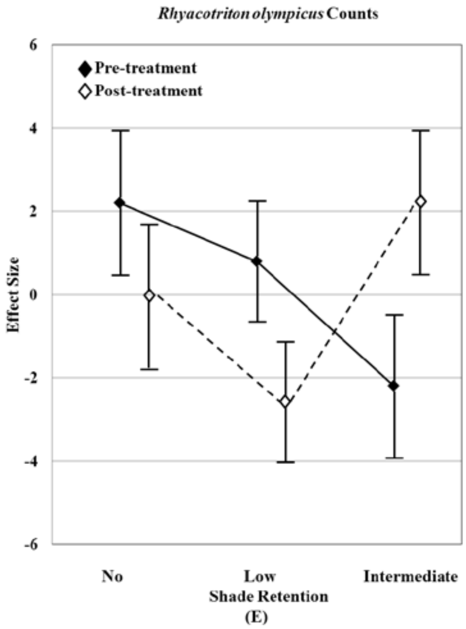


Figure 9. Continued.

Effect size

Mean ES differed from 100−400% among reaches pre-treatment (*P* = 0.03−0.35) and were greatest for the no- and intermediate-shade reaches (Fig. 9e). Estimates differed by 200−250% post-treatment (*P* = 0.05−0.37) with the largest difference between the intermediate-shade reaches and the low- reaches. Mean ES declined pre- to post-treatment by 233% in the no-shade (*P* = 0.21) and 833% in the low-shade reaches (*P* = 0.14), but increased 60% in the intermediate- reaches (*P* = 0.05), resulting in a significant (*P* = 0.06) interaction term (Appendix 2). In addition, the relatively large declines in the low-shade reaches fell below the lower 90% CL.

In summary, corrected counts, except those of Olympic torrent salamanders, increased from pre- to post-treatment periods in all reaches including references. Trends based on ES estimates differed among the five species. The greatest effect ($P \leq 0.1$) of shade reductions occurred for giant salamanders at the no-shade level (positive), at the intermediate-shade level for Cascade torrent salamanders (positive), and the low-shade treatment for Olympic torrent salamanders (negative). In addition, several levels of treatment had statistically non-significant pre- to post-treatment ES changes that fell outside the 90% CLs, including tailed frogs (positive), giant salamanders (positive), and Columbia torrent salamanders (negative) in the intermediate-shade treatments; and Cascade torrent salamanders and Olympic torrent salamanders (negative) in the no-shade treatment and low-shade treatments, respectively. The responses for giant salamanders, and Cascade and Olympic torrent salamanders had significant treatment interactions strengthening the assertion that those responses were due to the treatments.

Amphibian Body Condition

We conducted separate analyses for tailed frog larvae, metamorphs, and adults. We caught too few juvenile tailed frogs for analysis. In addition, the sample of tailed frog metamorphs and adults was incomplete (not all cells in the data matrix had entries), but we had enough for estimates to address all period and treatment combinations. In contrast, Olympic torrent salamanders were not captured in either treatment or reference reaches in each stream each year, precluding calculation of ESs and statistical analyses (Table 7). Body condition ES calculated from SMI estimates produced strong patterns in model residuals for each species and all life stages for tailed frogs, so were rank-transformed; this improved the dispersion of residuals in each case.

Tailed Frog

Larvae

Original Data

Over 160 larval tailed frogs captured were suitable for SMI calculations (i.e., no injuries or malformations). Mean SMI estimates varied by $\leq$11% among shade levels pre- treatment and were largest in the no-shade and reference reaches (Table 7). Mean SMI estimates post-treatment were the same for all reaches, except references, where they were 13% lower. Pre- to post-treatment, a decrease of 11% and 25% in SMI occurred in the no-shade and reference reaches, respectively.

Effect Size

Mean ranked ES of larval SMI differed from 42‒143% pre-treatment (*P* = 0.003‒0.62) with the largest estimate for the intermediate-shade reaches followed by the no- and low-shade reaches (Fig. 10a). However, ES estimates differed from by 0‒2% (*P* = 0.001‒0.94) post-treatment with the largest estimate for the intermediate-shade level. Mean ES increased at all shade levels by 32%, 143%, and 2% pre- to post-treatment at the no-shade (*P* = 0.07), low-shade (*P* = 0.001) and intermediate-shade levels (*P* = 0.91), respectively, resulting in a significant (*P* = 0.04) interaction term. The large positive percent change in the low-shade reaches exceeded the upper 90% CL estimate (Appendix 2).

Metamorphs

Original Data

Forty-seven tailed frog metamorphs were analyzed with mean SMI estimates differing by 0‒30% among reaches for the pre-treatment period, with the greatest estimate for the intermediate-shade reaches (Table 7). Mean SMI estimates differed 8‒30% post-treatment with the largest estimate for the intermediate-shade level followed by the low-, no-, and reference reaches. The SMI increased 20% from pre- to post-treatment periods for the low-shade reaches and did not change for the other reaches.

Table 7. Mean scaled mass (g) index of body condition for five taxa of stream-associated amphibians free-ranging in stream segments and for pre- and post-treatment periods at four shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind each mean are the standard errors of those means. Streams were sampled during July-September 2004-2009.

Species and	Pre-treatment shade level				Post-treatment shade level			
Developmental Stage	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference
Ascaphus truei								
Larvae	1.0(0.05)	0.9(0.03)	0.9(0.02)	1.0(0.04)	0.9(0.01)	0.9(0.01)	0.9(0.01)	0.8(0.03)
Metamorphs	1.1(0.06)	1.0(0.09)	1.3(0.25)	1.0(0.05)	1.1(0.06)	1.2(0.05)	1.3(0.03)	1.0(0.03)
Adults	5.4(0.42)	4.7(0.29)	4.0(0.63)	4.3(0.16)	3.8(0.28)	4.2(0.18)	4.4(0.16)	4.2(0.19)
Dicamptodon spp.	3.4(0.06)	3.4(0.06)	3.4(0.05)	3.5(0.12)	3.3(0.04)	3.5(0.04)	3.3(0.04)	3.4(0.04)
Rhyacotriton cascadae	1.1(0.02)	1.4(0.04)	1.2(0.05)	1.2(0.02)	1.1(0.02)	1.2(0.02)	1.2(0.04)	1.2(0.02)
R. kezeri	0.8(0.04)	0.7(0.12)	0.7(0.03)	0.8(0.05)	0.7(0.04)	0.7(0.01)	0.7(0.02)	0.7(0.01)
R. olympicus	1.6(0.06)	1.7[a]	2.0(0.34)	1.6(0.04)	NA[b]	1.8[a]	1.9[a]	2.2(0.34)

[a] only 1 individual captured in this category.
[b] not available, no captures in this category.

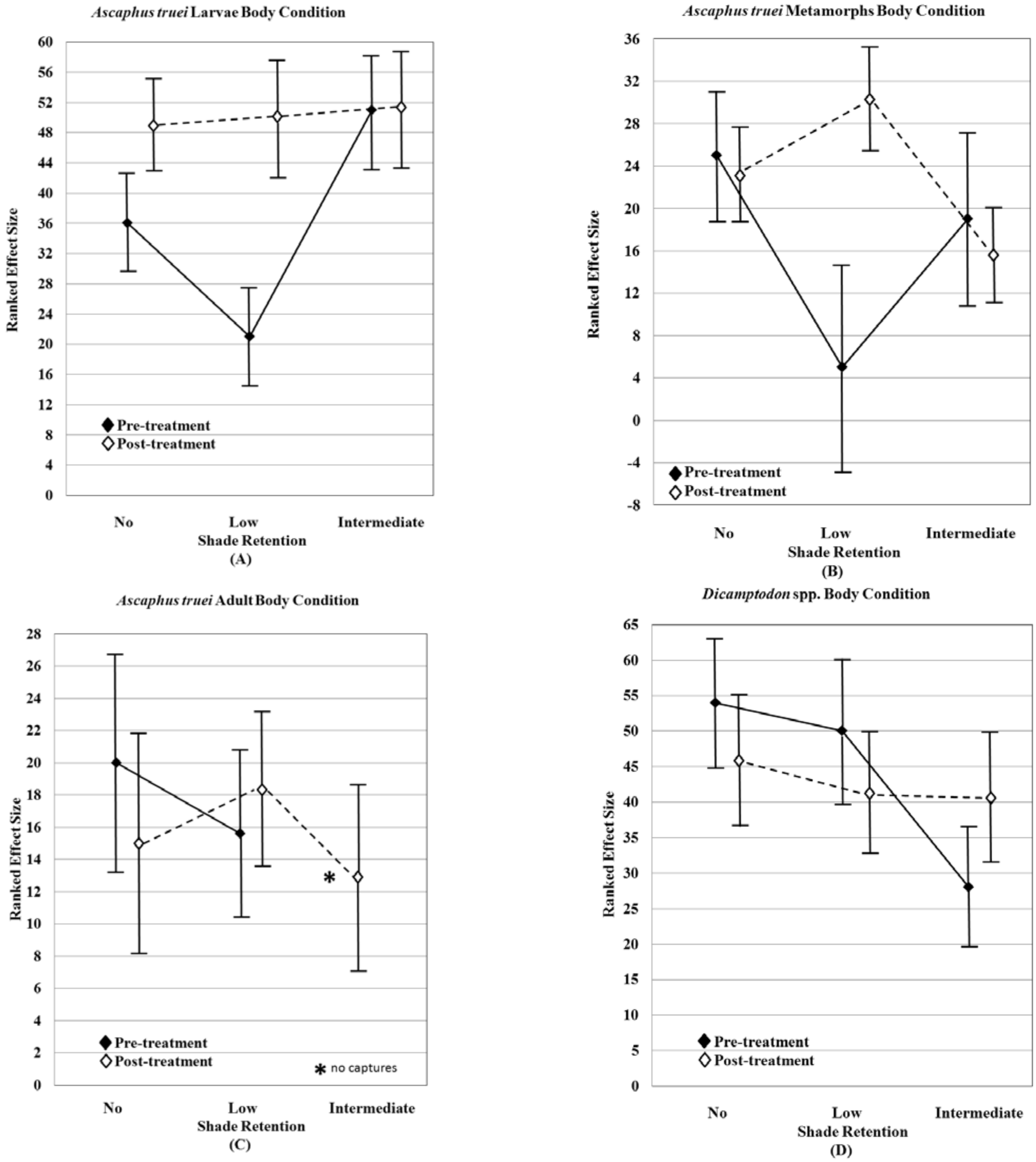


Figure 10. Effect sizes (treatment-reference) for body condition estimates (g) of tailed frog (*Ascaphus truei*) larvae (A), metamorphs (B) and adults (C), giant salamanders (*Dicamptodon* spp.; D), and two torrent salamanders (*Rhyacotriton* spp.; E, F) for stream reaches randomly assigned to one of three levels of shade retention for both pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted are the means of the ranked effect sizes; whiskers are the standard errors of the means.

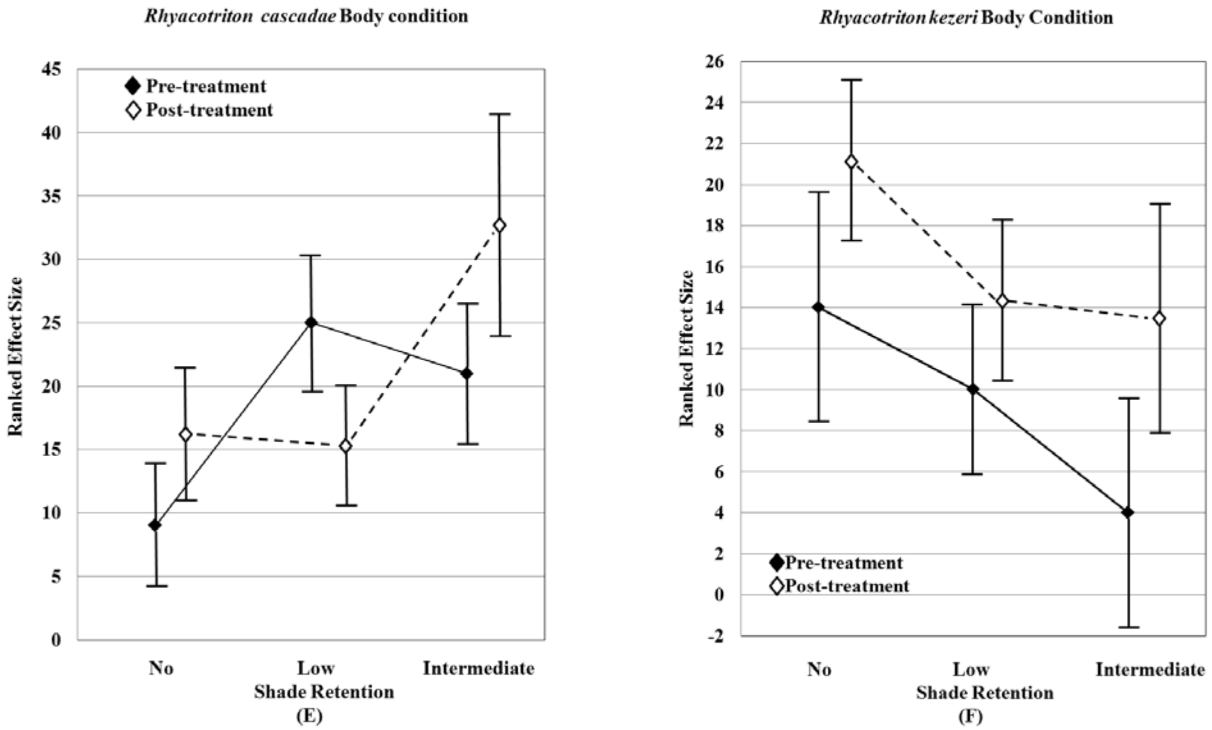


Figure 10. Continued.

Effect Size

Mean ranked ES estimates for tailed frog SMI differed among reaches 37–420% pre-treatment (*P* = 0.07–0.45) with the largest estimate for the no-shade reaches, and the smallest for the low-shade level (Fig. 10b). Post-treatment ES estimates differed 35–94% *P* = 0.008–0.20) with the largest estimate for the low-shade reaches followed by the no-shade reaches. ES estimates declined by 13% and 19% (*P* = 0.74 and 0.64) for the no-shade and intermediate- reaches, respectively, pre- to post-treatment, but increased 520% (*P* = 0.02) for the low-shade reaches, resulting in a non-significant interaction term (*P* = 0.13, Appendix 2). However, the large mean percent increase in the low-shade reach exceeded the upper 90% CL.

Adults

Original Data

A total of 24 adult tailed frogs were suitable for analysis. However, not all cells of the data matrix had SMI estimates and some treatment effects could not be analyzed. Mean SMI estimates for adults differed 8−35% across reaches pre-treatment, with the no-shade reaches having the greatest estimate followed by the low and reference reaches. Mean SMI differed 0-16% among reaches post-treatment with the intermediate-shade reaches having the greatest estimate also followed by the low- and reference reaches. Body condition estimates increased 10% in the intermediate-shade reaches and declined from 2−42% in the remaining reaches between pre- and post-treatment periods (Table 7).

Effect Size

Mean ranked ES estimates for adult tailed frog SMIs differed by 25% (*P* = 0.59) between the treatments with the largest estimate for the no-shade reaches, and ES could not be calculated for the intermediate-shade reaches pre-treatment due to a lack of captures (Fig. 10c). Post-treatment estimates differed from 15−38% (*P* = 0.44−0.82), with the largest estimate for the low-shade reaches followed by the no-shade reaches. Mean ranked ES declined 33% for the no-shade reaches (*P* = 0.57) and increased 12% for the low-shade reaches (*P* = 0.67), pre- to post-treatment. The interaction term was not significant (*P* = 0.78, Appendix 2) and neither change fell outside of the 90% CL.

Giant Salamanders

Original Data

We captured over 2,170 giant salamanders suitable for body condition analyses. Mean SMI estimates for giant salamanders differed from 0–3% across shade levels pre-treatment, with the only difference occurring between reference reaches (largest) and all other reaches (Table 7). Post-treatment SMI estimates differed by 0–6% among reaches, with the greatest value for the low-shade followed by the reference then both the no- and intermediate-shade reaches. SMI increased three percent from pre- to post-treatment for the low-shade reaches and declined three percent in all other reaches.

Effect Size

Mean ranked ES estimates were more variable and differed 8–93% among reaches pre-treatment (*P* = 0.02–0.72) with the largest estimates for no- and low-shade reaches (Fig. 10d). Differences among reaches post-treatment were smaller (0–10%) with a similar pattern among reaches as for the pre-treatment period (*P* = 0.69–0.71). Pre- to post-treatment declines of 17–19% occurred in the no- and low-shade reaches (*P* = 0.47 and 0.48, respectively), but increased by 50% (*P* = 0.21) in the intermediate- reaches, resulting in a non-significant (*P* = 0.46) interaction term but increases in the intermediate treatments exceeded the upper 90% CL (Appendix 2).

Cascade Torrent Salamanders

Original Data

Over 470 Cascade torrent salamanders captured were appropriate for condition analyses. Mean SMI estimates differed from 0–27% across reaches, pre-treatment and were greatest for the low-shade reaches followed by the intermediate- and reference reaches (Table 7). In contrast, SMI estimates differed by only 0–9% across reaches post-treatment with equivalent estimates for the low-, intermediate-, and reference reaches with the no-shade reaches having the lowest estimate. Mean SMI estimates did not change pre- to post-treatment except at the low-shade level where it declined by 17%.

Effect Size

Mean ranked ES estimates were more variable and differed from 38–164% across reaches pre-treatment (*P* = 0.01–0.50) with the greatest estimate for the low- and intermediate- reaches compared to the no-shade reaches (Fig. 10e). ES estimates differed from 7–75% among reaches post-treatment with the estimate for the intermediate- reaches greater than each of the no- and low-shade reaches (*P* = 0.07 and 0.05, respectively). Pre- to post-treatment ES increased 78% for the no-shade reaches (*P* = 0.19) and 57% for the intermediate-shade reaches (*P* = 0.28), but declined by 67% for the low-shade treatment (*P* = 0.07). These trends resulted in a significant (*P* = 0.10) interaction term and the percent decrease in the low-shade reaches fell below the lower 90% CL (Appendix 2).

Columbia Torrent Salamanders

Original Data

Mean SMI estimates of over 250 Columbia torrent salamanders differed from 0–14% pre-treatment with the no-shade and reference reaches greater than the low- and intermediate-shade reaches (Table 7). Post-treatment, mean SMI estimates for this species were the same across all reaches, resulting in a 14% decline in the no-shade and reference reaches and no change elsewhere.

Effect Size

Mean ranked ES estimates were more variable with pre-treatment differences ranging from 40–250% (*P* = 0.15–0.87) with the ES for the intermediate-shade reaches smaller than each of the low- (*P* = 0.34) and no-shade (*P* = 0.16) reaches (Fig. 10f). Post-treatment ES estimates differed 0–50% (*P* = 0.11–0.94) with the estimate for the no-shade reaches greater than each of the low-shade (*P* = 0.19) and intermediate-shade reaches (*P* = 0.23). Pre- to post-treatment ES estimates increased 40–225% across all reaches (*P* = 0.09) and was greatest for the intermediate-shade reaches (*P* = 0.18) and least for the low-shade retention level (*P* = 0.45), resulting in a non-significant (*P* = 0.65) interaction term (Appendix 2). However, the relatively large increase in the intermediate reaches exceeded the upper 90% CL.

Olympic Torrent Salamanders

Original Data

Too few captures (53) of Olympic torrent salamanders existed to calculate an ES for each period and treatment combination (Table 7). Mean SMI estimates differed 0–25% across all reaches, pre-treatment and were greatest for the intermediate-shade reaches followed by the low-shade reaches (Table 7). Estimates differed from 6–22% among reaches post-treatment increasing with increasing shade retention. Mean SMI estimates increased by 6% for the low-shade reaches and 38% for reference reaches pre- to post-treatment, but declined by 5% in the intermediate-reaches.

In summary, mean SMI estimates were relatively uniform within taxa differing by $\leq$0.3 g among reaches both pre- and post-treatment, except for tailed frog adults and Olympic torrent salamanders. Changes in original SMI values (Table 7) generally did not parallel shade reductions.

Post-treatment, mean SMI estimates (Table 7) were greatest at low (tailed frogs) or intermediate (giant and Columbia torrent salamanders) levels of shade retention, except for Cascade torrent salamander, which showed a negative response at low shade levels; Olympic torrent salamanders had too few captures to evaluate with confidence. Ranked ES estimates differed among reaches for both pre-treatment and post-treatment periods in a complex fashion, with no consistent relationship between reductions in shade and increases or decreases in SMI estimates. However, considering all species and life stages collectively, evidence of positive changes in SMI (statistically significant or exceedances of the 90% CLs) were least frequent at the no-shade level (none), intermediate at the low-shade level (66% of three were positive), and most frequent at the intermediate-shade level (100% of two were positive).

Amphibian Growth Rates

Residence time of individuals placed in the enclosures varied from ≤ one week to >18 weeks. Depending on the year, 75−226 individual tailed frog larvae were in the enclosures for a minimum of four weeks. Further, 40−112 tailed frog metamorphs, 52−146 giant salamanders, 26−97 Cascade torrent salamanders, 42−101 Columbia torrent salamanders, and 52−82 Olympic torrent salamanders also met that criterion.

With some exceptions (17%), the mass of most individuals of each species and life stage combination declined while in the enclosures during the pre-treatment period (Table 8). In contrast, growth rates were positive for 33% of species and life stage and treatment categories, post-treatment. Excluding tailed frog metamorphs, because these are known to typically lose mass at metamorphosis, those estimates increased to 25% and 40%, respectively.

Tailed Frogs

Larvae

Original Data

Growth rates for tailed frog larvae differed among reaches by 200−1,900% pre-treatment with larvae in the no-shade reaches experiencing positive growth and those in other reaches losing mass. Growth rates differed among reaches from 33−525% post-treatment with mass gains in all reaches, except the references, with the greatest gain in the no-shade reaches. Tailed frog larval growth rates increased from pre- to post-treatment periods 613−1000% in the low- and intermediate-shade reaches, respectively, but declined 59% in the no-shade reaches and 433% in the reference reaches.

Effect Size

Mean ES estimates for tailed frog larvae differed 225−300% among reaches pre-treatment with the largest estimates for the no and intermediate-shade reaches and the greatest differences between the no-shade reaches and each of the low (P = 0.03) and intermediate reaches (P = 0.15) (Fig. 11a). Effect size estimates were more variable post-treatment, differing 39−316% with a similar pattern across reaches and the largest differences between both the no-shade and intermediate and the low reaches (P = 0.01 and 0.10, respectively). Effect size increased 133-800% across all reaches from pre- to post-treatment periods (P = 0.01) and was greatest for the intermediate-shade reaches (P = 0.02), 150% for the no-shade reaches (P = 0.09), and least for the low-shade reaches (P = 0.09), resulting in a non-significant (P = 0.2) interaction term, despite the relatively large increase in the intermediate-shade treatment that exceeded the upper 90% CL (Appendix 2).

Table 8. Mean growth rate (mg change week^{-1}) of five taxa of stream associated amphibians held in in-stream enclosures for pre- and post-treatment periods at four shade levels for headwater streams in northwest Oregon, southwest Washington, and the Olympic Peninsula, Washington. Values in parentheses behind each mean are the standard errors of those means. Streams were sampled during July-September 2004-2009.

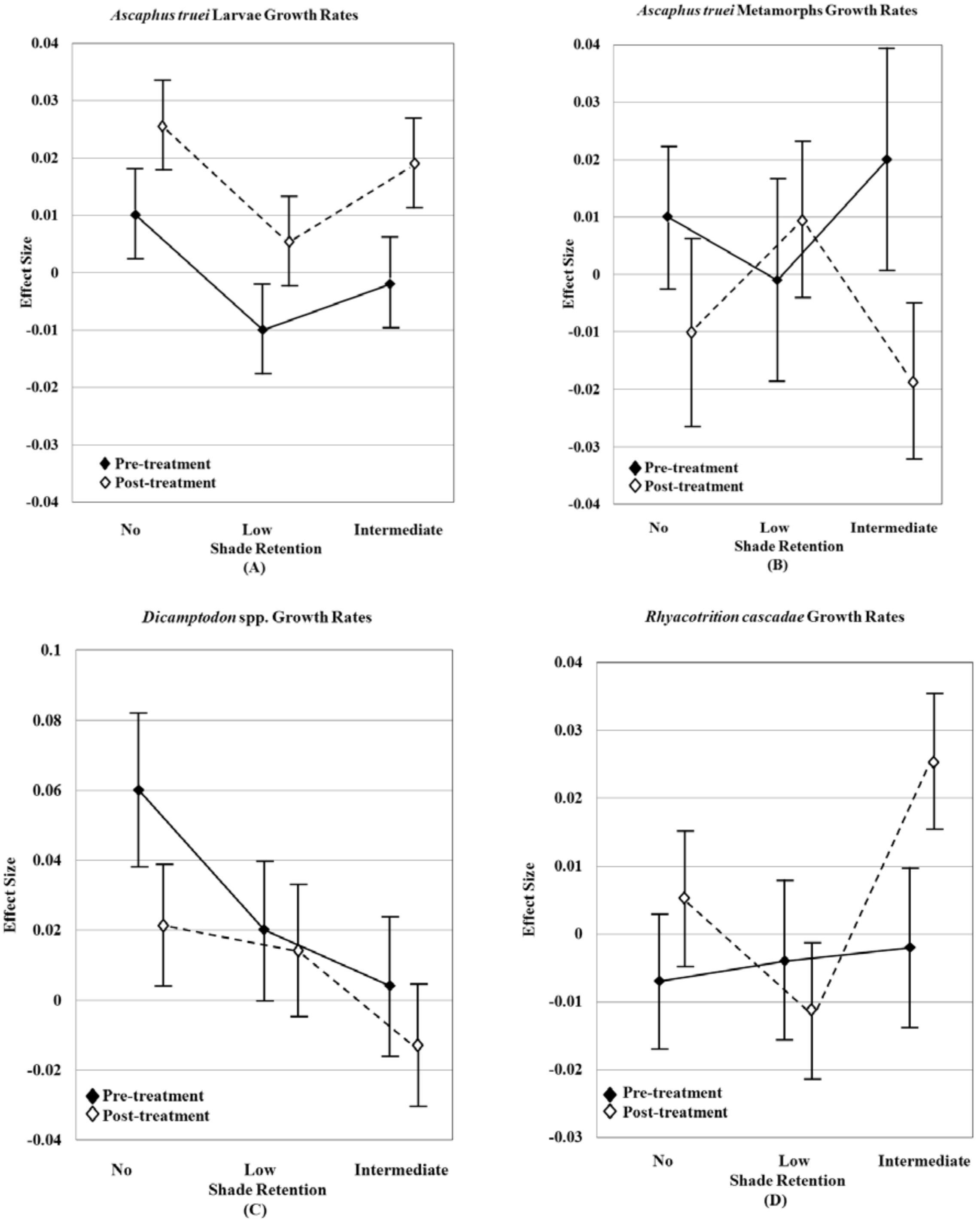
Species and	Pre-treatment shade level				Post-treatment shade level			
Developmental Stage	No	Low	Intermediate	Reference	No	Low	Intermediate	Reference
Ascaphus truei								
Larvae	19 (15)	-17 (14)	-1 (3)	-3 (4)	12 (4)	3 (4)	9 (4)	-16 (6)
Metamorphs	-48 (20)	-36 (16)	-27 (16)	-57 (18)	-43 (20)	-46 (15)	-54 (15)	-44 (9)
Dicamptodon spp.	16 (12)	-10 (10)	-9 (16)	-32 (20)	18 (17)	-5 (12)	-27 (24)	-12 (6)
Rhyacotriton cascadae	-11 (6)	-2 (9)	0 (16)	-1 (5)	-15 (9)	-36 (15)	-8 (12)	-23 (6)
R. kezeri	7 (18)	-16 (7)	-2 (6)	-1 (19)	13 (12)	-7 (10)	0 (5)	-11 (6)
R. olympicus	-2 (2)	-3 (3)	-24 (14)	0 (4)	0 (4)	6 (4)	-8 (2)	-3 (3)

Metamorphs

Tailed frog metamorphs lost weight in the enclosures during both pre- and post-treatment periods as expected (Table 8). However, mass changes differed more among reaches pre-treatment (33–111%; greatest in the reference and no-shade reaches and least in the intermediate reaches) than post-treatment (5–24%; greatest in the intermediate- and low- reaches and least in the no-shade reaches). Mass increased (11% and 30%) only in the no-shade and reference reaches and decreased in the low and intermediate reaches (28% and 100%) between pre- and post-treatment periods.

Effect Size

Mean ES estimates for tailed frog metamorphs differed 1,000–2,300% among reaches pre-treatment with the largest estimates for the intermediate- and no-shade reaches and the biggest difference (P = 0.37) between the intermediate- and low-shade reaches (Fig. 11b). Differences between reaches post-treatment ranged from 80–300% with the largest estimates for the low and no-shade reaches and greatest difference (P = 0.18) between the low- and intermediate-shade reaches. ES increased from pre- to post-treatment periods 800% (P = 0.67) in the low-shade reaches, but declined 28-100% (P = 0.10–0.32) in the intermediate- and no-shade reaches, respectively. These trends resulted in a non-significant (P = 0.39) interaction term despite the relatively large change in the low-shade reaches exceeding the upper 90% CL (Appendix 2).



Ascaphus truei Larvae Growth Rates

Ascaphus truei Metamorphs Growth Rates

Dicamptodon spp. Growth Rates

Rhyacotrition cascadae Growth Rates

Figure 11. Effect sizes (treatment-reference) for growth rates (g week^{-1}) of tailed frog (*Ascaphus truei*) larvae (A) and metamorphs (B), giant salamanders (*Dicamptodon* spp.; C), and three torrent salamanders (*Rhyacotriton* spp.; D-F) held in in-stream enclosures in stream reaches randomly assigned to one of three levels of shade retention for pre- and post-treatment periods for 25 streams in northwest Oregon and western Washington, 2004-2009. Plotted are the mean effect sizes; whiskers are the standard errors of the means.

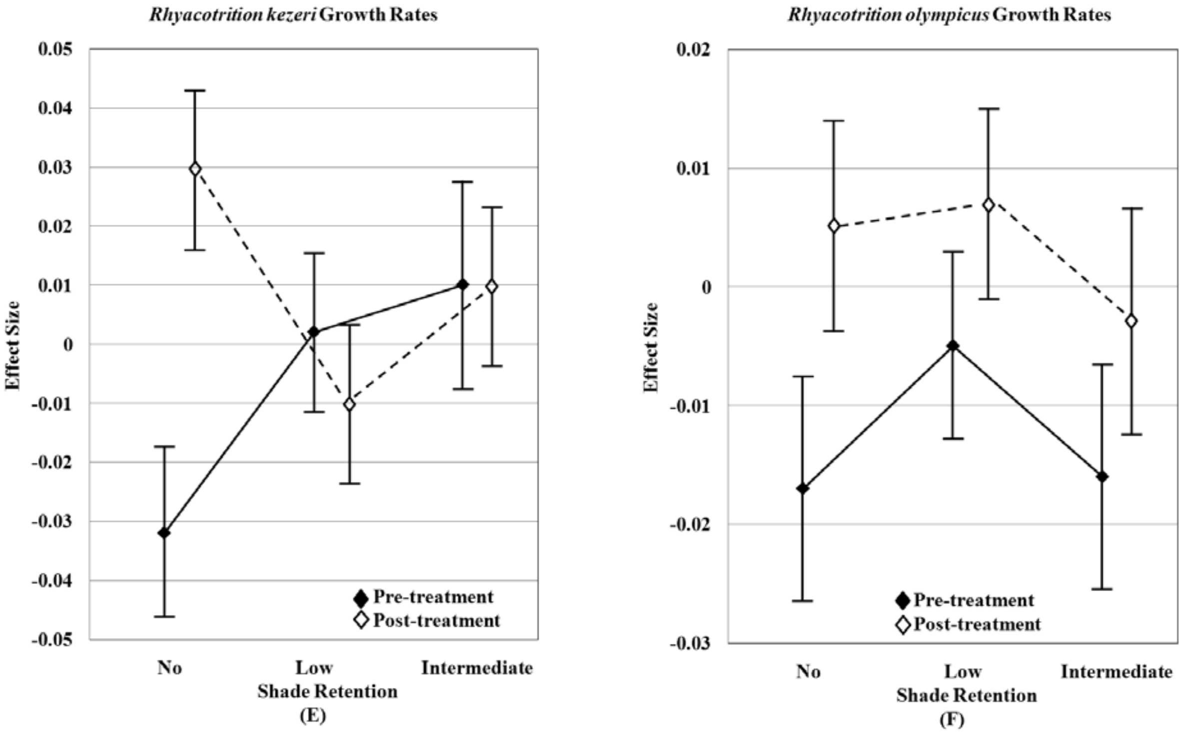


Figure 11. Continued.

Giant Salamanders

Original Data

Growth rates of giant salamanders were primarily negative during both pre- and post-treatment periods, except in the no-shade reaches (Table 8). In addition, growth rates increased in the no-shade (13%), low-shade (100%), and reference reaches (107%) from pre-to post-treatment periods. Growth rates differed by 11−200% across reaches pre-treatment, and were more variable (140−250%) post-treatment.

Effect Size

In contrast, mean ES estimates were positive for all reaches pre-treatment, greatest in the no-shade reaches, and differed from 480−1480% with the largest difference (P = 0.06) between the no-shade and intermediate-reaches (Fig. 11c). Estimates differed from 23−262% post-treatment with a similar pattern across reaches and the largest difference (P = 0.24) between the low- and intermediate-shade reaches. Furthermore, ES decreased 35−225% pre- to post-treatment (P = 0.24) with the largest decline in the intermediate-shade reach (P = 0.52) and the least in the low-shade reaches (P = 0.82), resulting in a non-significant (P = 0.72) interaction term (Appendix 2). The decline in the low-shade reaches fell below the lower 90% CL.

Cascade Torrent Salamanders

Original Data

Growth rates of Cascade torrent salamanders were negative for all reaches in both periods, except at the intermediate-shade level pre-treatment where there was no change (Table 8). Growth rates differed more across reaches (100−1,000%) pre-treatment, with the greatest decrease in the no-shade reaches, than post-treatment (87−350%), where the greatest change was in the low-shade treatment, and declined from pre- to post-treatment periods in all reaches with the largest declines in the reference and low-shade reaches.

Effect Size

Mean ES estimates for growth rate in Cascade torrent salamanders were also negative for all reaches pre-treatment and differed from 100−250% among reaches with the largest difference (*P* = 0.70) between the intermediate and no-shade reaches (Fig. 11d). Effect size estimates differed from 310−400% post-treatment with the greatest difference (*P* = 0.10) between the intermediate- and low-shade reaches. Pre- to post-treatment, effect size increased 1150% in the intermediate-shade (*P* = 0.06), had a non-significant increase (40%) in the no-shade reaches (*P* = 0.34), respectively, and declined 175% in the low-shade reaches (*P* = 0.64), resulting in a non-significant (*P* = 0.33) interaction term. However, the relatively large increase in the intermediate-shade treatment exceeded the upper 90% CL (Appendix 2).

Columbia Torrent Salamanders

Original data

Columbia torrent salamander mean growth rates were negative for all reaches and periods, except for the no-shade reaches pre-treatment, and the no- and intermediate-shade reaches post-treatment (Table 8). Growth rates differed among reaches from 100−1,500% pre-treatment with the largest change in the low-shade reaches, and 57−286% post-treatment with the largest change in the no-shade reaches. Growth rates increased 86−129% in all but the reference reaches, pre- to post-treatment where growth rates declined (1,000%). The greatest increases were in the low- (145%) and the intermediate-shade reaches (100%).

Effect Size

Differences among reaches in mean ES for Columbia torrent salamander growth rates were more variable pre- (350−100%) than post-treatment (217−521%, Fig. 11e). The largest difference between reaches in both the pre- (*P* = 0.13) and post-treatment (*P* = 0.10) periods was for the no- and low-shade reaches. From pre- to post-treatment periods, ES increased by 121% for the no-shade reaches (*P* = 0.01), going from the most extreme negative estimate to the largest positive estimate and declined by 200% for the low-shade reaches (*P* = 0.71), going from a small positive to a negative estimate, but did not change significantly in the intermediate reaches (29%; *P* = 0.93). These trends resulted in a significant interaction term (*P* = 0.10) and the large percent decline in the low-shade reaches exceed the upper 90% CL (Appendix 2).

Olympic Torrent Salamanders

Original Data

Growth rates of Olympic torrent salamanders differed 50−1,100% among reaches pre-treatment and were negative in all reaches, except references where animals maintained mass; the largest decline was in the intermediate reach (Table 8). Post-treatment changes in mass were positive in the low-shade reaches, and negative in the intermediate (largest decline) and reference reaches, but mass did not change in the no-shade reaches resulting in a 167−300% difference among reaches (Table 8). Pre- to post-treatment growth rates increased 100% in the no-shade reaches, 300% in the low- reaches, and 200% in the intermediate reaches, but declined 100% in the reference reaches.

Effect Size

Mean ES estimates differed from 6−240% pre-treatment with the largest estimates in the low- and intermediate-shade reaches and the greatest differences (*P* = 0.20−0.24) between the low-shade reaches and all of the others (Fig. 11f). Post-treatment, ES estimates differed from 40−317% and were positive for all treatments except the intermediate-shade reaches, with the largest estimates for the low and no-shade reaches. The greatest difference in growth rates was between the low- and intermediate- reaches (*P* = 0.29). Mean ES estimates increased 140-433% from pre- to post-treatment periods (*P* = 0.21) with the largest increase for the intermediate-shade reaches (*P* = 0.10) followed by the 240% increase in no-shade reaches (*P* = 0.09) and lowest percent increase in the low-shade reaches (*P* = 0.28). This resulted in a non-significant (*P* = 0.33) interaction term (Appendix 2), despite the fact that the relatively large (433%) increase in the intermediate-shade reaches exceeded the upper 90% CL.

In summary, most individuals of each taxon and development stage lost mass while in the enclosures. Trends in growth rates among reaches post-treatment were mixed and variable with some taxa maintaining or gaining mass in some reaches, most often at moderate levels of shading, and others losing mass in all reaches. However, based on ESs, considering all species and life stages, support for increases in growth rate (a significant treatment effect or values outside the upper 90% CL) were more frequent in the intermediate- and no-shade treatments (87% - seven of eight possible comparisons) than in the low-shade treatment (33% - one of three comparisons. Based on ES estimates, only giant salamanders had negative growth rates for all reaches but the decline in the low-shade treatment was above the upper 90% CL, indicating a relatively smaller decline in mass in those reaches. Also based on ES, three of the four largest increases in growth rates occurred at the intermediate level of shade, notably for tailed frog larvae and Cascade and Olympic torrent salamanders. However, based on the interaction term, only the changes in the Columbia torrent salamander mass appear clearly attributable to a treatment effect.

Discussion

The overarching objective of this study was to document the response of headwater stream communities to variation in vegetation shading, focusing on six species of SAAs and the mechanisms that led to those responses. We sought to create a gradient in light reaching streams spanning open to closed canopies through a multi-treatment (Steury et al. 2002) study design. Despite the vagaries and imprecision of spherical densiometers (Cook et al. 1995, Nuttle 1997), levels of PAR reaching streams over the post-treatment period indicated that this goal was largely met.

Stream Energetics and Predictions

Our experimental procedure shifted stream reaches that were primarily heterotrophic before shade reductions more towards autotrophy as exhibited by the relatively large increases in biofilm and declines in detritus drift following treatment implementation, particularly for the latter at the no-shade level. We expected this change to have large effects on the primary and secondary consumers we studied. In addition, we expected that effects could vary linearly or as a quadratic function over the gradient of shade we created, depending on the response variable (Kiffney et al. 2003, Hill et al. 2010, Ohta et al. 2011) and site conditions (Richardson and Béraud 2014). Based on post-treatment ES estimates, we observed linear, quadratic (U- or bell-curves), and asymptotic trends, depending on the response variable. Light, water temperature, biofilm and CPOM all had an inverse linear response to shade level, though the biofilm pattern was much less pronounced and not associated with a significant interaction; drift as FPOM was positively quadratic or asymptotic (depending on the metric evaluated); macroinvertebrate drift had either negative or positive quadratic responses, and SAAs had all response pattern classes (Figs. 5-11).

We also expected that the largest biotic effects of the treatments would be on biofilm accrual (positive), the abundance of macroinvertebrate scrapers (positive; Hill et al. 2010, Ohta et al. 2011), shredders (negative; Cummins et al. 1989, Richardson and Béraud 2014), and tailed frog larvae (Kiffney et al. 2004), and perhaps metamorphs (both positive). In addition, we expected that tailed frogs and possibly some salamanders (MacCracken 2002) would also exhibit better body condition and greater growth rates in stream reaches with less shade (Kiffney et al. 2004, Mallory and Richardson 2005).

Macroinvertebrates

Based on the results of the ES analyses, some of aforementioned predictions were met. In particular, all macroinvertebrate functional groups with the exception of filterers exhibited a significant pattern for at least one metric that agreed with predictions.

Within the macroinvertebrate community, gatherers exhibited positive responses to our light manipulations at the both low- and intermediate-shade levels, with unambiguously strong responses (38-53% increases) at the low-shade level regardless of metric. Conversely, though the declines (6-7%) at the greatest light (no shade) level were less pronounced, the g day^{-1} metric value fell below the lower 90% CL suggesting a real decline (Figs. 8k, l; Appendix 2). Significant interaction terms for both metrics clearly support attributing these responses to the shade treatment gradient. Generally, gatherers exploit detritus deposited in eddies and against streambed material (Merritt and Cummins 1996) that is created both by shredders feeding on CPOM and the physical breakdown of plant and animal material. The relatively large increases in biofilm at the low- and intermediate-shade level likely contribute to the response of gatherers that we observed, which also had the greatest drift rates at the low-shade level.

Shredding insect ES estimates declined up to 43% at the lowest level of canopy retention with little change at higher levels of canopy retention (Figs. 8g, h; Appendix 2). This agrees with the view that shredder population size, species composition, and life histories are tightly coupled to riparian area vegetation composition and disturbance regimes (Cummins et al. 1989, Richardson and Béraud 2014). This result suggests that the declines in allochthonous subsidies had inconsistent effects on shredders numbers until canopy reduction fell below the low-shade level (~61% canopy cover).

Conversely, scraper ES estimates increased up to 24% in the intermediate reaches for one metric with little change evident at lower levels of canopy retention. At best, this result provides ambiguous support for the predictions of the light:nutrient hypothesis since lack of significant interaction terms reflects inconsistent responses.

Macroinvertebrate predator ES estimates declined up to 26% pre- to post-treatment in the no-shade reaches. Prior to treatment application, predators were the most abundant macroinvertebrate class based on ranked ES estimates, but fell to fifth post-treatment in no-shade reaches. Detailed studies on selection of macroinvertebrate prey by macroinvertebrate predators for the region are lacking, but most studies indicate that predators are opportunistic (Hildrew et al. 1985, Giller and Sangpradub 1993, Lancaster and Robertson 1995), so these large declines in predators may reflect the aforementioned decline in shredders in no-shade reaches.

Decline in shredder drift rates under the highest shade reduction levels is consistent with expectations (Richardson and Béraud 2014) and the assumption that macroinvertebrate drift reflects abundance patterns in the treated reaches. Hammock and Wetzel (2013) found that stream invertebrate herbivores initiate drift in response to food limitations and invertebrate predators. Furthermore, food limitation was density-dependent in their study and they found no evidence that increases in forest canopy increased drift due to lower food quality or quantity under closed canopies. Regarding a canopy closure gradient, Hammock and Wetzel (2013; see also Ebel et al. 2014) found the greatest support for the hypothesis that sunnier sites supported more herbivores, which consumed biofilm at a higher rate, and dispersed via drift when herbivore density reached or exceeded carrying capacity. Hammock and Wetzel (2013) also noted that this mechanism kept biofilm mass relatively constant across a canopy closure gradient, which may also explain the increased but relatively equivocal mass of biofilm across the canopy gradient established in this study. Macroinvertebrate drift is a complex process involving both passive (Elliot 1967, 2003) and active mechanisms (Kohler 1985, Peckarsky 1980). If shredders in our test streams responded as those in the literature cited above, our drift sampling may be serving as a general index of stream invertebrate abundance (also see Kiffney et al. 2014).

Potential bias from using drift as a measure of changes in macroinvertebrates merits brief comment. Drift either cannot capture or minimally captures non-drifting taxa or stationary cased species (Pringle and Ramirez 1998). We assume that variation among drift macroinvertebrates was uninfluenced by variation among non-drifting taxa differently across treatments. In other words, the drift macroinvertebrate variation we measured reflects unbiased responses that are useful for distinguishing functional differences among treatments. We lack the data to test this assumption but it should considered in the design of future work.

We also considered the possibility of trophic interactions between amphibians and macroinvertebrates (Atwood and Richardson 2012). Total macroinvertebrates (as $\#/m^2$) and larval tailed frog counts had parallel patterns across the light gradient (Appendix 4), perhaps independent parallel responses. However, one has to view these patterns in context of the fact that neither was significant, so parallelism is questionable. In contrast, count data for three of the four salamander taxa examined were significant over the light gradient, but relationship strength is poor. In all three cases, patterns relative total macroinvertebrates measured as $\#/m^2$ not consistent. Further, none of the invertebrate functional groups considered independently had clearly evident patterns relative to any of the stream-associated amphibians. Atwood and Richardson (2012) contrasted stream insect assemblages in streams with and without Coastal giant salamander larvae, and found no significant difference between the streams with and without salamanders. They concluded that while the Coastal giant salamanders are top predators in many streams, they may not always cause shifts in community structure, which may reflect unclear context-dependent effects.

Amphibian Overview

Amphibian responses were complex, but patterns emerged when considering response assemblages across analyses. In particular, based on the amphibian metrics for the instream assessment (i.e., counts and body condition), the distribution of overall positive versus negative responses tracked the treatment gradient. Specifically, SAAs and their developmental stages had more positive responses (either statistically significant or falling outside the 90% CL) than negative responses within the intermediate-shade level (86%) than in either the low-shade or no-shade levels (both 50%; Fig. 12). Breakdown of this instream assessment pattern by examining each of the amphibian species abundance and condition data alone revealed that both contributed to the pattern (Figs. 13 and 14), with abundance data supporting the response pattern more clearly (i.e., more positive responses at the intermediate-shade level) than the condition data.

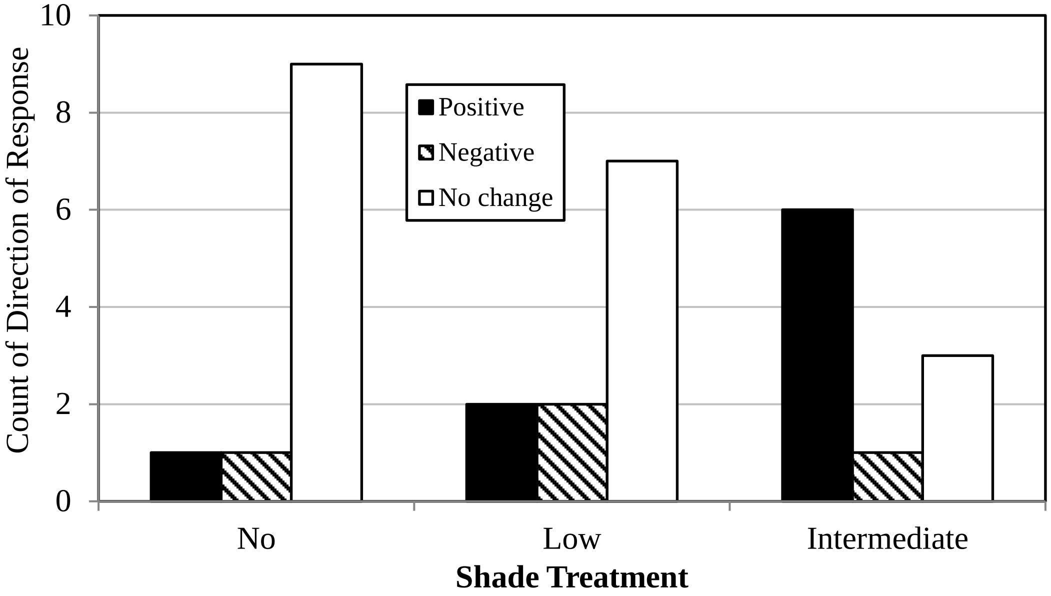


Figure 12. Amphibian responses based on instream data (combined abundance [counts] and body condition [SMI] data) across shade level treatment categories. Response count was based on the number of taxa on which abundance [count] data were assessed (n = 5) combined with the number of taxa/life stages on which body condition was assessed (n = 6). Positive and negatives responses were those that were either statistically significant or fell outside the 90% CLs for the percentage change in the ES were included; responses scored as no change represent the balances of responses.

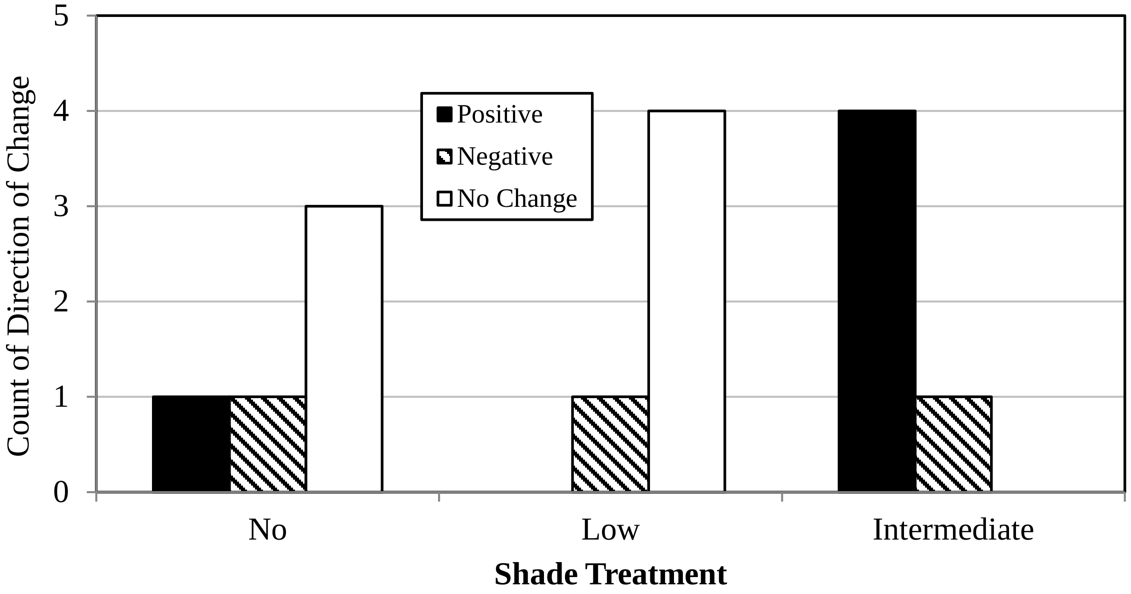


Figure 13. Amphibian responses based on abundance [count] data across shade treatment categories. Count of amphibian taxa based on the total number of taxa on which abundance data were assessed (n = 5). Positive and negatives responses are exclusively those that were either statistically significant or fell outside the 90% CLs for the percentage change in the ES; responses scored as no change represent the balances of responses.

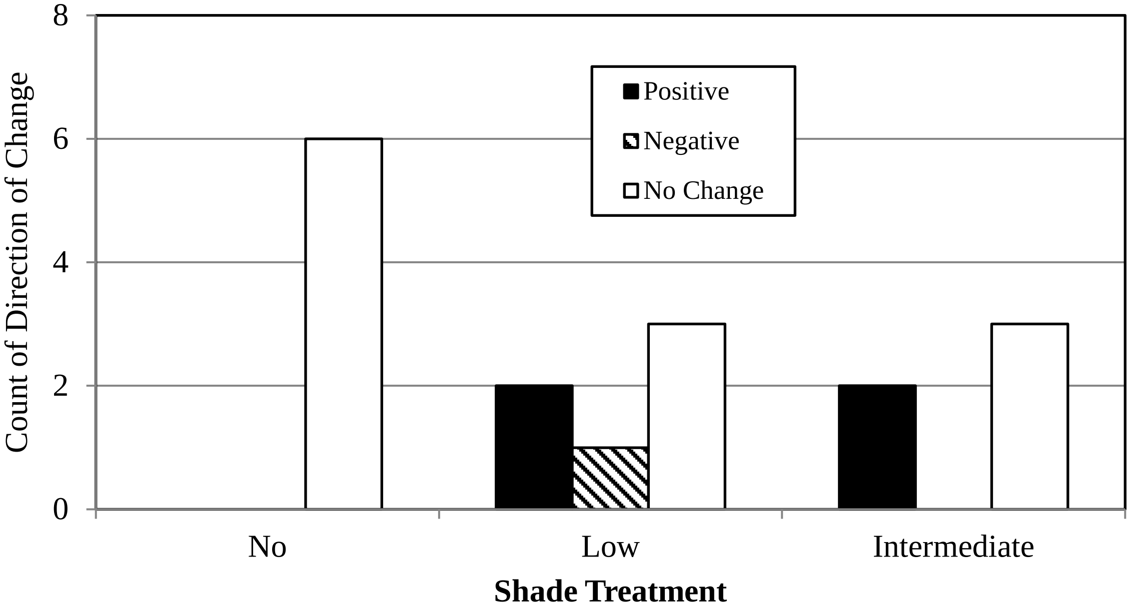


Figure 14. Amphibian responses based on body condition [SMI] data across shade treatment categories. Count of amphibian taxa based on the total number of taxa or life stages on which body condition were assessed (n = 6). Positive and negatives responses are exclusively those that were either statistically significant or fell outside the 90% CLs for the percentage change in the ES; responses scored as no change represent the balances of responses.

Further, selected patterns may reflect taxon-specificity. In particular, tailed frogs showed the strongest positive responses at either the low-shade (for counts) or intermediate-shade (for body condition) levels. In contrast, torrent salamanders had the most complex responses that least fit predictions (Appendix 2). Regardless of species, torrent salamanders appeared to have a more positive responses (6 of 7) at the intermediate-shade level than at either of the low- (2 of 4) or no-shade (1 of 2) levels.

Amphibian growth response was more complex with some similarities to instream analyses. In particular, similarities included more positive than negative responses at intermediate-shade levels, more negative responses in the low-shade level than the intermediate-shade treatment, and a similar pattern of more complex responses collectively for torrent salamanders with changes in growth being more negative at the low-shade than either of the no- and intermediate-shade levels (Fig. 15, Appendix 2). We caution that interpretation of the responses from enclosures should consider, at least in part, a possible confounding effect of the enclosures themselves. For example, the warmest (7-day maximum) post-treatment temperatures occurred in the low-shade treatment exclosure. However, the fact that the intermediate- and no-shade treatment exclosures had essentially the same temperature response pattern suggests that a confounding effect of enclosures, which would be expected to increase in magnitude with the severity of the treatment, cannot alone provide an adequate explanation. Although a negative enclosure effect was likely, particularly when animals were first introduced, we assumed that the effects of shade manipulations would override an enclosure effect and become more detectable particularly as the time that an individual was in an enclosure increased, i.e., the treatment effect was additive to the exclosure effect. As noted later in this discussion, we believe that examination of differential groundwater contributions among streams would be the best next avenue for identifying an adequate explanation for these patterns.

Complex responses, in our case, those patterns that neither the light:nutrient or energetic hypotheses could readily explain, merit additional attention. Our experiment was not designed to identify the basis of variation in such complex responses, but several sources of variation exist beyond potential methods-based confounding effects (Mallory and Richardson 2005, Kroll 2009, Leuthold et al. 2012, Richardson and Béraud 2014). These include: 1) management history; 2) abiotic and 3) biotic variation across the landscape (e.g., species-specific traits and competitive and predator-prey interactions); 4) latitudinal or 5) longitudinal gradients; and 6) differences in detectability. We briefly discuss each.

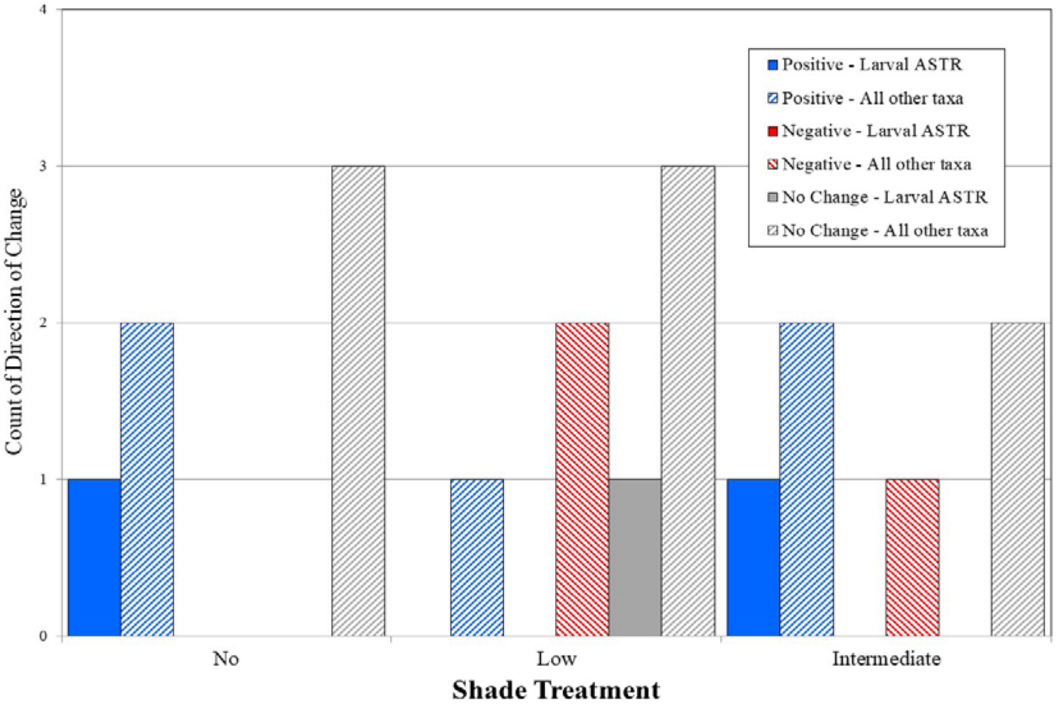


Figure 15. Amphibian responses based on enclosure data (growth) across shade manipulation categories. Count of amphibian taxa or life stage responses based on the total number of taxa or life stages on which body condition were assessed (n = 6). Larval tailed frogs (ASTR), largely primary consumers, are separated from all other taxa or life stages, which represent higher trophic levels. Positive and negatives responses are exclusively those that were either significant or fell outside the 90% CLs for the percentage change in the ES; no change responses represent the balance of responses.

The streams we selected were uniform in a general management context, that is, all streams ran through forest stands resulting from silvicultural practices in use about 50 years ago, but site-specific variation existed in management regimes that may have a panoply of effects. A basic aspect of this variation could arise from differences in management regimes between state and private forest landowners, though even different private landowners may implement different management regimes. Characteristics, such as rotation ages, harvest unit sizes, and use of chemicals such as herbicides or fertilizers, may vary among landowners. Further, variation induced by management can interact with natural processes contributing to the pre-treatment differences we observed; not only in SAA metrics (Kroll 2009), but also in other response variables (biofilm and some macroinvertebrate classes) exhibiting significant differences (also see Richardson and Béraud 2014). In this study, all the sites in the Olympic block were on DNR lands; all but one remaining site was on private lands. However, that asymmetry in ownership is unlikely to have contributed to the complexities we found because we randomly assigned different shade treatments across ownership categories. We did not evaluate alternative landowner-specific differences in management that may have contributed to site-specific differences in response, but we believe that few, if any, such differences exist.

Inherent differences among streams within blocks may reflect abiotic differences in the landscape. In this study, we expressly selected sites to have a south-facing aspect (range: 96º-238º), and generally similar lithologies, and low-elevation and low-gradient ranges. Examining variation in elevation, aspect, and gradient across treatments (Figs. 16A-C; see also the Methods section), that variation seems unlikely to explain complexity in treatment response. However, our selection criteria did not address aspects of either hydrology or lithology other than the fact that experimental streams were perennial and underlain by consolidated substrates (hard rock substrates producing large clasts). In particular, the relative contribution of groundwater, which has the potential to strongly influence stream temperature (and may have a number of secondary effects) and often exhibits high local variation, was not addressed. Lithological categories can also modulate groundwater patterns.

Differences among streams within blocks that may reflect variation in biotic (riparian vegetation, stream subsidies from the terrestrial habitat, SAA densities) factors, nutrient regimes or both, some of which may reflect management legacy. For example, pre-treatment variation may have influenced post-treatment responses of amphibian taxa to shade reductions and changes in pre-treatment differences in ES following shade reductions could also be indicative of a treatment effect. Further, the Olympic blocks lacked a species of *Dicamptodon*, which can express top-down control by reducing the standing crop of macroinvertebrates under conditions where grazers are not armored (Parker 1992, Atlas and Palen 2014). Variability across the Olympic blocks among macroinvertebrates did not make them particularly stand out relative to the remainder of study units, but as our drift sampling might only capture some armored macroinvertebrates, such as cased caddisflies in their early instars, so we cannot discern whether variability in stream response reflects asymmetries in abundance of armored versus unarmored macroinvertebrates.

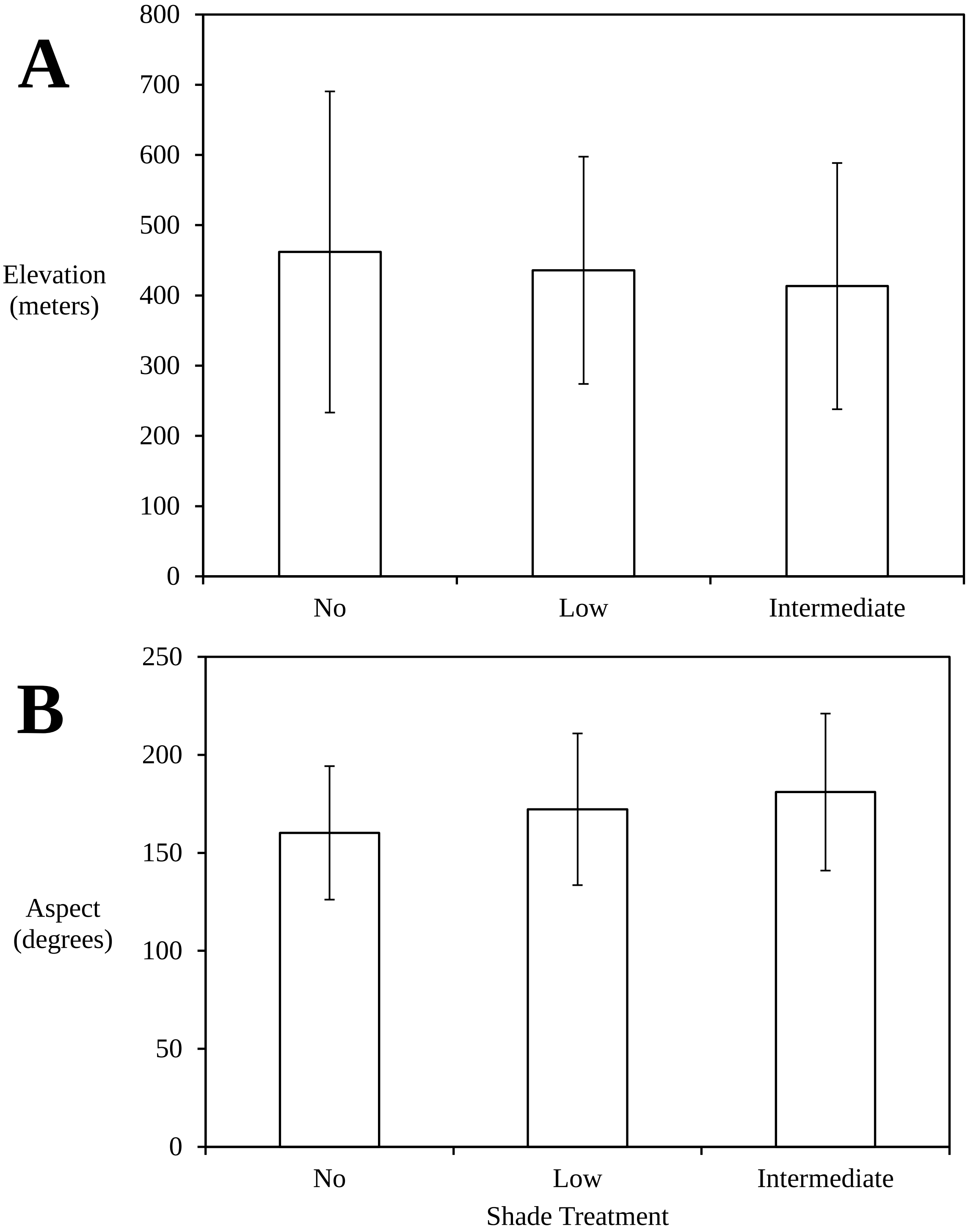


Figure 16. Site variation in elevation (A) and aspect (B) among treatments. Mean and standard deviation of respective values are shown. Treatment descriptors follow labels described in methods.

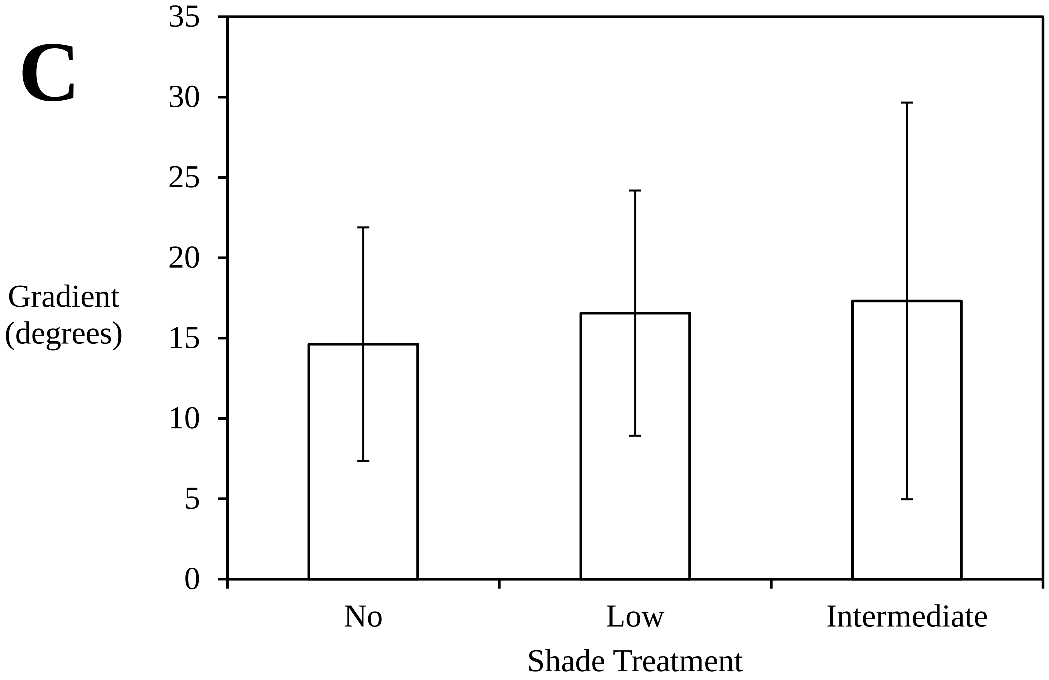


Figure 16. (continued) Site variation in gradient (C) among treatments. Mean and standard deviation of values are shown. Treatment descriptors follow labels described in methods.

Shade reductions either did not change the direction (positive or negative) of pre-treatment differences (two of 15 comparisons; five species × three shade-levels), resulted in a switch in shade-levels that were statistically different from pre- to post-treatment periods (2 of 15, e.g. no- vs. low-shade pre-treatment to low- vs. intermediate-shade post-treatment), or eliminated the pre-treatment differences (i.e., no post-treatment significant differences; 10 of 15 comparisons). These patterns suggest that most (12 of 15) of these pre-treatment differences (i.e., those that were changed direction or eliminated post-treatment) were influenced by vegetation cover. These types of changes occurred most often for pre-treatment differences in amphibian body condition (8 of 12) and counts of giant salamanders (5 of 12) and tailed frogs (4 of 12). For those differences that changed, reaches with the largest ES estimate maintained that rank, whereas the other two switched their rank order. One should not infer from these statements that in spite of reporting mean shade density levels above 92% pre-treatment that many sites were already in the range of treatment targets. We lack a basis for identifying other pre-treatment differences among sites that may have contributed to asymmetric treatment responses.

Differences in latitude or longitude may also play a role in selected pre-treatment differences. In general, populations at higher latitudes are adapted to shorter growing seasons and cooler temperatures, which influence rates of growth and development. Liess et al. (2013) found that pool frog (*Rana temporaria*) tadpoles from the Arctic grew faster than conspecifics from the Boreal region (5° latitude difference), where temperatures and food quality were greater. Our sites differed in latitude by only 1.7°; nonetheless, a gradient may exist in local adaptation for some species that could account for selected pre-treatment differences. Potential latitude-based life history differences could also have influenced post-treatment responses, as observed by Liess et al. (2013) and reflected by tailed frog larvae in this study in the no-shade treatment where both water temperature and biofilm increased. However, similar to asymmetry in ownership, latitude- or longitude-based life history differences are unlikely to have contributed to the complex within-treatment responses we found because we randomly assigned different shade treatments across different latitudinally and longitudinally blocked regions.

We found some large differences in estimates of detection probability (p) for some amphibian species in the low- and intermediate-shade treatment reaches in both pre- and post-treatment periods. However, p was only weakly related to both species abundance (r = -0.01–0.20; *contra* McCarthy et al. 2013), or the time between the initial search of a plot and subsequent resampling (r = -0.03–0.29). Differences in p also illustrate the effects that site-specific characteristics can have on amphibian studies, underscoring the importance of estimating p for studies addressing SAAs to refine interpretation of results (Bailey et al. 2004, Kroll 2009, Petitot et al. 2014; *contra* Welsh 2011, whose assertions were partly based on preliminary results of this study).

Some patterns were clearly not attributable to treatments. Abundance (based on counts corrected for *p*, Table 6) of all taxa except Olympic torrent salamanders increased from pre- to post-treatment periods in the reference reaches as well as most treatment reaches. Explanations for this pattern include an overall increase in amphibian populations due to conditions for SAAs improving throughout the region during 2006‒2007 (i.e., a year effect), changes in behavioral patterns that increased capture probabilities, differential movement of amphibians into treatment reaches from the area between the treatment and reference reaches, or better sampling conditions during the post-treatment period. Changes in behavioral patterns that increases SAA capture probabilities is unlikely because their behavior is highly stereotyped and behavioral changes would have to be parallel across different SAA genera. Differential movement of amphibians into treatment reaches is unlikely because reference reaches displayed the same pattern. We could not easily rule out better sampling conditions because a major determinant of sampling efficiency, stream discharge, was on average 62% lower in 2006‒2007 (1.75 [0.19] L sec^{-1}) than 2004‒2005 (2.83 [0.59] L sec^{-1}) in the southern Washington and northern Oregon streams we sampled. Yet, mean detection probability, considering the pattern across all species, in those streams differed by only 1% between the two periods (0.93[0.03] vs. 0.92[0.03], respectively), implying that sampling efficiency was similar in both periods. However, consistent with the idea that region-wide environmental conditions were favorable for SAAs during 2006 and 2007 is the large increase in 2007 in Coastal giant salamander densities reported from paired third-order watersheds in southwestern Oregon (Leuthold et al. 2012). Some unknown year effect provides the most plausible explanation for many pre- to post-treatment differences.

Species-Specific Patterns

Tailed Frogs (Larvae only)

Shade treatments did not appear to influence tailed frog ES estimates of abundance enough to override other sources of variation and produce statistically significant contrasts. However, abundance ESs for tailed frogs in the intermediate treatment increased 1,263% pre- to post-treatment. This increase is likely biologically meaningful. Tailed frogs are a relatively long-lived anuran with a relatively low reproductive rate and it may take several years for populations to respond to shade manipulations as long as the manipulations did not result in acute direct mortalities or a large decline (e.g., from extreme water temperatures).

Body condition estimates for tailed frog larvae showed the greatest response to shade manipulations of the variables measured, increasing significantly in the low-shade reaches as generally predicted (Appendix 2). Presumably, algal abundance in those reaches was great enough to more than compensate for greater structural carbon and lower digestibility, i.e., tailed frog larvae may have been able to ingest more algae per unit time in those reaches than in more shaded reaches. Alternatively, differing light levels favor different species and structural forms of diatoms (Hill et al. 2011b, Lange et al. 2011); tailed frog larvae may favor or more easily assimilate diatoms that increase in high light environments. Kiffney et al. (2004) reported greater response (growth rates and survival) of tailed frog larvae to full sun than moderate levels and found a strong linear correlation ($r \geq 0.7$) between those two metrics and chlorophyll *a* concentrations in biofilm, which in turn was a function of light intensity. However, they did not speculate about the basis of the relationship.

In contrast to body condition, growth rates of larval tailed frogs in in-stream mesocosms in this study increased significantly in the no-shade treatment and also increased substantially in the intermediate-shade reaches from pre- to post-treatment periods (Appendix 2). This finding is inconsistent with the light:nutrient hypothesis. Inconsistencies between these two response metrics, as well as with the results of Kiffney et al. (2004), may be due to a number of factors (e.g., methods, sampling asymmetries, site conditions). It also suggests that measurements that reflect primarily current conditions (growth) and past conditions (energy stores) may be needed to fully evaluate the effects of altering habitat on responses of individuals.

Mean body condition estimates for free-ranging tailed frog metamorphs did not change measurably in the no- and intermediate-shade reaches but increased significantly (520%) in the low-shade reaches, consistent with the light:nutrient hypothesis (Appendix 2). Body condition of metamorphs may have carry over from the larval stage (Chelgren et al. 2006, Davis and Maerz 2009) and perhaps tailed frog metamorphs in the low-shade reaches were able to store and retain more energy than those in the other reaches. This finding could be important in that greater mass and body condition at metamorphic climax results in greater survival, fitness, and physical performance in anurans (Goater 1994, Newman and Dunham 1994, Goater and Vandenbos 1997). In addition, growth rates of tailed frog metamorphs followed the same pattern as body condition estimates for the low-shade treatment, consistent with a carry-over effect. However, this same pattern did occur in the no- and intermediate-shade treatment in spite of having greater growth of larvae. In general, anurans at metamorphic climax cannot feed and the accompanying physiological and morphological changes result in a decline in mass. Thus, we would not expect a change in stream subsidies to have a direct effect on growth rates of metamorphs. Both food levels (biofilm) and temperature showed large increases in the no-shade reaches in the streams, precisely in the reverse direction of body condition estimates (Appendix 2). Though not presented here, temperature profiles for stream reaches had considerable intervals of time (>20 days) during which stream temperatures exceeded 14° C, temperatures rarely selected by first- and second-year larval Coastal tailed frogs in a thermal gradient (de Vlaming and Bury 1970). This may suggest that despite increased biofilm levels, food resources either were poorer in quality, less used, or not adequate to meet increased metabolic demands associated with increased water temperatures; a bioenergetic pattern with parallels in salmonids (Brett et al. 1969, Leach et al. 2012).

Overall, our results for tailed frogs in terms of trends in body condition estimates and growth rates are at least partly consistent with the potential for bottom-up control of tailed frog populations; at worst, they do not clearly support alternatives. However, ES estimates of abundance are consistent with this interpretation only for the intermediate-shade reaches, which suggests that if this interpretation is valid, one or more additional factors complicate the pattern (Appendix 2). Tailed frogs are preyed on by American dippers (*Cinclus mexicanus*; Morrissey and Olenick 2004) both species of giant salamanders sampled in this study (Bury 1968), red-legged frogs (*Rana aurora*; Jones and Raphael 1998), and garter snakes (*Thamnophis* spp.; Karraker 2001); cutthroat trout (*Oncorhynchus clarkii*) are suspected predators also (Daugherty and Sheldon 1982). Increased light levels may increase larval susceptibility to predation (Forbes and Hammill 2013) particularly by diurnal and crepuscular predators like American dippers and nocturnal predators under a full moon and clear skies. However, we cannot evaluate the impact of predation and it is unknown whether any of these predators can actually limit tailed frog populations.

Captures of post-metamorphic tailed frogs were too few to conduct a meaningful analysis and provide reliable inferences about treatment effects. Sampling mature adults that spent their entire life in a single treatment reach would likely reveal the true effects of shade reductions on the species (Mallory and Richardson 2005). However, to accomplish this our study would have had to continue for several more years and efficiently target adults for sampling with pitfall traps

(MacCracken 2005, Matsuda and Richardson 2005), night spotlighting (Diller 2011, pers. comm.), or some other method.

Mallory and Richardson (2005) conducted a study with tailed frog larvae in British Columbia (about 1.7-3.4° north of our sites) with an experimental design similar to ours. They examined the effects of two light levels (full sun and complete shade), nutrient additions (N and P), and six levels of tailed frog density in three sizes of in-stream enclosures; sampling chlorophyll *a* concentration, biofilm accrual, and tadpole growth rates. Estimates for all response variables were greater under the full sun treatment. They also reported density-dependent effects on tadpole growth rates at 14−29 tadpoles m^{-2}. We maintained a density of 23−35 tadpoles m^{-2} in our enclosures, which may have contributed to limiting growth rates, based on the negative values we obtained. Mallory and Richardson (2005) also reported an effect of the enclosures themselves on the response variables, which was also related to enclosure size. An enclosure effect may contribute to some of the patterns observed in this study as maximum water temperatures (both modes of measurement considered) in exclosures were warmer than stream temperatures in over half (nine of 16) the contrasts (Table 2), and biofilm accrual was also consistently less in exclosures than in streams (Appendix 2). However, absolute temperature differences between exclosures and streams were small to moderate and were inconsistent with expectations from treatments. Regarding the magnitude of temperature differences, only two differences in mean temperature maxima exceeded 1.5ºC (those were the mean maximum at the intermediate-shade level post-treatment and the same metric in the references pre-treatment, respectively, 3ºC and 2ºC; Table 2). Regarding inconsistency with expectations from treatments, the most and least severe treatments (no and intermediate shade) each had patterns opposite expectations post-treatment: exclosure maxima averaged 1-1.5ºC colder than streams in the no-shade treatment, whereas exclosure maxima averaged 1-3ºC warmer than streams in the intermediate-shade treatment. Hence, while some data suggest that conditions in enclosures differed from the streams, perhaps reflecting reduced water flow (J.G. MacCracken, pers. observ.), prominent inconsistencies in expectations from treatments strongly suggest that site- and perhaps year-specific influences on temperature are more important in driving the aforementioned patterns. This reinforces our earlier suggestion that hydrology, especially the potentially modulating influence of cool groundwater, clearly deserves attention since modest changes in temperature may alter the benefits of canopy reduction treatments. We remain cognizant that, as Mallory and Richardson (2005) point out, enclosure effects could confound comparisons among studies that use different enclosure designs. Our enclosure design was constant, but year-to-year changes in manufacturer's specifications and availability of different models of plastic boxes used for enclosures resulted in small variation (< 9 cm^{-2}, 35%) in enclosure size. Given the magnitude and pattern of temperature variation, the latter variation was unlikely to contribute significantly to temperature patterns.

Giant Salamanders

The abundance of giant salamanders increased significantly in the no-shade reaches and substantially in the intermediate-shade reaches following shade reductions, treatments also had a substantial effect on body condition in the intermediate reaches, but growth rates declined at all treatment levels but substantially less so (35%) in the low-shade reaches (Appendix 2). In general, the response of giant salamanders to the opening of forest canopies due to timber harvest has been somewhat mixed (Murphy and Hall 1981, Hawkins et al. 1983, Bisson et al. 1996, Steele et al. 2003, Kiffney and Roni 2007) and can vary by species. Coastal giant salamanders have either responded positively to canopy reductions (Murphy and Hall 1981, Adams and Bury 2002, Steele et al. 2003, Kiffney and Roni 2007) or exhibited little change (Hawkins et al. 1993), probably due to site-specific effects. On the other hand, the two studies that differentiated Cope's giant salamanders found little effect of canopy openings on that species (Bisson et al. 1996, Steele et al. 2003). Because we did not partition giant salamander response between the two species, interpretation of our results may be compromised. The increased counts in the no-shade reaches suggests that our study sites may have been dominated by Coastal giant salamanders and supports the findings of other studies of this species if that is true. Steele et al. (2003) surveyed streams within our Texas Creek and Beacon Rock blocks in the Cascade Range and captured nearly equal numbers of the two species (221 Cope's, 212 Coastal) over two years of sampling, but in the specific streams that had both species present Coastal giants outnumbered Cope's by 10-20%. If the two species respond differently and their site-specific relative abundances also differ, this could explain the complex responses in giant salamander abundance and their other metrics.

Cascade Torrent Salamanders

Cascade torrent salamanders showed some of the largest responses to shade reductions of any species. Abundance declined (50%) at the no-shade level (≤90% CL), but increased (50%) at the intermediate-shade level. The significant interaction term suggests this response is a result of treatment (Appendix 2). Growth and body condition, however, had more complex patterns. Body condition of Cascade torrent salamander decreased (67%) in the low shade treatment (*P* ≤0.1-0.01), but was positive but neither significant nor substantial at either the intermediate- and no-shade levels. The significant interaction provides basis for assuming this change was primarily a result of treatment. Growth increased significant (P ≤0.1-0.01) at the intermediate-shade level, and though negative at the low-shade level, this response was neither significant nor substantial. A non-significant interaction term may indicate that factors other than treatment contributed to the intermediate-shade growth response. Steele et al. (2002) sampled streams across a forest age gradient (0−94 years) in or near our Texas Creek and Beacon Rock blocks and had the lowest captures in streams in forests 0–24 years of age and the greatest captures in streams in forests 25–60 years old. They noted the relationship between captures, forest stand characteristics associated with developmental stages, and trends in light penetration levels. The results of this study and Steele et al. (2002) are consistent with the predictions of the light:nutrient hypothesis in that abundance, body condition, and growth rates peaked at some intermediary light level. Furthermore, these findings suggest a bottom-up response for these west Cascade Range stream ecosystems. No predators of larval or post-metamorphic torrent salamanders have been documented (Petranka 1998) and torrent salamanders placed in experimental test aquaria with giant salamanders were captured, but almost invariably quickly expelled (Rundio and Olson 2001).

In contrast to our results, Russell et al. (2005) did not find a relationship between Cascade torrent salamander abundance or occupancy and stand age at the stream reach (10 m) scale. However, those authors did report a positive relationship with forest age (0–90 years) at the landscape scale (2.58 km^2), a result at least partly consistent with that of Steele et al. (2003). However, neither study nor others published before 2009 estimated detection probabilities.

Columbia Torrent Salamanders

MacCracken (2002) found that Columbia torrent salamanders had greater body condition, but lower densities in streams where the overhead tree canopy had been reduced, retaining 50-70% in the Coast Range of southwest Washington. In contrast, the only statistically significant response of this species to shade reductions in our study was an increase in growth rates for the no-shade reaches (Appendix 2); although, a substantial but non-significant reduction in numbers occurred in the intermediate-shade treatment. We detected no statistically significant trends in body condition estimates for this species in our study, but this comparison may be confounded because MacCracken (2002) used the residuals body condition index which can be unreliable if a number of conditions are not met (Green 2001). However, ranked ES estimates of SMI increased (40–225%) in our study across all shade levels, with the greatest increase in the intermediate-shade reaches, which may be meaningful as it exceeded the upper 90% CL (Appendix 2). Though this is consistent with MacCracken (2002) and the light:nutrient hypothesis as well as a bottom-up response, the non-significant interaction term for our data indicates that site-specific factors likely confounded treatment effects. In contrast, Russell et al. (2004) did not find a relationship between Columbia torrent salamander abundance or occupancy and forest age or overhead cover in the Coast Range of Oregon, but his estimates were not corrected for imperfect detectability.

Olympic Torrent Salamanders

Olympic torrent salamanders declined in abundance in the low-shade reaches (833%) following shade reductions (*P* ≤0.1-0.01), but increased in the intermediate-shade treatment (*P* ≤0.1-0.01; Appendix 2). Growth rates significantly increased (240%) in the no-shade reaches and substantially increased (433%) in the intermediate-shade reaches (>90% CL), but the non-significant interaction term indicates that site-specific factors likely confounded treatment effects (Appendix 2). These trends appear consistent with a bottom-up effect.

Body Condition and Growth Rates

MacCracken and Stebbings (2012) suggested that changes in habitat that affect amphibian populations may become evident through indices of body condition before changes in demographic parameters can be detected. For relatively long-lived species with moderate reproductive rates like PNW SAAs, we would expect energy stores to fluctuate on a finer temporal scale than population numbers, barring a large mortality event or mass movements. In this study, we found more statistically significant period × treatment interactions for count data (n = 3) and body condition (n = 2) than growth rate (n = 1) estimates. However, the addition of relatively large ES changes that may reflect biologically important patterns increased by two in both the count and body condition tally, but the growth rate tally by five. Factors unrelated to habitat change can affect population size, e.g., predation and movements, but energy stores and growth are largely a function of habitat quality. However, body condition may not always reflect habitat quality, depending on energy demands, food availability, life history stage, predation pressure, population densities, and other extrinsic factors. For example, Schultner et al. (2013) found that black-legged kittiwakes (*Rissa tridactyla*) did not maximize energy stores when given supplemental food during chick-rearing periods, presumably to reduce the energetic costs of frequent and extended foraging trips. Animals may also limit energy storage when long-distance movements are undertaken to reduce movement costs or when predation pressure is high in order to enhance maneuverability if attacked. As Schultner et al. (2013:53) noted, "…equating large energy stores with prime environmental conditions may oversimplify the natural situation." This could explain why body condition estimates for amphibians are sometimes equivocal, counterintuitive, and inconsistent with other metrics.

Growth rates as estimated in this study (change in mass) and others (Kiffney et al. 2004, Mallory and Richardson 2005) would fluctuate on an even finer temporal scale and could reflect energy stores more than actual growth. Relative changes in measures of total length, limb length, or head size may reflect changes in growth rates better than changes in mass.

Assuming that both body condition and growth rates largely reflect the assimilation of food resources, our results suggest that tailed frogs and all three torrent salamander species were enhanced in at least one of the shade treatments (Appendix 2). Little is known about the foods of torrent salamanders (Petranka 1998) and limited information available is for *R. cascadae* (Cudmore and Bury 2014), *R. variegatus* (Bury 1970) and *R. kezeri* (O'Donnell and Richart 2012).

These studies found a wide variety of food items in stomachs, suggesting the species are opportunistic. Linking greater body condition and growth rates of torrent salamanders in this study to the response of macroinvertebrates to shade reductions is hampered by current understanding of their dependence on autochthonous versus allochthonous sources. The drift of gathering collectors (which included Diptera - a major item found in Columbia torrent salamander stomachs [O'Donnell and Richart 2012]), increased significantly in the low-shade reaches, but we did not identify a torrent salamander response at that level (Appendix 2).

Water Temperatures

Numerous studies in the PNW have reported increases in water temperatures in small streams with reduced shading (Brown 1969, Johnson 2004, Danehy et al. 2005, Gomi et al. 2006). Steele et al. (2003) suggested headwater streams were less susceptible to temperature increases associated with reduced shade due to groundwater inputs. Our results may reflect some consistency with that conclusion. Steele et al. (2003) conducted their study in relatively high elevation streams in and near our Beacon Rock and Texas Creek blocks in the western Cascade Range (Fig. 3) and some of our streams in those blocks had the least amount of change in water temperature following shade reductions (1.0 vs. 1.5-2.0 ^{o} C). Inconsistencies point to the potential magnitude of site-specific effects as emphasized by Richardson and Béraud (2014).

Stream temperature increases have been implicated in the low SAA numbers in managed forests (Hawkins et al. 1988, Welsh and Lind 1996, Wahbe and Bunnell 2003, Olson et al. 2007). However, many studies have made only one-time, spot readings of stream temperature when sampling amphibians. This can be misleading because readings may be biased (up or down) relative to the temporal profile (for example, they cannot account for intervals of potential exposure to elevated temperatures) and spot measurements may miss cold-water refugia (Bilby

1984, Danehy et al. 2005, Groom et al. 2011). The laboratory derived critical thermal maxima for the amphibian species studied here are about 10-15° C greater than maximum temperatures recorded in many field studies (Brattstrom 1963, Bury 2008), and temperatures actually selected may be much lower (de Vlaming and Bury 1970). Pollett et al. (2010) found that occupancy of headwater streams by Cascade torrent salamanders was reduced when stream temperature was $\geq$14° C for 35 consecutive hours. The seasonal maximum and maximum seven-day moving average of most of our study reaches equaled or exceeded 14° C prior to shade reductions and one species of *Rhyacotriton* as well as tailed frogs occupied all reaches. However, our water temperature estimates may not represent the entire 50-m reach as the thermistors were placed at the bottom of each reach, and may overestimate a reach-long average, particularly where cool ground water inputs may have contributed. Localized patterns of ground water inputs within a reach may also influence the specific temperatures that individual amphibians experience.

The relationship between changes in levels of shading and changes in stream temperature is remarkably consistent among recent studies. We recorded an average increase in seasonal maxima of 4.0° C following a 100% reduction in shade when compared to reference reaches. Johnson (2004) also reported a 4.0° C difference in temperature between streams with 100% artificial shading and those with no shading. In addition, Groom et al. (2011) found that the best model relating shade and stream temperature predicted a 2.0° C change at 50% shading. A simple ordinary least squares regression of change in seasonal maximum temperature from pre- to post-treatment (y, ° C) as a function of percent change in shade (x, quantified as a fraction) over all the reaches sampled in this study resulted in the following relationship: $y = -0.57 + 4.14(x)$, $r^2 = 0.85$.

Lastly, identification of stream warming despite the relatively small scale (50 m) of our reaches is noteworthy. Considering exclusively flow volume (all else being equal), sensitivity to stream warming is greatest at low volumes. Further, low volumes generally characterize summer low flows in the mostly 1st- and 2nd-order (headwater) streams we monitored. However, summer low flows may be non-intuitively cooler at low volumes where cooler groundwater contributes a greater proportion of the flow (Tague et al. 2007). Though we identified stream warming at a relatively small scale, we found substantial temperature variability. Though its basis is unclear, we suspect that the differential contribution of groundwater during summer low flows, a feature we did not measure, may be important. As a result, we feel that examination of groundwater may be an important area in which opportunity to limit measurement variability may exist in future work.

Management Implications

Most studies that evaluated the potential effects of timber harvesting on headwater streams are limited in spatial and temporal scope, and few incorporate pre-harvest sampling. Thus, their scope of inference is limited, which often constrains their application when developing management plans and regulations, assessing species status, and for other purposes. In this study, we included pre-treatment sampling using a BACI design, kept our scope of inference broad by selecting sites from a large geographic area and a range of treatments that were replicated eight or nine times, and evaluated responses of SAAs from three stream-associated genera that occur in the PNW. In addition, we controlled for aspect, gradient, and parent lithology, rarely attempted in manipulative ecological experiments, yet site and yearly differences appeared to have a greater effect on response variable estimates than shade reductions in 29 of 42 (69%) comparisons. Many of our results (e.g., biofilm, CPOM, and shredders ESs) are consistent with the findings of a meta-analysis of replicated studies on the effects of riparian forest harvesting on key stream biological and chemical components from studies world-wide (Richardson and Béraud 2014); emphasizing the role of site-specific responses and the need for context-specific stream protection measures.

Several constraints limit conducting geographically broad manipulative experiments. Other than cost and logistics, the practice of frequentist statistical null hypothesis testing and the peer-refereed publication process are also influential. It is not uncommon for ecologists to narrowly define an experimental unit and the study area in hopes of reducing background variation and increasing the likelihood of demonstrating a statistically significant effect, which is often perceived as a requirement for publication (Russell et al. 2012). Much has been written on the use and misuse of statistics in ecology (Johnson 1999, 2002, Anderson et al. 2000) and alternatives have been identified (Dixon and Ellison 1996, De’ath and Fabricus 2000, Burnham and Anderson 2002), but null hypothesis testing remains the dominant approach (Low-Décarie et al. 2014). Low-Décarie et al. (2014) found that as ecological studies have become more complex, their explanatory power has declined and suggest that overemphasis on null hypothesis testing is partly to blame along with publication bias, i.e., lack of statistical significance limits publication. Because forestry practices are regulated over broad geographies (e.g., by states or uniformly on federal lands across the PNW), the most relevant studies will also have to have broad application. As noted in the Introduction, studies of SAAs in the PNW are variable, likely due to a combination of the narrow focus of each and regional, local, and site-specific variation in physical and abiotic conditions (see Richardson and Béraud 2014).

A number of previous studies have also confounded the primary effects of timber harvest on headwater streams – reduced shade and increased fine sediment inputs – by not controlling for either and by sampling at sites where both variables can vary widely. We intentionally avoided manipulating vegetation with ground-based harvesting and skidding equipment by applying shade reduction treatments by hand and not removing felled trees to minimize increases of sediment input to study reaches and specifically examined responses to four levels of shade retention, attempting to cover the entire gradient in light levels. One of the purposes of that approach is to determine if thresholds in community responses to irradiance could be detected that would apply to riparian area management guidelines.

Over the last few decades, fixed-width buffers with limited or no manipulation have become the standard prescription to protect aquatic resources during forestry operations (Richardson et al. 2012). This approach has come under increasing scrutiny as it can create unnatural linear patterns of forest landscape structure, may result in a decline in the complexity and diversity of riparian stands and networks, a potential decline in resiliency, and a loss of aquatic community structure and function that is associated with various types and intensities of disturbance (Kreutzweiser et al. 2012, Sibley et al. 2012). In addition, riparian forests that make up these regulatory buffers were planted at high stocking levels 40-50 years ago and may have high tree densities and closed canopies that maximize shade but limit productivity and are not reflective of old-forest conditions. One proposed solution is to manage riparian forests in ways that emulate natural disturbances, acknowledging that a cautious, site-specific experiment-by-management approach is required (Sibley et al. 2012, Richardson and Béraud 2014). Two of the primary natural disturbance regimes of riparian forests in the PNW are windthrow and channel realignment that create relatively small to moderate gaps in the forest canopy (Naiman et al. 1998). The results of our study provide insights into the effects of disturbances that create similar-sized forest canopy gaps (≈ 0.1 ha) and potential guidance for gap management.

In areas of intensive forest management in the PNW, headwater riparian stands are often dominated by red alder (*Alnus rubra*) (MacCracken 2002, Wipfli and Musselwhite 2004), but can also be composed entirely of conifers or mixed hardwood-conifer stands depending on past harvest practices and site conditions. Regardless of stand composition, dense shading limits stream productivity, and to optimize stream productivity those stands may need thinning or have gaps created in them. For example, in the Extensive Riparian Status and Trends Program – Stream Temperature Study, 75% of non-fish-bearing (Type N) streams exceeded 75% cover (W. Ehinger, pers. comm.). Even in riparian areas dominated by hardwoods, decreases in canopy cover can result in positive responses in light-limited ecosystems, both aquatic and terrestrial (MacCracken 2002). Our results indicated that the productivity of streams with dense canopy cover (>90%) would be positively influenced by creating openings in the canopy at a scale and shading level that corresponds to the intermediate-shade level tested in this study. While some evidence of benefits also appeared at the low-shade level, results were more mixed. We emphasize that the intermediate-shade treatment level was more often associated with improvements in stream productivity metrics and positive amphibian responses than the low-shade treatment level with the added benefit of smaller water temperature increases (mean ES seven-day moving average <1.0^{o} C as compared with 2.5^{o} C). As such, among the treatments we applied, the intermediate shade level best balanced the trade-off between the benefits of autochthonous productivity and any decrease in thermal suitability. What remains unclear is how much site-specific conditions, such as local groundwater inputs, have the ability to alter smaller water temperature increases, and what biological repercussions may result from those small increases.

Stream reaches associated with open canopy forests typically have greater variance in stream temperatures (Groom et al. 2011, Bisson et al. 2013, Hossack et al. 2013, Kibler et al. 2013, this study). Hossack et al. (2013) found that Rocky Mountain tailed frog (*A. montanus)* larvae from streams with open canopies had greater survival rates when exposed to increased water temperatures (10−18^{o} C), which may reflect tadpole acclimation to warm temperatures from high-variance streams. Coastal tailed frogs from high-variance streams in managed forests may have benefited from such potential adaptation, and may be one reason the species is still widespread in managed forest streams (see Kroll et al. 2009). As Hossack et al. (2013) noted, tadpoles from high-variance streams might be more likely to survive increased water temperatures due to a warming climate.

The pulse of energy to streams due to canopy reductions will be relatively short-lived; particularly at greater shade retention levels as remaining vegetation will re-establish shading levels essentially equivalent to closed canopy within two to 10 years (Howard and Newton 1984, Newton et al. 1993, MacCracken 2002, Popescu et al. 2012, Schuett-Hames et al. 2012). Nonetheless, canopy openings could provide two or more annual cohorts of SAAs with high quality habitat in terms of food resources that could increase their lifetime fitness. These forest canopy dynamics may result in a lagged response with adults of SAA populations peaking up to a decade (see generation time estimates for tailed frogs [Hayes and Quinn 2015], giant salamanders [Nussbaum and Clothier 1973], and torrent salamanders [Nussbaum and Tait 1977]) or so after complete canopy closure (e.g., Steele et al. 2002, see also Findlay and Bourdages 2000 and Lövenhaft et al. 2004 for lagged responses by herptiles to road construction and urban development, respectively). Periodic reductions in shade over headwater channels on the time and spatial scale of commercial forest rotations in the PNW can increase short-term stream productivity with minimal on-site negative impacts, as well as some potential positive responses, given current regulations for private and state lands, and also benefit downstream reaches (Bisson and Bilby 1998).

Our experiment addressed non-fish-bearing (headwater) streams. Western Washington headwater stream buffer prescriptions rely on a combination of continuous buffers and patch buffers around specific stream features. At least 50% of the length of a perennial headwater stream receives a 15-m wide unmanaged buffer on both sides of the channel starting at the junction with the fish-bearing segment. In addition, all sensitive sites (seeps, springs, stream origins, and tributary junctions) receive a ≥ 0.07 ha patch buffer, depending on the size and type of sensitive site. The scale of our experimental reaches (≈ 0.1 ha) is similar to that of the patch buffers provided on sensitive sites and our results, particularly for the greater shade retention levels are likely most applicable to changes that would occur in patch buffers due to changes in vegetation cover. In addition, buffers may be required on > 50% of the channel length if buffers of sensitive sites, areas of unstable slopes, and the junction with the fish-bearing stream encompass more than the 50% length.

Marketable trees will not be retained in non-buffered reaches of headwater streams in western Washington; however, a 9-m streamside equipment exclusion zone is required on both sides, and should maintain the shrub layer and associated shading that could range from 0−100% depending on site conditions. For example, in the recently completed Westside Type N BCIF Study, the mean percent understory plant cover obscuring the channel went from 18−41% within five years post-treatment (Schuett-Hames et al. 2012). Openings created upstream of fully shaded buffered areas could provide salamanders residing in the stream within those buffered reaches with increased macroinvertebrate prey via drift. However, those openings may do little for larval tailed frogs residing in the buffered reaches, as light penetration and biofilm mass may remain largely unchanged.

Application of our results at the watershed level should be undertaken with caution given the increases in water temperatures over a relatively short distance (50 m) at the two lower shade levels and the potential for cumulative impacts. In particular, if longer total segments of streams, even at shade levels we describe as intermediate, received increased isolation, or if downstream reaches were insufficiently shaded and lacked groundwater input or subsurface flow to counter the warming influence on water temperature, the negative effects of warming may overwhelm benefits accrued from increased primary productivity.

Overall, our results indicate that different species (and life stages of SAAs) respond differently and in complex patterns to changes in habitats resulting from reduced vegetation cover depending on their trophic position in either algal- or detrital-based food webs, and perhaps their physiological tolerances to increased temperature. For specific shade level, ecoregion, and stream, ecological winners and losers may exist. Under most regulatory buffering requirements, as well as under unmanaged conditions, negative impacts will occur for some species at particular times and places, positive effects will be realized by others, and still others will be unaffected. Specifically in the context of the relatively small spatial scale (i.e., 50 m) of our experiment, our data indicate that the balance of SAAs are more likely to respond positively to the shade levels we define as intermediate (i.e., 77% [3% SE]), and less so at the lower shade levels we examined (No = 40% [4% SE]; and Low = 61% [3% SE]). However, the current patch buffer prescription in headwater (non-fish-bearing) streams in Washington State incorporates a mix of shade levels, the low end of which invariably exceeds the treatment range applied in this study (0% in the clearcut portions of prescription reaches) and the high end of which may approximate levels close to what we had in our reference reaches (>90% in buffered prescription reaches). Moreover, except for patches that involve sensitive site buffers, most buffered portions of this prescription are operationally typically packed (i.e., merged together), so the extremely different shade levels of this prescription are typically distributed across greater spatial scales than in our experiment. Precisely how this mix of shading affects amphibian response at a basin scale is one of the foci of the Hardrock Study, but how amphibian responses to intermediate shading at small spatial scales can inform the current prescription is less clear. However, our study does suggest that opportunity may exist to explore amphibian response to the intermediate shade-level range for the buffered portion of the prescription, if positive or null responses can be maintained in the context of either the full prescription or alternative arrangements. Such responses will require an understanding of the conditions most prominent in affecting to site-specific variability among the amphibian responses in this study; though uncertain, differential contributions of groundwater are a prominent suspect that merits investigation. Situations that result in positive and null effects define the scope of possible management alternatives (Guthery et al. 2001) and those “treatments” need exploration under an adaptive management framework.

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Literature Cited

Adams, M.J., and R.B. Bury. 2002. The endemic headwater stream amphibians of the American Northwest: associations with environmental gradients in a large forested preserve. Global Ecology and Biogeography 11:169-178.

Anderson, D.R., K.P. Burnham, and W.L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Atlas, W.I., and W.J. Palen. 2014. Prey vulnerability limits top-down control and alters reciprocal feedbacks in a subsidized model food web. PLOS 9: e85830. doi:10.1371/journal.pone.0085830

Atwood, T., and J.S. Richardson. 2012. Trophic interactions between insects and stream-associated amphibians in steep, cobble-bottom streams of the Pacific Coast of North America. Insects 3:432-441.

Bailey, L.L., T.R. Simons, and K.H. Pollock. 2004. Estimating site occupancy and species detection probability parameters for terrestrial salamanders. Ecological Applications 14:416-432.

Bailey, R.G., P.E. Avers, T. King, and W.H. McNab eds. 1994. Ecoregions and subregions of the United States (map). USDA, Forest Service, Washington, DC.

Baxter, C.V., K.D. Fausch, and W.C. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. Freshwater Biology 50:201-220.

Bilby, R.E., and P.A. Bisson. 1987. Emigration and production of hatchery coho salmon (*Oncorhynchus kisutch*) stocked in streams draining an old-growth and clear-cut watershed. Canadian Journal of Fisheries and Aquatic Sciences 44:1397-1407.

Bilby, R.E., 1984. Characteristics and frequency of cool-water areas in a western Washington stream. Journal of Freshwater Ecology 2:593-602.

Bisson, P.A., and J.R. Sedell. 1984. Salmonid populations in streams in clearcuts vs. old-growth forests in western Washington. Pp. 121-129 *In* W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (editors)., Fish and wildlife relationships in old-growth forests. American Institute Fishery Research Biologists, Juneau, Alaska, USA.

Bisson, P.A., M.G. Raphael, A.D. Foster, and L.L.C. Jones. 1996. Influence of site and landscape features on vertebrate assemblages in small streams. COPE Report 9: 61-72, Oregon State University, Corvallis.

Bisson, P.A., and R.E. Bilby. 1998. Organic matter and trophic dynamics. Pp. 373-398 *In* R.J. Naiman and R.E. Bilby (editors). River ecology and management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, New York, New York, USA.

Bisson, P.A., A.M. Claeson, S.M. Wondzell, A.D. Foster, and A. Steel. 2013. Evaluating headwater stream buffers: lessons learned from watershed-scale experiments in southwest Washington. Pp. 169-188 *In* P. D. Anderson, and K. L. Ronnenberg (editors). Density management for the 21st century: west side story. U.S. Department of Agriculture, Forest

Service, Pacific Northwest Research Station, General Technical Report, PNW-GTR-880. Portland, Oregon, USA.

Bolker, B.M., M.E. Brooks, C.J. Clark, S.W. Geange, J.R. Poulsen, M.H.M. Stevens, and J.S. White. 2008. Generalized liner mixed models: a practical guide for ecology and evolution. Trends in Ecology and Evolution 24:127-135.

Brattstrom, B. H. 1963. A preliminary review of the thermal requirements of amphibians. Ecology 44:238-255.

Brett, J.R., J.E. Shelbourn, and C.T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration size. Journal of the Fisheries Research Board of Canada 26:2363-2394.

Brett, J.R., and T.D.D. Groves. 1979. Physiological energetics. Pp. 279-352 *In* W.S. Hoar, D.J. Randall, and J.R. Brett (editors). Fish Physiology, Volume VIII, Bioenergetics and Growth. Academic Press, New York, New York, USA.

Brown, G.W. 1969. Predicting temperatures of small streams. Water Resources Research **5**: 68–75.

Bull, E.L., and B.E. Carter. 1996. Tailed frogs: distribution, ecology and association with timber harvest in northeastern Oregon. U.S. Department of Agriculture, Forest Service, Research Paper PNW-RP-497.

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

Bury, R.B. 1968. The distribution of *Ascaphus truei* in California. Herpetologica 24:39-46.

Bury, R.B. 1970. Food similarities in the tailed frog, *Ascaphus truei*, and the Olympic salamander, *Rhyacotriton olympicus*. Copeia 1970:170-171.

Bury, R.B., and P.S. Corn. 1988. Responses of aquatic and streamside amphibians to timber harvest: a review. Pp. 165-181 *In* K.J. Raedeke (editor), Streamside management: Riparian wildlife and forestry interactions. Institute of Forest Resources Contribution No. 59, University of Washington, Seattle, Washington, USA.

Bury, R.B, P.S. Corn, K.B. Aubry, F.F. Gilbert, and L.L.C. Jones. 1991. Aquatic amphibian communities in Oregon. Pp. 353-362 *In* L.F. Ruggiero, K.B. Aubry, and M.H. Huff, (technical coordinators.), Wildlife and vegetation of unmanaged Douglas-fir forests. U.S. Department of Agriculture, Forest Service, General Technical Report, PNW-GTR-285.

Bury, R.B. 2008. Low thermal tolerances of stream amphibians in the Pacific Northwest: Implications for riparian and forest management. Applied Herpetology 5: 63-74.

Cecala, K.K., W.H. Lowe, and J.C. Maerz. 2014. Riparian disturbance restricts in-stream movement of salamanders. Freshwater Biology, 59:2354-2364.

Charnov, E.L. 1976. Optimal foraging, the marginal value theorem. Theoretical Population Biology 9:129-136.

Chelgren, N.D., D.K. Rosenberg, S.S. Heppell, and A.I. Gitelman. 2006. Carryover aquatic effects on survival of metamorphic frogs during pond emigration. Ecological Applications 16:250-261.

Cook, J.G., T.W. Stutzman, C.W. Bowers, K.A. Brenner, and L.L. Irwin. 1995. Spherical densiometers produce biased estimates of forest canopy cover. Wildlife Society Bulletin 23:711-717.

Conover, W.J. and R.L. Iman. 1981. Rank Transformations as a bridge between parametric and nonparametric statistics. The American Statistician 35:124-129.

Corn, P.S., and R.B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management 29:38-57.

Cudmore, W.W., and R.B. Bury. 2014. Resource partitioning in two stream salamanders, *Dicamptodon tenebrosus* and *Rhyacotriton cascadae*, from the Oregon Cascade Mountains. American Midland Naturalist 172(1):191-199.

Cummins, K.W., M.A. Wilzbach, D.M. Gates, J.B. Perry, and W.B. Taliaferro. 1989. Shredders and riparian vegetation. BioScience 39:24-30.

Danehy, R.J., C.G. Colson, K.B. Parrett, and S.D. Duke. 2005. Patterns and sources of thermal heterogeneity in small mountain streams within a forested setting. Forest Ecology and Management 208: 287-302.

Danehy, R.J., R.B. Langshaw, S.D. Duke, and R.E. Bilby. 2011. Drift distance of macroinvertebrates throughout summer in headwater tributaries of the Calapooia River. Fundamental and Applied Limnology/Archiv für Hydrobiologie 178:111-120.

Daugherty, C.H., and A.L. Sheldon. 1982. Age-determination, growth and life history of a Montana Population of the Tailed Frog *(Ascaphus truei).* Herpetologica 38: 461-468.

Davis, A.K., and J.C. Maerz. 2009. Effects of larval density on hematological stress indices in salamanders. Journal of Experimental Zoology Part A: Ecological Genetics and Physiology 311:697-704.

De'ath, G., and K.E. Fabricus. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology 81:3178-3192.

deMaynadier, P. G., and M. L. Hunter. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Reviews 3**:**230–261.

de Vlaming, V.L., and R.B. Bury. 1970. Thermal selection in the tadpoles of the tailed-frog, *Ascaphus truei*. Journal of Herpetology 4:179-189.

Diller, L.V., and R.L. Wallace. 1996. Distribution and habitat of *Rhyacotriton variegatus* in streams on managed, young forests in North Coastal California. Journal of Herpetology 30:184-191.

Diller, L.V., and R.L. Wallace. 1999. Distribution and habitat of *Ascaphus truei* in streams on managed, young forests in North Coastal California. Journal of Herpetology 33:71-70.

Di Stefano, J. 2004. A confidence interval approach to data analysis. Forest Ecology and Management 187:173-183.

Dixon, P., and A.M. Ellison. 1996. Introduction: ecological applications of Bayesian inference. Ecological Applications 6:1034-1035.

Earl, J.E., T.M. Luhring, B.K. Williams and R.D. Semlitsch. 2011. Biomass export of salamanders and anurans from ponds is affected differentially by changes in canopy cover. Freshwater Biology. 56:2473-2482.

Ebel, J.D., A.M. Marcarelli, and A.E. Kohler. 2014. Biofilm nutrient limitation, metabolism, and standing crop responses to experimental application of salmon carcass analog in Idaho streams. Canadian Journal of Fisheries and Aquatic Sciences 71:1796-1804

Elliot, J.M. 1967. Invertebrate drift in a Dartmoore stream. Archeological Hydrobiology 63:202-237.

Elliot, J.M. 2003. A comparative study of the dispersal of 10 species of stream invertebrates. Freshwater Biology 48:1652-1668.

England, L.E., and A.D. Rosemond. 2004. Small reductions in forest cover weaken terrestrial-aquatic linkages in headwater streams. Freshwater Biology 49:721-734.

Feminella, J.W., and C.P. Hawkins. 1995. Interactions between stream herbivores and periphyton: a quantitative analysis of past experiments. Journal of the North American Benthological Society 14:465-509.

Ferguson, H. M. 2000. Larval colonization and recruitment in the Pacific giant salamander (*Dicamptodon tenebrosus*) in British Columbia. Canadian Journal of Zoology 78:1238-1242.

Findlay, C.S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Forbes, C. and E. Hammill. 2013. Fear in the dark? Community-level effects of non-lethal predators change with light regime. Oikos 122:1662-1668.

Forests and Fish Report. 2000. Washington State Department of Natural Resources, Olympia, Washington, USA.

Fretwell, S.D. 1987. Food chain dynamics: the central theory of ecology? Oikos 50:291-301.

Giller, P.S., and N. Sangpradub. 1993. Predatory foraging behavior and activity patterns of larvae of two species of limnephilid cased caddis. Oikos 67:351-357.

Goater, C.P. 1994. Growth and survival of postmetamorphic toads: Interactions among larval history, density, and parasitism. Ecology 75:2264-2274.

Goater, C.P. and Vandenbos. 1997. Effects of larval history and lungworm infection on the growth and survival of juvenile wood frogs (*Rana sylvatica*). Herpetologica 53: 331-338.

Gomi, T., R.D. Moore and A.S. Dhakal. 2006. Headwater stream temperature response to clear-cut harvesting with different riparian treatments, coastal British Columbia, Canada. Water Resources Research 42.

Green, A.J. 2001. Mass/length residuals: Measures of body condition or generators of spurious results? Ecology 82:1473-1483.

Gregory, S.V., G.A. Lamberti, D.C. Erman, K.V. Koski, M.L. Murphy, and J.R. Sedell. 1987. Influence of forest practices on aquatic production. Pp. 233–255 *In* E. Salo and T. Cundy (editors), Streamside management: forestry and fishery interactions. Institute of Forest Resources Contribution No. 57, University of Washington, Seattle, Washington, USA.

Groom, J.D., L. Dent, L.J. Madsen, and J. Fleuret. 2011. Response of western Oregon (USA) stream temperatures to contemporary forest management. Forest Ecology and Management 262:1618-1629.

Guthery, F.S., J.J. Lusk, and M.J. Peterson. 2001. The fall of the null hypothesis: liabilities and opportunities. Journal of Wildlife Management 65:379-384.

Hall. R.O., J.B. Wallace and S.L. Eggert. 2000. Organic matter flow in stream food webs with reduced detrital resource base. Ecology 81:3445-3463.

Hammock, B.G., and W.C. Wetzel. 2013. The relative importance of drift causes for stream insect herbivores across a canopy gradient. Oikos 122:1586-1593.

Hansmann, E.W., and H.K. Phinney. 1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54:194-199.

Hauer, F.R., and G.A. Lamberti. 1996. Methods in stream ecology. Academic Press, San Diego, California, USA.

Hawkins, C.P., M.L. Murphy, and N.H. Anderson. 1982. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade Range streams of Oregon. Ecology 63:1840-1856.

Hawkins, C.P., M.L. Murphy, N.H. Anderson, and M.A. Wilzbach. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences 40:1173-1185.

Hawkins, C.P., L.J. Gottschalk, and S.S. Brown. 1988. Densities and habitat of tailed frog tadpoles in small streams near Mt. St. Helens following the 1980 eruption. Journal of the North American Benthological Society 7: 246-252.

Hayes, M.P., and T. Quinn (editors). 2015. A review and synthesis of literature on tailed frogs (genus *Ascaphus*) with special reference to managed landscapes. Cooperative Monitoring Evaluation and Research Report CMER 01-107. Washington State Forest Practices Adaptive Management Program. Washington Department of Natural Resources, Olympia, Washington, USA.

Hayes, M.P., T. Quinn, D.J. Dugger, T.L. Hicks, M.A. Melchiors, and D.E. Runde. 2006. Dispersion of Coastal Tailed Frog (*Ascaphus truei*): An hypothesis relating to the occurrence of frogs in non-fish-bearing headwater basins to their seasonal movement. Journal of Herpetology 40:531-543.

Hetrick, N.J., M.A. Brusven, W.R. Meehan, and T.C. Bjorn. 1998. Changes in solar input, water temperature, periphyton accumulation, and allochthonous input and storage after canopy removal along two small salmon streams in southeast Alaska. Transactions of the American Fisheries Society 127:859-875.

Hildrew, A.G., C.R. Townsend, and A. Hasham. 1985. The predatory Chironomidae of an iron-rich stream: feeding ecology and food web structure. Ecological Entomology 10:403-413.

Hill, W.R., J.G. Smith and A.J. Stewart. 2010. Light, nutrients and herbivore growth in oligotrophic streams. Ecology 91: 518-527.

Hill, W.R., J. Rinchard, and S. Czesny. 2011a. Light, nutrients and the fatty acid composition of stream periphyton. Freshwater Biology 56:1825-1836.

Hill, W.R., B.J. Roberts, S.N. Francoeur, and S.E. Fanta. 2011b. Resource synergy in stream periphyton communities. Journal of Ecology 99:454-463.

Holtby, L.B., and J.C. Scrivener. 1989. Observed and simulated effects of climatic variability, clear-cut logging, and fishing on the numbers of chum salmon (*Oncorhynchus keta*) and coho salmon (*Oncorhynchus kisutch*) returning to Carnation Creek, British Columbia. Pp. 62-81 *In* C.D. Levings, L.B. Holtby, and M.A. Henderson (editors). Proceedings of the national workshop on the effects of habitat alterations on salmonid stocks. Canadian Special Publication in Fisheries and Aquatic Sciences 105, Ottawa, Ontario, CAN.

Hossack, B.R., W.H. Lowe, M.A.H. Webb, M.J. Talbot, K.M. Kappenman, and P.S. Corn. 2013. Population-level thermal performance of a cold-water ectotherm is linked to ontogeny and local environmental heterogeneity. Freshwater Biology 58:2215-2225.

Howard, K.M., and M. Newton. 1984. Overtopping by successional coast-range vegetation slows Douglas-fir seedlings. Journal of Forestry 82:178-180.

Huey, R.B., and R.D. Stevenson. 1979. Integrating thermal physiology and ecology of ectotherms: A discussion of approaches. American Zoologist 19:357-366.

Iman, R.L., and W.J. Conover. 1979. The use of the rank transform in regression. Technometrics 21:499-509

Jaccard, J., and V. Guilamo-Ramos. 2002. Analysis of variance frameworks in clinical child and adolescent psychology: advanced issues and recommendation. Journal of Clinical Child Psychology 31:278-294.

Jackson, C.R., D.P. Batzer, S.S. Cross, S.M. Haggerty, and C.A. Sturm. 2007. Headwater streams and timber harvest: Channel, macroinvertebrate, and amphibian response and recovery. Forest Science 53:356–370.

Jennings, S.B., N.D. Brown, and D. Sheil. 1999. Assessing forest canopies and understory illumination, canopy closure, canopy cover and other measures. Forestry 72:59-73.

Johnson, D.H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763-772.

Johnson, D.H. 2002. The role of hypothesis testing in wildlife science. Journal of Wildlife Management. 66:272-276.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fisheries and Aquatic Sciences 61: 913-923.

Jones, L. and M. Raphael. 1998. *Ascaphus truei* (Tailed Frog) predation. Herpetological Review 29: 39.

Jones, L.L.C., W.P. Leonard, and D.H. Olson (editors). 2005. Amphibians of the Pacific Northwest. Seattle Audubon Society, Seattle, Washington, USA.

Karraker, Nancy E. 2001. *Ascaphus truei* (Tailed frog). Predation. Herpetological Review 32:100.

Keith, R.M., T.C. Bjorn, W.R. Meehan, N.J. Hetrick, and M.A. Brusven. 1998. Response of juvenile salmonids to riparian and instream cover modifications in small streams flowing through second-growth forests of southeast Alaska. Transactions of the American Fisheries Society 127:889-907.

Kelsey, K.A. 1995. Responses of headwater stream amphibians to forest practices in western Washington. PhD. Dissertation, College of Forest Resources, University of Washington, Seattle, Washington, USA.

Kibler, K.M., A. Skaugset, L.M. Ganio, and M.M. Huso. 2013. Effect of contemporary forest harvest practices on headwater stream temperatures: initial response of the Hinkle Creek catchment, Pacific Northwest, USA. Forest Ecology and Management 310:680-691.

Kiffney, P.M., E.R. Buhle, S.M. Naman, G.R. Pess, and R.S. Klett. 2014. Linking resource availability and habitat structure to stream organisms: an experimental and observational assessment. Ecosphere 5:1-27.

Kiffney, P.M., J.S. Richardson, and J.P. Bull. 2003. Responses of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. Journal of Applied Ecology 40:1060-1076.

Kiffney, P.M., J.S. Richardson, and J.P. Bull. 2004. Establishing light as a causal mechanism structuring stream communities in response to experimental manipulation of riparian buffer width. Journal of the North American Benthological Society 23:542-555.

Kiffney, P.M, and P. Roni. 2007. Relationships between productivity, physical habitat, and aquatic invertebrate and vertebrate populations of forest streams: and information-theoretic approach. Transactions of the American Fisheries Society 136:1088-1103.

Kohler, S.L. 1985. Identification of stream drift mechanisms: an experimental and observational approach. Ecology 66:1749-1761.

Kroll, A.J., K.L. Risenhoover, T. McBride, E. Beach, B.J. Kernohan, J. Light, and J. Bach. 2008. Factors influencing stream occupancy and detection probability parameters of stream-associated amphibians in commercial forests of Oregon and Washington, USA. Forest Ecology and Management 255:3726–3735.

Kroll, A.J. 2009. Sources of uncertainty in stream-associated amphibian ecology and responses to forest management in the Pacific Northwest, USA: a review. Forest Ecology and Management 257:1188-1199.

Kreutzweiser, D.P., P.K. Sibley, J.S. Richardson, and A.M. Gordon. 2012. Introduction and a theoretical basis for using disturbance by forest management activities to sustain aquatic ecosystems. Freshwater Science 31:224-231.

Lagrue, C., J.S. Kominoski, M. Danger, J.M. Baudoin, S. Lamothe, D. Lambrigot, and A. Lecerf. 2011. Experimental shading alters leaf litter breakdown in streams of contrasting riparian canopy cover. Freshwater Biology 56: 2059-2069.

Lancaster, J., and A.L. Robertson. 1995. Microcrustacean prey and macroinvertebrate predators in a stream food web. Freshwater Biology 34:123-134.

Lange, K., A. Liess, J.J. Piggott, C.R. Townsend, and C.D. Matthaei. 2011. Light, nutrients, and grazing interact to determine stream diatom composition and functional group structure. Freshwater Biology 56:264-278.

Leach, J.A., R.D. Moore, S.G. Hinch, and T. Gomi. 2012. Estimation of forest harvesting-induced stream temperature changes and bioenergetic consequences for cutthroat trout in a coastal stream in British Columbia. Aquatic Sciences 74:427-441.

Leberfinger, K., I. Bohman and J. Herrmann. 2011. The importance of terrestrial resource subsidies for shredders in open-canopy streams revealed by stable isotope analysis. Freshwater Biology 56:470-480.

Leuthold, N., M.J. Adams, and J.P. Hayes. 2012. Short-term response of *Dicamptodon tenebrosus* larvae to timber management in southwestern Oregon. Journal of Wildlife Management 76:28-37.

Liess, A., O. Rowe, J. Guo, G. Thomssonn, and M.I. Lind. 2013. Hot tadpoles from cold environments need more nutrients – life history and stoichiometry reflects latitudinal adaptation. Journal of Animal Ecology 82:1316-1325.

Lövenhaft, K., S. Runborg, and P. Sjögren-Gulve. 2004. Biotope patterns and amphibian distribution as assessment tools in urban landscape planning. Landscape and Urban Planning 68:403-427.

Low-Décarie, C. Chivers, and M. Granados. 2014. Rising complexity and falling explanatory power in ecology. Frontiers in Ecology and the Environment 12:412-418.

MacCracken, J.G. 2002. Response of forest floor vertebrates to riparian hardwood conversion along the Bear River, southwest Washington. Forest Science 48:299-308.

MacCracken, J.G. 2005. Effects of uneven-aged timber harvest on forest floor vertebrates in the Cascade Mountains of southern Washington. Forest Ecology and Management 208:123-135.

MacCracken, J.G, and J.L. Stebbings. 2012. Test of a body condition index with amphibians. Journal of Herpetology 46:346-350.

Mallory, M.A., and J.S. Richardson. 2005. Complex interactions of light, nutrients and consumer density in a stream periphyton-grazer (tailed frog tadpole) system. Journal of Animal Ecology 74:1020-1028.

Marcarelli, A.M., C. V. Baxter, M.M. Mineau, and R.O. Hall. 2011. Quantity and quality: unifying food web and ecosystem perspectives on the role of resource subsidies in freshwaters. Ecology 92:1215–1225.

Matsuda, B.M., and J.S. Richardson. 2005. Movement patterns and relative abundance of coastal tailed frogs in clearcuts and mature forest stands. Canadian Journal of Forest Research 35:1131-1138.

McCarthy, M.A. J.L. Moore, W.K. Morris, K.M. Parris, G.E. Garrard, P.A. Vesk, L. Rumpff, K.M. Giljohann, J.S. Camac, S. Sana Bau, T. Friend, B. Harrison, and B. Yue. 2013. The influence of abundance on detectability. Oikos 122: 717–726

McDonald, T.L., W.P. Erickson, and L.L. McDonald. 2000. Analysis of count data from before-after control-impact studies. Journal of Agricultural, Biological, and Environmental Statistics 5:262-279.

McGill, B. 2013. Ecologists need to do a better job of prediction – part I – the insidious evils of ANOVA (UPDATED). (online at: http://dynamicecology.wordpress.com/2012/11/27/ecologists-needto-do-a-better-job-of-prediction-part-i-the-insidious-evils-ofanova/.

McNeely, C., J.C. Finlay and M.E. Power. 2007. Grazer traits, competition, and carbon sources to a headwater-stream food web. Ecology 88:391-401.

Merritt, R W, and K.W. Cummins. 1996. An introduction to the aquatic insects of North America. 3rd edition. Kendall/Hunt Publishing Co., Dubuque, Iowa, USA.

Moore, R.D., D.L. Spittlehouse and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. Journal of the American Water Resources Association. August 2005:813-834.

Morrissey, C.A. and R.J. Olenick. 2004. American Dipper, *Cinclus mexicanus*, preys upon larval tailed frogs, *Ascaphus truei.* The Canadian Field-Naturalist 118:446-448.

Murphy, M.L. 1998. Primary production. Pp. 144-168 *In* R.J. Naiman and R.E. Bilby (editors), River ecology and management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, New York, New York, USA.

Murphy, M.L., and J.D. Hall. 1981. Varied effects of clear-cut logging on predators and their habitat in small streams of the Cascade Mountains, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 38:137-145.

Murtaugh, P.A. 2014. In defense of *P* values. Ecology 95:611-617.

Naiman, R.J., K.L. Fetherston, S.J. McKay, and J. Chen. 1998. Riparian forests. Pp. 289-232 *In* R.J. Naiman and R.E. Bilby (editors), River ecology and management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, New York, New York, USA.

Newman, R.A., and A.E. Dunham. 1994. Size at metamorphosis and water loss in a desert anuran (*Scaphiopus couchii*). Copeia 1994:372-381.

Newton, M. E.C. Cole, and D.C. White. 1993. Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region. New Forests 7:107-121.

Nussbaum, R.A., and G.W. Clothier. 1973. Population structure, growth, and size of larval *Dicamptodon ensatus* (Eschscholtz). *Northwest Science* 47(4):218-227.

Nussbaum, R.A., and C.K. Tait. 1977. Aspects of the life history and ecology of the Olympic salamander, *Rhyacotriton olympicus* (Gaige). American Midland Naturalist 98:176–199.

Nussbaum, R. A., E.D. Brodie, Jr., and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University of Idaho Press, Moscow, Idaho.

Nuttle, T.1997. Densiometer bias? Are we measuring the forest or the trees? Wildlife Society Bulletin 25:610–611.

O'Donnell, R.P., and C.H. Richart. 2012. Diet of the Columbia torrent salamander, *Rhyacotriton kezeri* (Caudata: Rhyacotritonidae): linkages between aquatic and terrestrial ecosystems in forested headwaters. Northwestern Naturalist 93:17-22.

Ohta, T., Y. Miyake, and T. Hiura. 2011. Light intensity regulates growth and reproduction of a snail grazer (*Gyraulus chinensis*) through changes in the quality and biomass of stream periphyton. Freshwater Biology 56: 2260-2271.

Olson, D.H., P.D. Anderson, C.A. Frissell, H.H. Welsh Jr., and D.F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates and amphibians. Forest Ecology and Management 246: 81-107.

Parker, M.S. 1994. Feeding ecology of stream-dwelling Pacific giant salamander larvae (*Dicamptodon tenebrosus*). Copeia 1994:705-718.

Peig, J., and A.J. Green. 2009. New perspectives for estimating body condition from mass/length data: the scaled mass index as an alternative method. Oikos 118:1883-1891.

Peig, J., and A. J. Green 2010. The paradigm of body condition: A critical reappraisal of current methods based on mass and length. Functional Ecology 23:1323-1332.

Petitot, M., N. Manceau, P. Geniez, and A. Besnard. 2014. Optimizing occupancy surveys by maximizing detection probability: application to amphibian monitoring in the Mediterranean region. Ecology and Evolution 4:3538-3549.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC, USA.

Peckarsky, B.L. 1980. Predator-prey interactions between stoneflies and mayflies: behavioral observations. Ecology 61:932-943.

Pollett, K.L., J.G. MacCracken and J.A. MacMahon. 2010. Stream buffers ameliorate the effects of timber harvest on amphibians in the Cascade Range of Southern Washington, USA. Forest Ecology and Management 260:1083-1087.

Popescu, V.D., D.A. Patrick, M.L. Hunter Jr., and A.J.K. Calhoun. 2012. The role of forest harvesting and subsequent vegetation regrowth in determining patterns of amphibian habitat use. Forest Ecology and Management 270:163-174.

Pringle, C.M., and A. Ramírez. 1998. Use of both benthic and drift sampling techniques to assess tropical stream invertebrate communities along an altitudinal gradient, Costa Rica. Freshwater Biology 39:359-373.

Quinn, J.M., A.B. Cooper, M.J. Stroud, and G.P. Burrell. 1997. Shade effects on stream periphyton and invertebrates: An experiment in streamside channels. New Zealand Journal of Marine and Freshwater Research 31:665-683.

Railsback, S.F., and K.A. Rose. 1999. Bioenergetics modeling of stream trout growth: temperature and food consumption effects. Transactions of the American Fisheries Society 128:241-256.

Risley, J.C., E.A. Roehl, and P.A. Conrads. 2003. Estimating water temperatures in small streams in western Oregon using neural network models. Water Resources Investigations Report 02-4218, Oregon Watershed Enhancement Board, Salem, Oregon, USA.

Richardson, J.S., and R.J. Danehy. 2007. A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. Forest Science 53:131-147.

Richardson, J.S., R.J. Naiman, and P.S. Bisson. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? Freshwater Science 31:232-238.

Richardson, J.S., and S. Béraud. 2014. Effects of riparian forest harvest on streams: a meta-analysis. Journal of Applied Ecology 51:1712-1721.

Ruetz, C.R., R.M. Newman, and B. Vondracek. 2002. Top-down control in a detritus-based food web: fish, shredders, and leaf breakdown. Oecologia 132:307-315.

Rundio, D.E., and D.H. Olson. 2001. Palatability of the southern torrent salamander (*Rhyacotriton variegatus*) larvae to Pacific giant salamander (*Dicamptodon tenebrosus*) larvae. Journal of Herpetology 35:133-136.

Russell, B.D., C.D.G. Harley, T. Wernberg, N. Mieszkowska, S. Widdicombe, J.M. Hall-Spencer, and S.D. Connell. 2012. Predicting ecosystem shifts requires new approaches that integrate the effects of climate change across entire systems. Biology Letters 8:164-166.

Russell, K.R., A.A. Gonyaw, J.D. Strom, K.E. Diemer, and K.C. Murk. 2002. Three new nests of the Columbia torrent salamander, *Rhyacotriton kezeri*, in Oregon with observations of nesting behavior. Northwest Naturalist 83:19-22.

Russell, K.R., T.J. Mabee, and M.B Cole. 2004. Distribution and habitat of Columbia torrent salamanders at multiple spatial scales in managed forests of northwestern Oregon. Journal of Wildlife Management 68:403-415.

Russell, K.R., T.J. Mabee, M.B Cole, and M.J. Rochelle. 2005. Evaluating biotic and abiotic influences on torrent salamanders in managed forests of western Oregon. Wildlife Society Bulletin 33:1413-1424.

Schmidt, B.R. 2003. Count data, detection probabilities, and the demography, dynamics, distribution, and decline of amphibians. Comptes Rendus Biologies 326:S119-S124.

Schrader-Frechette, K.S. and D.C. McCoy. 1993. Methods in ecology: Strategies for conservation. Cambridge University Press, Cambridge, UK.

Schuett-Hames, D., A.E. Pleus, E. Rashin, and J. Mathews. 1999. TFW monitoring program method manual for the stream temperature survey. Washington Department of Natural Resources, TFW-AM9-99-005, Olympia, Washington, USA.

Schuett-Hames, D., A. Roorbach, and R. Conrad. 2012. Results of the westside Type N buffer characteristics, integrity and function study. Final Report to the Cooperative Monitoring, Evaluation and Research Committee, Forests and Fish Adaptive Management Program, Olympia, Washington, USA.

Schultner, J., A.S. Kitaysky, J. Welcker, and S. Hatch. 2013. Fat or lean: adjustment of endogenous energy stores to predictable and unpredictable changes in allostatic load. Functional Ecology 27:45-55.

Sibley, P.K., D.P. Kreutzweiser, B.J. Naylor, J.S. Richardson, and A.M. Gordon. 2012. Emulation of natural disturbance (END) for riparian forest management: synthesis and recommendations. Freshwater Science 31:258-264.

Smith, E.P. 2002. BACI design, Pp. 141-148. *In* A.H. El-Shaarawi and W.W. Piegorsch (editors). Encyclopedia of Environmetrics. John Wiley & Sons, Chichester, West Sussex, UK.

Stanton-Geddes, J., C. Gomes de Freitas, and C. de Sales Dambros. 2014. In defense of *P* values:

comment on the statistical methods actually used by ecologists. Ecology 95:637-642.

Steele, C.A., E.D. Brodie, Jr., and J.G. MacCracken. 2002. Influence of forest age on densities of Cope’s and Pacific giant salamanders. Northwest Science 76:347-352.

Steele, C.A., E.D. Brodie, Jr., and J.G. MacCracken. 2003. Relationships between abundance of Cascade torrent salamanders and forest age. Journal Wildlife of Management 67:447-453.

Sterner, R.W., J.J. Elser, E.J. Fee, S.J. Guildford, and T.H. Chrzanowski. 1997. The light:nutrient ratio in lakes: the balance of energy and materials affects ecosystem structure and process. American Naturalist 150:663–684.

Steury, T.D., A.J. Wirsing, and D.L. Murray. 2002. Using multiple treatment levels as a means of improving inference in wildlife research. Journal of Wildlife Management 66:292-299.

Strahler, A.N. 1957. Quantitative Analysis of Watershed Geomorphology. Transactions of the American Geophysical Union 38:913-920.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783–1786.

Tague, C., M. Farrell, G. Grant, S. Lewis, and S. Rey. Hydrogeologic controls on summer stream temperatures in the McKenzie River basin, Oregon. Hydrological Processes 21:3288-3300.

Toft, C.A. 1991. Reply to Seaman and Jaeger: An appeal to common sense. A controversy in statistical ecology. Herpetologica 46:357-361.

Toft, C.A., and P.J. Shea. 1983. Detecting community-wide patterns: estimating power strengthens statistical inference. American Naturalist 122:618-625.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3-15.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37:130–137.

Wahbe, T.R. and F.L. Bunnell. 2001. Preliminary observations on movements of tailed frog tadpoles (*Ascaphus truei*) in streams through harvested and natural forests. Northwest Science 75:77–83.

Wahbe, T.R. and F.L. Bunnell. 2003. Relations among larval tailed frogs, forest harvesting, stream microhabitat and site parameters in southwestern British Columbia. Canadian Journal of Forestry Research 33:1256-1266.

Warnaars, T.A., M. Hondzo and M.E. Power. 2007. Abiotic controls on periphyton accrual and metabolism in streams: Scaling by dimensionless numbers. Water Resources Research 43: W08425, doi:10.1029/2006WR005002.

Washington Department of Natural Resources. 2005. Forest Practices Habitat Conservation Plan, Washington Department of Natural Resources, Olympia, Washington. (http://www.dnr.wa.gov/businesspermits/topics/forestpracticeshcp/pages/fp_hcp.aspx)

Wellnitz, T. and N.L. Poff. 2006. Herbivory, current velocity and algal regrowth: how does periphyton grow when the grazers have gone? Freshwater Biology 51:2114-2123.

Welsh, H.H., Jr. 2011. Frogs, fish and forestry: an integrated watershed network paradigm conserves biodiversity and ecological services. Diversity 3:503-530.

Welsh, H.H., and A.J. Lind. 1996. Habitat correlates of the southern torrent salamander *Rhyacotriton variegates* (Caudata: Rhyacotritonidae), in northwestern California. Journal of Herpetology 30:385-398.

Wilkins, R.N., and N.P. Peterson. 2000. Factors related to amphibian occurrence and abundance in headwater streams draining second-growth Douglas-fir forests in southwestern Washington. Forest Ecology and Management 139:70-91.

Wilzbach, M.A., B.C. Harvey, J.L. White, and R.J. Nakamoto. 2005. Effects of riparian canopy opening and salmon carcass addition on the abundance and growth of resident salmonids. Canadian Journal of Fisheries and Aquatic Sciences 62:58-67.

Wipfli, M.S. 2005. Trophic linkages between headwater forests and downstream fish habitats: implications for forest and fish management. Landscape and Urban Planning 72:205-213.

Wipfli, M.S., and D.P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. Freshwater Biology 47:957-969.

Wipfli, M.S., and J. Musselwhite. 2004. Density of red alder (*Alnus rubra*) in the headwaters influences invertebrate and detritus subsidies to downstream habitats in Alaska. Hydrobiologia 520:153-163.

Wootton, J.T. 2012. River food web response to large-scale riparian zone manipulations. PLOS One 7(12): e51839. doi:10.1371/journal.pone.0051839

Yoccoz, N.G. 1991. Use, overuse, and misuse of significance tests in evolutionary biology and ecology. Bulletin of the Ecological Society of America 72:106-111.

Zuur, A.F., E.N. Ieno, H.J. Walker, A.A. Saveliev and G.M. Smith. 2009. Mixed effects models and extensions in ecology with R. Springer Science + Business Media, New York, New York, USA.

Appendix 1. Location and major physical and vegetation features of the sampling units in the study. The general location of blocks is shown in Figure 1. Treatment (T) or reference (R) reaches are specified.

Ecoregion	Block	Reach	Treatment (% cover)	Latitude (DD)	Longitude (DD)	Elevation (m)	Aspect (°)	Gradient (°)	Basin Area (ha)	Dominant Vegetation[a]	Amphibian Taxa[b]
South	Beacon	T	0	45.68539	-122.03196	734	153	15	56.8	TSHE/ALRU	ASTR/DISP/RHCA
Cascades	Rock	R		45.68607	-122.03248	745	147	15	30.9	TSHE/ALRU	ASTR/DISP/RHCA
		T	30	45.70679	-122.02994	774	188	11	112.4	ALRU/PSME	ASTR/DISP/RHCA
		R		45.70777	-122.02658	796	218	12	101.2	ALRU/PSME	ASTR/DISP/RHCA
		T	70	45.71371	-122.04448	563	170	10	1.1	TSHE/ALRU	ASTR/DISP/RHCA
		R		45.71469	-122.04406	670	194	11	0.8	TSHE/ALRU	ASTR/DISP/RHCA
	Texas	T	0	45.70414	-122.19852	655	180	25	16.4	ALRU/PSME	ASTR/DISP/RHCA
	Creek	R		45.70488	-122.19817	702	180	24	11.5	ALRU/PSME	ASTR/DISP/RHCA
		T	30	45.69526	-122.21708	448	206	18	15.8	ALRU/PSME	ASTR/DISP/RHCA
		R		45.69625	-122.21681	504	201	15	12.8	ALRU/PSME	ASTR/DISP/RHCA
		T	70	45.70352	-122.19765	592	179	19	18.4	ALRU/PSME	ASTR/DISP/RHCA
		R		45.70471	-122.19696	699	188	18	13.5	ALRU/PSME	ASTR/DISP/RHCA

[a] Dominant vegetation codes: TSHE = *Tsuga heterophylla* (Western hemlock), ALRU = *Alnus rubra* (Red alder), and PSME = *Pseudotsuga menziesii* (Douglas-fir).

[b] Amphibian taxon codes: ASTR = *Ascaphus truei* (Coastal tailed frog), DISP = *Dicamptodon* species (giant salamanders – includes *D. tenebrosus* [Coastal giant salamander] and *D. copei* [Cope's giant salamander]), and RHCA = *Rhyacotriton cascadae* (Cascade torrent salamander).

Appendix 1 (continued). Location and major physical and vegetation features of the sampling units in the study. The general location of blocks is shown in Figure 1. Treatment (T) or reference (R) reaches are specified.

Ecoregion	Block	Reach	Treatment (% cover)	Latitude (DD)	Longitude (DD)	Elevation (m)	Aspect (°)	Gradient (%°)	Basin Area (ha)	Dominant Vegetation[a]	Amphibian Taxa[b]
South Cascades	Rock Creek	T	0	46.02393	-122.48784	567	213	15	68.0	TSHE/ALRU	ASTR/DISP/RHCA
		R		46.02529	-122.48718	610	187	19	60.8	TSHE/ALRU	ASTR/DISP/RHCA
		T	30	46.01143	-122.45325	511	225	22	2.3	PSME/TSHE	ASTR/DISP/RHCA
		R		46.01163	-122.45259	513	208	13	1.5	PSME/TSHE	ASTR/DISP/RHCA
		T	70	46.02341	-122.44988	567	222	17	48.7	ALRU/TSHE	ASTR/DISP/RHCA
		R		46.02431	-122.44905	610	193	10	46.0	PSME/ALRU	ASTR/DISP/RHCA
Coast Range	KM Mountain	T	0	46.38024	-123.53820	65	224	21	13.3	ALRU/TSHE	ASTR/DISP/RHKE
		R		46.38087	-123.53740	156	183	19	12.0	TSHE/ALRU	ASTR/DISP/RHKE
		T	30	46.36103	-123.47655	314	193	17	29.0	ALRU/TSHE	ASTR/DISP/RHKE
		R		46.36200	-123.47609	318	202	21	25.8	ALRU/TSHE	ASTR/DISP/RHKE
		T	70	46.35953	-123.47423	315	225	24	9.0	TSHE/ALRU	ASTR/DISP/RHKE
		R		46.35970	-123.47310	345	250	18	8.6	ALRU/TSHE	ASTR/DISP/RHKE

[a] Dominant vegetation codes: TSHE = *Tsuga heterophylla* (Western hemlock), ALRU = *Alnus rubra* (Red alder), and PSME = *Pseudotsuga menziesii* (Douglas-fir).

[b] Amphibian taxon codes: ASTR = *Ascaphus truei* (Coastal tailed frog), DISP = *Dicamptodon* species (giant salamanders – includes *D. tenebrosus* [Coastal giant salamander] and *D. copei* [Cope's giant salamander]), RHCA = *Rhyacotriton cascadae* (Cascade torrent salamander), and RHKE = *Rhyacotriton kezeri* (Columbia torrent salamander).

Appendix 1 (continued). Location and major physical and vegetation features of the sampling units in the study. The general location of blocks is shown in Figure 1. Treatment (T) or reference (R) reaches are specified.

Ecoregion	Block	Reach	Treatment (% cover)	Latitude (DD)	Longitude (DD)	Elevation (m)	Aspect (°)	Gradient (°)	Basin Area (ha)	Dominant Vegetation[a]	Amphibian Taxa[b]
Coast	Humbug	T	0	45.91600	-123.67700	362	153	13	42.5	ALRU/TSHE	ASTR/DISP/RHKE
Range	Mountain	R		45.91746	-123.67844	388	140	13	32.5	ALRU/TSHE	ASTR/DISP/RHKE
		T	30	45.89016	-123.72037	326	144	10	29.0	ALRU/TSHE	ASTR/DISP/RHKE
		R		45.88993	-123.72100	344	147	11	20.9	ALRU/TSHE	ASTR/DISP/RHKE
		T	70	45.88095	-123.69739	300	218	10	89.6	TSHE/ALRU	ASTR/DISP/RHKE
		R		45.88231	-123.69699	304	207	10	75.4	TSHE/ALRU	ASTR/DISP/RHKE
	Soapstone	T	0	45.79903	-123.88137	335	151	25	24.1	TSHE/PSME	ASTR/DISP/RHKE
	Creek	R		45.79959	-123.88245	339	171	13	23.8	TSHE/PSME	ASTR/DISP/RHKE
		T	30	45.83788	-123.85273	387	186	17	19.8	TSHE/PSME	ASTR/DISP/RHKE
		R		45.83861	-123.85299	431	155	21	17.6	TSHE/PSME	ASTR/DISP/RHKE
		T	70	45.78962	-123.89407	341	194	10	35.4	TSHE/PSME	ASTR/DISP/RHKE
		R		45.79100	-123.89400	341	156	12	33.6	TSHE/PSME	ASTR/DISP/RHKE

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[a] Dominant vegetation codes: TSHE = *Tsuga heterophylla* (Western hemlock), ALRU = *Alnus rubra* (Red alder), PSME = *Pseudotsuga menziesii* (Douglas-fir), and THPL = *Thuja plicata* (Western red cedar).

[b] Amphibian taxon codes: ASTR = *Ascaphus truei* (Coastal tailed frog), DISP = *Dicamptodon* species (Giant salamanders – includes *D. tenebrosus* [Coastal giant salamander] and *D. copei* [Cope's giant salamander]), and RHKE = *Rhyacotriton kezeri* (Columbia torrent salamander).

Appendix 1 (continued). Location and major physical and vegetation features of the sampling units in the study. The general location of blocks is shown in Figure 1. Treatment (T) or reference (R) reaches are specified.

Ecoregion	Block	Reach	Treatment (% cover)	Latitude (DD)	Longitude (DD)	Elevation (m)	Aspect (°)	Gradient (°)	Basin Area (ha)	Dominant Vegetation[a]	Amphibian Taxa[b]
Olympics	Waketickeh	T	0	47.60458	-123.00734	628	100	4	15.8	ALRU/TSHE	ASTR/RHOL
	Creek	R		47.60509	-123.00830	632	180	5	11.1	ALRU/ACMA	ASTR/RHOL
		T	30	47.60232	-123.06597	505	154	32	104.3	THPL/PSME	ASTR/RHOL
		R		47.60365	-123.06609	538	197	35	75.2	ALRU/TSHE	ASTR/RHOL
		T	70	47.58063	-123.06123	304	116	17	79.5	ALRU/THPL	ASTR/RHOL
		R		47.58170	-123.06155	283	127	15	65.7	ALRU/ACMA	ASTR/RHOL
	Sund	T	0	47.43532	-123.15615	233	116	4	19.7	ALRU/TSHE	ASTR/RHOL
	Creek	R		47.43569	-123.15799	239	85	4	15.7	ALRU/TSHE	ASTR/RHOL
		T	30	47.45435	-123.15811	185	95	6	19.9	ALRU/TSHE	ASTR/RHOL
		R		47.45459	-123.15962	433	97	7	18.2	ALRU/TSHE	ASTR/RHOL
		T	70	47.45944	-123.13631	178	97	8	61.9	ALRU/PSME	ASTR/RHOL
		R		47.46001	-123.13686	200	160	16	52.1	ALRU/PSME	ASTR/RHOL

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[a] Dominant vegetation codes: TSHE = *Tsuga heterophylla* (Western hemlock), ALRU = *Alnus rubra* (Red alder), PSME = *Pseudotsuga menziesii* (Douglas-fir), THPL = *Thuja plicata* (Western red cedar), and ACMA = *Acer macrophyllum* (Big leaf maple).

[b] Amphibian taxon codes: ASTR = *Ascaphus truei* (Coastal tailed frog) and RHOL = *Rhyacotriton olympicus* (Olympic torrent salamander).

Appendix 1 (continued). Location and major physical and vegetation features of the sampling units in the study. The general location of blocks is shown in Figure 1. Treatment (T) or reference (R) reaches are specified.

Ecoregion	Block	Reach	Treatment (% cover)	Latitude (DD)	Longitude (DD)	Elevation (m)	Aspect (°)	Gradient (°)	Basin Area (ha)	Dominant Vegetation[a]	Amphibian Taxa[b]
Olympics	Jorsted	T	30	47.52435	-123.10975	242	142	20	79.1	ALRU/ACMA	ASTR/RHOL
	Creek	R		47.52507	-123.11100	275	142	10	78.1	ACMA/ALRU	ASTR/RHOL

[a] Dominant vegetation codes: ALRU = *Alnus rubra* (Red alder) and ACMA = *Acer macrophyllum* (Big leaf maple).

[b] Amphibian taxon codes: ASTR = *Ascaphus truei* (Coastal tailed frog) and RHOL = *Rhyacotriton olympicus* (Olympic torrent salamander).

Appendix 2. Pre- and post-treatment (T) and reference (R) reach wetted widths (in meters). Wetted width statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
South Cascades	Beacon Rock	T(0)	5	2.7 ± 0.44	0.36	5	1.7 ± 0.30	0.40	5	2.5 ± 0.30	0.24	5	1.9 ± 0.34	0.39
		R	5	2.6 ± 0.33	0.28	5	1.5 ± 0.22	0.34	5	1.4 ± 0.20	0.27	5	1.6 ± 0.17	0.23
		T(30)	5	2.3 ± 0.29	0.28	6	1.7 ± 0.41	0.42	5	1.2 ± 0.33	0.50	5	1.3 ± 0.34	0.55
		R	5	2.4 ± 0.36	0.30	5	1.5 ± 0.33	0.38	4	1.3 ± 0.21	0.29	5	2.2 ± 0.73	0.71
		T(70)	5	2.0 ± 0.38	0.42	5	0.9 ± 0.14	0.37	5	1.4 ± 0.34	0.39	5	1.6 ± 0.17	0.23
		R	6	2.9 ± 0.36	0.30	5	1.4 ± 0.30	0.46	5	1.9 ± 0.52	0.62	5	1.9 ± 0.20	0.22
	Texas Creek	T(0)	5	1.4 ± 0.11	0.17	5	1.1 ± 1.63	0.32	5	1.0 ± 0.11	0.24	5	1.6 ± 0.12	0.39
		R	5	2.0 ± 0.22	0.24	5	1.4 ± 0.20	0.34	5	1.4 ± 0.30	0.49	5	1.4 ± 0.37	0.58
		T(30)		no data		5	1.1 ± 0.11	0.22	5	1.0 ± 0.13	0.21	5	1.1 ± 0.16	0.32
		R		no data		5	0.9 ± 0.14	0.22	5	1.3 ± 0.12	0.26	5	1.1 ± 0.11	0.22
		T(70)	5	1.3 ± 0.15	0.24	5	1.0 ± 0.12	0.31	5	1.4 ± 0.10	0.18	5	1.5 ± 0.09	0.13
		R	5	1.8 ± 0.43	0.52	5	0.9 ± 0.04	0.08	5	1.7 ± 0.42	0.47	5	1.6 ± 0.44	0.59

Appendix 2 (continued). Pre- and post-treatment (T) and reference (R) reach wetted widths (in meters). Wetted width statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
South Cascades	Rock Creek	T(0)	5	2.4 ± 0.20	0.18	5	1.8 ± 0.22	0.22	5	2.0 ± 0.30	0.37	5	3.1 ± 0.40	0.29
		R	5	2.2 ± 0.25	0.25	5	1.9 ± 0.31	0.34	5	1.8 ± 0.32	0.43	5	2.3 ± 0.50	0.47
		T(30)	5	1.8 ± 0.21	0.26	5	1.3 ± 0.20	0.35	5	1.8 ± 0.22	0.29	5	3.1 ± 0.70	0.49
		R	5	1.5 ± 0.13	0.19	5	1.2 ± 0.14	0.21	5	1.8 ± 0.21	0.28	5	1.9 ± 0.42	0.49
		T(70)	5	2.1 ± 0.32	0.34	5	1.5 ± 0.20	0.32	5	1.8 ± 0.44	0.46	5	1.9 ± 0.31	0.35
		R	5	2.3 ± 0.26	0.25	5	1.7 ± 0.10	0.18	5	2.1 ± 0.22	0.18	5	2.9 ± 0.48	0.36
Coast Ranges	KM Mountain	T(0)	5	2.3 ± 0.46	0.44	5	0.9 ± 0.23	0.61	5	1.4 ± 0.20	0.35	5	1.3 ± 0.17	0.30
		R	5	2.4 ± 0.53	0.49	5	1.1 ± 0.22	0.41	5	1.6 ± 0.20	0.25	5	1.5 ± 0.12	0.18
		T(30)	5	2.1 ± 0.24	0.25	5	1.2 ± 0.30	0.50	5	1.0 ± 0.13	0.22	5	1.4 ± 0.14	0.22
		R	6	2.0 ± 0.21	0.26	5	0.9 ± 0.24	0.40	5	0.9 ± 0.12	0.28	5	1.1 ± 0.17	0.33
		T(70)	6	2.0 ± 0.33	0.41	5	1.2 ± 0.12	0.21	5	1.2 ± 0.10	0.21	5	1.4 ± 0.24	0.37
		R	6	1.3 ± 0.23	0.30	5	1.1 ± 0.14	0.29	5	0.7 ± 0.03	0.11	5	0.9 ± 0.13	0.31

Appendix 2 (continued). Pre- and post-treatment (T) and reference (R) reach wetted widths (in meters). Wetted width statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Coast Ranges	Humbug Creek	T(0)	5	1.5 ± 0.06	0.08	5	0.7 ± 0.22	0.57	5	1.1 ± 0.20	0.45	5	1.1 ± 0.19	0.37
		R	5	1.4 ± 0.10	0.16	5	0.7 ± 0.31	0.65	5	0.9 ± 0.32	0.60	5	1.3 ± 0.22	0.37
		T(30)	5	2.2 ± 0.03	0.03	5	1.3 ± 0.20	0.56	8	1.1 ± 0.23	0.37	5	1.5 ± 0.19	0.28
		R	5	1.9 ± 0.05	0.06	5	0.9 ± 0.06	0.14	5	1.1 ± 0.21	0.32	5	1.2 ± 0.19	0.29
		T(70)	5	2.2 ± 0.20	0.20	5	1.7 ± 0.11	0.21	5	1.4 ± 0.10	0.21	5	1.5 ± 0.23	0.33
		R	5	2.4 ± 0.25	0.23	5	1.9 ± 0.13	0.12	5	1.7 ± 0.12	0.17	5	1.5 ± 0.23	0.33
	Soapstone Creek	T(0)		no data		5	2.0 ± 0.23	0.25	3	2.2 ± 0.33	0.21	5	2.3 ± 0.14	0.13
		R		no data		5	2.1 ± 0.12	0.13	2	1.3 ± 0.20	0.16	5	1.9 ± 0.23	0.27
		T(30)	5	1.7 ± 0.07	0.09	5	1.0 ± 0.10	0.34	5	1.7 ± 0.30	0.42	5	1.4 ± 0.24	0.37
		R	5	1.5 ± 0.32	0.46	5	2.1 ± 0.14	0.06	5	1.1 ± 0.21	0.34	5	1.8 ± 0.34	0.42
		T(70)	5	1.7 ± 0.12	0.15	5	1.4 ± 0.12	0.19	5	1.4 ± 0.10	0.22	5	1.9 ± 0.24	0.27
		R	3	1.9 ± 0.38	0.34	5	1.2 ± 0.04	0.06	5	1.6 ± 0.33	0.48	5	2.4 ± 0.18	0.17

Appendix 2 (continued). Pre- and post-treatment (T) and reference (R) reach wetted widths (in meters). Wetted width statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2006)			Year 2 (2007)			Year 1 (2008)			Year 2 (2009)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Olympics	Waketickeh	T(0)	15	1.6 ± 0.24	0.56	15	1.9 ± 0.20	0.41	15	1.7 ± 0.26	0.58	15	1.6 ± 0.14	0.34
	Creek	R	15	1.4 ± 0.16	0.44	15	1.5 ± 0.12	0.32	15	1.8 ± 0.21	0.45	15	1.9 ± 0.15	0.31
		T(30)	15	1.7 ± 0.26	0.61	15	2.3 ± 0.18	0.30	15	2.0 ± 0.23	0.44	15	1.7 ± 0.22	0.52
		R	14	1.3 ± 0.12	0.33	15	2.0 ± 0.31	0.59	15	1.9 ± 0.34	0.70	15	1.6 ± 0.22	0.52
		T(70)	15	1.0 ± 0.12	0.45	15	1.2 ± 0.21	0.69	15	1.1 ± 0.16	0.54	15	1.9 ± 0.21	0.44
		R	10	1.1 ± 0.14	0.39	15	0.7 ± 0.16	0.95	15	0.9 ± 0.16	0.68	15	1.1 ± 0.22	0.79
	Sund	T(0)	15	2.6 ± 0.15	0.23	15	3.1 ± 0.39	0.49	15	1.7 ± 0.11	0.26	15	1.7 ± 0.14	0.31
	Creek	R	15	2.0 ± 0.18	0.35	15	2.4 ± 0.18	0.29	15	1.2 ± 0.14	0.44	15	1.4 ± 0.18	0.50
		T(30)	15	1.3 ± 0.10	0.29	15	1.2 ± 0.09	0.31	15	0.8 ± 0.10	0.47	15	1.2 ± 0.16	0.51
		R	15	1.1 ± 0.14	0.48	15	0.9 ± 0.07	0.30	15	1.5 ± 0.12	0.31	15	1.2 ± 0.12	0.40
		T(70)	15	1.1 ± 0.10	0.35	15	1.7 ± 0.18	0.42	15	1.3 ± 0.21	0.62	15	1.4 ± 0.22	0.60
		R	15	1.0 ± 0.04	0.17	15	1.3 ± 0.10	0.31	15	1.1 ± 0.22	0.77	14	1.3 ± 0.25	0.71

Appendix 2 (continued). Pre- and post-treatment (T) and reference (R) reach wetted widths (in meters). Wetted width statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2006)			Year 2 (2007)			Year 1 (2008)			Year 2 (2009)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Olympics	Jorsted	T(30)	6	0.6 ± 0.01	0.02	15	1.5 ± 0.19	0.46	14	1.9 ± 0.20	0.40	10	1.4 ± 0.17	0.40
	Creek	R	15	1.7 ± 0.11	0.26	15	1.7 ± 0.11	0.26	15	2.0 ± 0.20	0.39	15	2.0 ± 0.13	0.25

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Appendix 3. Pre- and post-treatment (T) and reference (R) reach maximum water depths (in centimeters). Depth statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
South Cascades	Beacon Rock	T(0)	5	14 ± 2.5	0.42	5	9 ± 2.0	0.47	5	7 ± 1.1	0.33	5	11 ± 2.1	0.43
		R	5	13 ± 4.7	0.80	5	5 ± 0.9	0.38	2	6 ± 1.7	0.32	5	8 ± 1.4	0.42
		T(30)	5	18 ± 1.7	0.21	4	5 ± 1.1	0.27	5	6 ± 2.2	0.82	5	7 ± 1.8	0.54
		R	5	18 ± 1.7	0.23	3	8 ± 1.5	0.41	5	14 ± 2.9	0.47	5	11 ± 2.2	0.43
		T(70)	5	14 ± 2.4	0.42	5	10 ± 1.3	0.29	5	10 ± 1.7	0.38	5	9 ± 2.2	0.53
		R	6	15 ± 1.1	0.20	5	10 ± 2.6	0.56	5	7 ± 0.7	0.23	5	9 ± 1.1	0.43
	Texas Creek	T(0)	5	9 ± 1.1	0.31	5	5 ± 0.4	0.21	5	5 ± 0.6	0.27	5	3 ± 0.3	0.23
		R	5	7 ± 0.9	0.34	5	4 ± 0.6	0.26	5	4 ± 0.7	0.36	5	4 ± 0.8	0.40
		T(30)		no data		5	5 ± 0.6	0.24	5	6 ± 0.5	0.17	5	7 ± 1.1	0.34
		R		no data		5	4 ± 0.7	0.36	5	4 ± 0.5	0.25	5	6 ± 0.5	0.21
		T(70)	5	7 ± 1.2	0.42	5	7 ± 1.0	0.31	5	6 ± 0.8	0.31	5	5 ± 0.4	0.18
		R	5	10 ± 1.4	0.32	5	6 ± 0.2	0.18	5	3 ± 0.3	0.21	5	4 ± 0.2	0.40

Appendix 3 (continued). Pre- and post-treatment (T) and reference (R) reach maximum water depths (in centimeters). Depth statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
South Cascades	Rock Creek	T(0)	5	24 ± 1.7	0.21	5	12 ± 3.1	0.56	5	13 ± 1.9	0.31	5	12 ± 2.2	0.39
		R	5	18 ± 2.1	0.32	5	9 ± 2.5	0.55	5	5 ± 1.0	0.48	5	14 ± 3.5	0.56
		T(30)	5	8 ± 1.0	0.32	5	6 ± 0.8	0.31	5	4 ± 0.6	0.28	5	6 ± 0.4	0.17
		R	5	8 ± 0.6	0.20	5	4 ± 0.6	0.29	5	5 ± 0.5	0.24	5	6 ± 0.3	0.11
		T(70)	5	16 ± 2.2	0.34	5	10 ± 1.0	0.23	5	9 ± 2.0	0.49	5	5 ± 0.4	0.18
		R	5	18 ± 1.3	0.22	5	10 ± 0.9	0.20	5	11 ± 1.4	0.26	5	4 ± 0.2	0.12
Coast Ranges	KM Mountain	T(0)	5	11 ± 1.9	0.44	5	5 ± 0.8	0.34	5	8 ± 1.4	0.26	5	3 ± 0.5	0.32
		R	5	7 ± 1.2	0.40	5	5 ± 0.7	0.30	5	4 ± 0.3	0.17	5	4 ± 1.0	0.58
		T(30)	5	18 ± 1.9	0.20	5	6 ± 0.9	0.30	5	7 ± 1.3	0.43	5	7 ± 0.3	0.08
		R	5	24 ± 5.3	0.51	5	5 ± 1.0	0.39	5	4 ± 0.8	0.40	5	8 ± 1.3	0.37
		T(70)	6	15 ± 1.5	0.21	5	8 ± 2.4	0.63	5	8 ± 1.4	0.39	5	8 ± 1.5	0.44
		R	3	11 ± 0.7	0.10	5	4 ± 0.4	0.23	5	4 ± 0.3	0.18	5	3 ± 0.3	0.18

Appendix 3 (continued). Pre- and post-treatment (T) and reference (R) reach maximum water depths (in centimeters). Depth statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2004)			Year 2 (2005)			Year 1 (2006)			Year 2 (2007)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Coast Ranges	Humbug Creek	T(0)	5	14 ± 0.7	0.11	5	8 ± 1.3	0.36	5	6 ± 1.0	0.36	5	7 ± 1.3	0.14
		R	5	11 ± 1.2	0.23	5	5 ± 0.7	0.29	5	6 ± 1.7	0.70	5	6 ± 1.1	0.37
		T(30)	5	11 ± 0.8	0.20	5	5 ± 0.6	0.29	8	7 ± 0.9	0.36	5	6 ± 1.1	0.42
		R	5	10 ± 1.5	0.32	5	6 ± 0.6	0.20	5	7 ± 1.0	0.33	5	6 ± 1.0	0.36
		T(70)	5	18 ± 3.4	0.40	5	10 ± 0.8	0.17	5	7 ± 1.0	0.20	5	9 ± 1.5	0.37
		R	5	18 ± 1.4	0.23	5	6 ± 0.8	0.28	5	22 ± 1.5	1.53	5	8 ± 0.4	0.10
	Soapstone Creek	T(0)		no data		5	8 ± 0.8	0.22	3	11 ± 2.1	0.31	5	10 ± 0.9	0.19
		R		no data		5	7 ± 0.7	0.21	2	12 ± 0.7	0.08	5	10 ± 1.3	0.28
		T(30)	5	9 ± 0.5	0.12	5	3 ± 0.7	0.52	5	5 ± 0.8	0.36	5	6 ± 0.8	0.30
		R	5	6 ± 0.3	0.11	5	3 ± 0.7	0.43	5	5 ± 0.6	0.29	5	5 ± 0.9	0.41
		T(70)	5	18 ± 1.6	0.23	5	11 ± 1.1	0.22	5	12 ± 2.2	0.38	5	12 ± 2.3	0.43
		R	3	10 ± 0.2	0.01	5	9 ± 1.3	0.35	5	7 ± 1.6	0.49	5	13 ± 2.6	0.45

Appendix 3 (continued). Pre- and post-treatment (T) and reference (R) reach maximum water depths (in centimeters). Depth statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2006)			Year 2 (2007)			Year 1 (2008)			Year 2 (2009)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Olympics	Waketickeh Creek	T(0)	15	11 ± 2.5	0.86	15	15 ± 2.8	0.71	15	18 ± 3.1	0.68	15	8 ± 1.3	0.63
		R	15	7 ± 0.4	0.24	15	16 ± 1.2	0.29	15	10 ± 1.0	0.42	15	13 ± 1.9	0.54
		T(30)	15	22 ± 4.7	0.83	15	12 ± 2.4	0.78	15	12 ± 1.5	0.51	15	10 ± 1.8	0.71
		R	14	12 ± 1.3	0.40	15	17 ± 4.1	0.94	15	9 ± 0.9	0.41	15	18 ± 2.5	0.55
		T(70)	15	8 ± 2.1	1.00	15	11 ± 3.7	1.28	15	9 ± 1.7	0.76	15	14 ± 1.8	0.50
		R	10	15 ± 2.2	0.45	15	10 ± 2.7	1.11	15	17 ± 8.1	1.86	15	11 ± 2.1	0.76
	Sund Creek	T(0)	15	20 ± 2.8	0.55	15	17 ± 1.1	0.24	15	9 ± 0.5	0.22	15	13 ± 1.4	0.42
		R	15	12 ± 0.5	0.16	15	16 ± 1.5	0.35	15	15 ± 1.8	0.47	15	18 ± 2.2	0.46
		T(30)	15	6 ± 0.3	0.21	15	10 ± 1.9	0.75	15	6 ± 0.6	0.40	15	8 ± 1.1	0.54
		R	15	8 ± 0.9	0.47	15	8 ± 0.8	0.35	15	9 ± 1.1	0.48	15	8 ± 0.9	0.43
		T(70)	15	7 ± 0.9	0.53	15	15 ± 6.2	1.61	15	8 ± 1.7	0.84	15	14 ± 7.6	2.06
		R	15	11 ± 1.2	0.42	15	9 ± 1.1	0.47	15	9 ± 2.1	0.87	14	11 ± 5.4	1.86

Appendix 3 (continued). Pre- and post-treatment (T) and reference (R) reach maximum water depths (in centimeters). Depth statistics are sample size (*n*), mean ($\bar{x}$) ± standard error of the mean (SE) and coefficient of variation (CV). Sample sizes are based on the non-dry reach plots.

			Pre-Treatment						Post-Treatment					
			Year 1 (2006)			Year 2 (2007)			Year 1 (2008)			Year 2 (2009)		
Ecoregion	Block	Reach	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV	n	$\bar{x}$ ± SE	CV
Olympics	Jorsted	T(30)	6	3 ± 0.2	0.18	15	15 ± 3.3	0.84	14	21 ± 8.9	1.60	10	16 ± 2.1	0.41
	Creek	R	15	17 ± 3.1	0.69	15	18 ± 2.6	0.58	15	17 ± 1.5	0.35	15	23 ± 5.4	0.90

Appendix 4. Mean effect size (ES)(post-treatment minus pre-treatment) and 90% confidence limits (CL; in parentheses) for each shade level, percentage change in ES pre- to post-treatment and 90% CLs for percent change for physical and biotic variables at three levels of shade retention (no, low, intermediate) based on treatment minus reference stream reach contrasts. Stream reaches were sampled for two years each both pre- and post-treatment in 25 streams in northwestern Oregon, southwestern Washington, and the Olympic peninsula from 2004-2009; the Olympic block had a two-year stagger in time. *P*-value is for the period × treatment interaction of a linear mixed effects model. We set $\alpha \leq 0.1$ for statistical significance. For each estimate: * = $P = 0.1$, # = $P < 0.1\text{-}0.01$, § = $P < 0.01\text{-}0.001$, and ‡ = $P < 0.001$. Statistically significant difference in ES are in red and percent changes falling outside the 90% CLs are **emboldened**.

	Shade Level							
	No (n = 8)		Low (n = 9)		Intermediate (n = 8)			
Response Variable	ES	% Change	ES	% Change	ES	% Change	90% CL	*P*
PAR[a] (μmols m^{-2} sec^{-1})	589(505–673)‡	1538	422(343–501)‡	1765	210(126–294)‡	**465**	598–1914	0.0001
Water temperature (°C)								
Stream								
Seasonal maximum	3.0(2.0–4.0)‡	**682**	1.5(0.5–2.5)#	172	0.5(-0.5–1.5)	78	3–619	0.001
7-day maximum[b]	2.5(1.5–3.5)‡	560	2.0(1.0–3.0)‡	429	0.5(-0.5–1.5)	**81**	122–591	0.0001
Exclosure								
Seasonal maximum[c]	-10.0(-31.0–11.0)	-99	8.0(-13.0–29.0)	122	15.0(-5.0–35.0)	**558**	-123–511	0.03
7-day maximum	-17.0(-37.0–3.0)	-259	-2.5(-23.5–18.5)	**-589**	9.0(-11.0–29.0)	30	-556–21	0.11
Biofilm accrual (g m^{-2} AFDM)[d]								
Stream	28(8–48)#	**39**	27(8–46)#	48	26(6–46)#	45	40–48	0.23
Exclosure	12(-11–35)	18	12(-9–33)	19	-4(-16–24)	**-5**	-2–24	0.78
Stream drift[e]								
CPOM[f]								
kg m^{-3}	-63(-102–-54)	**-39**	-10(-48–28)	-5	-7(-46–32)	-3	-35–4	0.19
g day^{-1}	-30(-69–9)	**-17**	-15(-53–23)	-7	-1(-40–38)	0	-16–0	0.75
FPOM[g]								
kg m^{-3}	-32(-71–7)	-17	20(-18–58)	10	-8(-49–33)	-5	-17–9	0.43
g day^{-1}	-32(-70–6)	**-16**	14(-22–50)	7	16(-23–55)	8	-13–13	0.42

[a] PAR = photosynthetically active radiation. [b] Seven-day moving average of daily maximum temperature. [c] Rank-transformed. [d] AFDM = Ash-free dry mass. [e] Includes CPOM, FPOM and macroinvertebrates. [f] CPOM = Coarse particulate organic matter. [g] FPOM = Fine particulate organic matter.

Appendix 4 (continued). Mean effect size (ES)(post-treatment minus pre-treatment) and 90% confidence limits (CL; in parentheses) for each shade level, percentage change in ES pre- to post-treatment and 90% CLs for percent change for physical and biotic variables at three levels of shade retention (no, low, intermediate) based on treatment minus reference stream reach contrasts. Stream reaches were sampled for two years each both pre- and post-treatment in 25 streams in northwestern Oregon, southwestern Washington, and the Olympic peninsula from 2004-2009; the Olympic block had a two-year stagger in time. *P*-value is for the period × treatment interaction of a linear mixed effects model. We set $\alpha \leq 0.1$ for statistical significance. For each estimate: * = $P = 0.1$, # = $P < 0.1$-0.01, § = $P < 0.01$-0.001, and ‡ = $P < 0.001$. Statistically significant difference in ES are in red and percent changes falling outside the 90% CLs are **emboldened.**

	Shade Level							
	No (n = 8)		Low (n = 9)		Intermediate (n = 8)			
Response Variable	ES	% Change	ES	% Change	ES	% Change	90% CL	*P*
Macroinvertebrates								
Filtering collectors (Filterers)								
g m^{-3}	-18(-57–21)	-8	-3(-41–35)	-1	20(-19–59)	**10**	-8–9	0.72
g day^{-1}	-12(-50–26)	-6	4(-34–42)	2	28(-11–67)	**15**	-6-14	0.66
Gathering collectors (Gatherers)								
g m^{-3}	-14(-52–24)	-7	**84(48–120)‡**	**53**	31(-7–69)	15	-8–49	**0.008**
g day^{-1}	-13(-51–25)	**-6**	**63(27–99)§**	38	37(-1–75)	20	-4–38	**0.06**
Predators								
g m^{-3}	**-42(-81–-3)#**	**-26**	23(-15–61)	**11**	-15(-56–26)	-8	-25–10	0.22
g day^{-1}	-25(-64–14)	**-14**	17(-22–56)	8	9(-32–50)	5	-12–11	0.59
Scrapers								
g m^{-3}	-1(-40–38)	-1	9(-29–47)	5	19(-20–58)	11	-1–11	0.91
g day^{-1}	23(-15–61)	12	4(-32–40)	2	**40(2–78)#**	**24**	2–23	0.56
Shredders								
g m^{-3}	**-69(-107–-31)§**	**-43**	-4(-40–32)	-2	1(-37–39)	0	-38–8	**0.09**
g day^{-1}	-33(-71–5)	**-18**	19(-19–57)	10	-4(-43–35)	-2	-17–10	0.46
Total macroinvertebrates								
g m^{-3}	-38(-77–1)	**-21**	16(-22–54)	8	29(-12–70)	16	-17–19	0.20
g day^{-1}	-6(-45–33)	**-3**	22(-16–60)	11	35(-4–74)	21	-2–21	0.55

Appendix 4 (continued). Mean effect size (ES)(post-treatment minus pre-treatment) and 90% confidence limits (CL; in parentheses) for each shade level, percentage change in ES pre- to post-treatment and 90% CLs for percent change for physical and biotic variables at three levels of shade retention (no, low, intermediate) based on treatment minus reference stream reach contrasts. Stream reaches were sampled for two years each both pre- and post-treatment in 25 streams in northwestern Oregon, southwestern Washington, and the Olympic peninsula from 2004-2009; the Olympic block had a two-year stagger in time. *P*-value is for the period × treatment interaction of a linear mixed effects model. We set $\alpha \leq 0.1$ for statistical significance. For each estimate: * = $P = 0.1$, # = $P < 0.1$-0.01, § = $P < 0.01$-0.001, and ‡ = $P < 0.001$. Statistically significant difference in ES are in red and percent changes falling outside the 90% CLs are **emboldened**.

	Shade Level							
	No (n = 8)		Low (n = 9)		Intermediate (n = 8)			
Response Variable	ES	% Change	ES	% Change	ES	% Change	90% CL	*P*
Macroinvertebrates								
Total counts of individuals								
number m^{-3}	**-41(-79–-3)**	**-22**	-2(-38–34)	-1	31(-7–69)	**19**	-21–18	0.47
number day^{-1}	30(-9–69)	15	32(-6–70)	16	16(-23–55)	**7**	8-17	0.82
Amphibians								
Counts (number reach-1)[a]								
Ascaphus truei[b]	-2(-7–3)	-154	0(-8–2)	0	3(-2–8)	**1263**	-376–1107	0.74
Dicamptodon spp.	**8(3–13)§**	22	3(-4–6)	20	<1(-5–5)	36	16–42	**0.08**
Rhyacotriton cascadae	-3(-10–0)	**-50**	6(0–10)	100	**9(4–14)#**	50	-39–106	**0.10**
Rhyacotriton kezeri	1(-1–4)	71	<1(-4–2)	25	-3(-7–3)	**-100**	-85–83	0.61
Rhyacotriton olympicus	-3(-5–1)	-233	**-3(-6–0)#**	**-833**	**5(2–8)#**	60	-767–96	**0.06**
Body condition (g)[c]								
Ascaphus truei								
larvae	15(2–28)	32	**32(17–47)‡**	**143**	1(-15–17)	2	-11–129	**0.04**
metamorphs	-2(-12–8)	-13	**26(10–42)#**	**520**	-4(-15–7)	-19	-131–456	0.13
adults	-5(-20–10)	-33	3(-7–13)	12	no data[d]	nd	-41–20	0.78
Dicamptodon spp.	-8(-26–10)	-17	-8(-26–10)	-19	14(-4–32)	**50**	-33–42	0.46
Rhyacotriton cascadae	7(-1–15)	78	**-10(-18–-2)#**	**-67**	11(-4–26)	57	-52–97	**0.10**
Rhyacotriton kezeri	7(-3–17)	50	4(-4–12)	40	11(-1–21)	**225**	6–204	0.65

[a]corrected for probability of detection. [b]larvae only. [c]data rank-transformed. [d]too few adults were captured in the Intermediate Shade treatment to estimate body condition.

Appendix 4 (continued). Mean effect size (ES)(post-treatment minus pre-treatment) and 90% confidence limits (CL; in parentheses) for each shade level, percentage change in ES pre- to post-treatment and 90% CLs for percent change for physical and biotic variables at three levels of shade retention (no, low, intermediate) based on treatment minus reference stream reach contrasts. Stream reaches were sampled for two years each both pre- and post-treatment in 25 streams in northwestern Oregon, southwestern Washington, and the Olympic peninsula from 2004-2009; the Olympic block had a two-year stagger in time. *P*-value is for the period × treatment interaction of a linear mixed effects model. We set $\alpha \leq 0.1$ for statistical significance. For each estimate: * = $P = 0.1$, # = $P < 0.1$-0.01, § = $P < 0.01$-0.001, and ‡ = $P < 0.001$. Statistically significant difference in ES are in red and percent changes falling outside the 90% CLs are **emboldened**.

	Shade Level							
	No (n = 8)		Low (n = 9)		Intermediate (n = 8)			
Response Variable	ES	% Change	ES	% Change	ES	% Change	90% CL	*P*
Amphibians								
Growth (g week-1)								
Ascaphus truei								
larvae	**0.01(0.00–0.02)#**	150	0.01(0.00–0.02)	133	0.02(0.01–0.03)	**800**	1–721	0.20
metamorphs	-0.02(-0.05–0.01)	-100	0.01(-0.02–0.04)	**800**	**-0.04(-0.07–-0.01)#**	-28	-250–698	0.39
Dicamptodon spp.	-0.04(-0.09–0.01)	-200	-0.01(-0.06–0.04)	**-35**	-0.02(-0.07–0.03)	-225	-251–55	0.72
Rhyacotriton cascadae	0.01(0.00–0.03)	40	-0.01(-0.03–0.01)	-175	**0.03(0.01–0.05)#**	**1150**	-336–1012	0.33
Rhyacotriton kezeri	**0.06(0.03–0.09)§**	121	-0.01(-0.04–0.02)	**-200**	<1(-0.03–0.03)	29	-173–140	**0.10**
Rhyacotriton olympicus	**0.02(0.00–0.04)#**	240	0.01(-0.01–0.03)	140	0.01(-0.01–0.03)	**433**	130–412	0.33

TIMBER FISH
& WILDLIFE

Timber, Fish and Wildlife Policy Committee
Forest Practices Board

PO BOX 47012, Olympia, WA 98504-4712

Policy Co-Chairs:
Terra Rentz, WA Department of Fish & Wildlife
Curt Veldhuisen, Skagit River System Cooperative

October 18, 2019

TO: Washington Forest Practices Board
FROM: Terra Rentz and Curt Veldhuisen
SUBJECT: TFW Policy Committee Report (August, September & October 2019)

SUMMARY OF POLICY RECOMMENDATIONS TO THE BOARD

Action Items

Accept policy's recommendation to accept the Extended Monitoring Framework as presented in Attachment 1.

Recommended Actions to be Presented by the AMPA

Accept Policy's recommendation that the following study does not warrant action by the Board: Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading.

Recommended Actions for February

Accept Policy's recommendation that the following study does not warrant action by the Board: Type N Experimental Buffer Treatment Study: Post-harvest comparison of genetic diversity and demographic findings for three stream-associated amphibians.

Informational Items

Policy has provided the following materials for the Board as they relate to current or recent action items:

1. Report on Extended Monitoring Framework (Attachment 1)

EXISTING PRIORITIES AND UPDATES

1. *Master Project Schedule - updated October 2019*
   Policy continues to work to maintain an up to date MPS reflective of current overages and underspending by projects. At this time, no additional formal review or approval is needed by the FPB since approval of the revised MPS in August. Policy continues to discuss the financial obligations of the ENREP study, per the Board's direction, and will provide any final recommended changes to the budget at the Board's February meeting.

2. *Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading*
   The report and associated documents were provided to the Board at your August meeting. Since then, at Policy's August 2019 meeting, Policy has determined that this study does not, by itself, warrant action by the FPB. However, this study will be among the studies considered by the Technical Type Np Prescriptions Workgroup process and the Charter will be modified accordingly. This vote passed with 6 thumbs up, 1 sideways, and Eastside Tribes and Federal Caucus absent. This Workgroup process is described further in the following topic.

Policy recommends that the findings of the Stream-Associated Amphibian Response do not warrant action by the Board at this time, however the technical implications and recommendations portion of the report warrant action by the Adaptive Management Program.

Additionally, Policy recommends that the study and findings be provided to the Technical Type Np Prescriptions Workgroup as a source of information.

3. *Amphibians Genetics Report (Type Np Hardrock)*
   In September, Policy was presented with findings and a presentation on the amphibian genetics component of the Type Np Hardrock study. Study findings did not indicate evidence of immediate effects of treatment on amphibian populations; however, the team qualified the study may not have had the power to detect slow and gradual changes over the long term. Therefore, they have limited ability to infer effects across further generations. The team recommended that the study could be further fortified by funding resamples several years into the future. Policy has determined that this study does not warrant action by the FPB. This motion passed with full consensus.

   The report for this study will be provided by the AMPA at a later meeting date.

   Policy recommends that the Amphibian Genetics Findings report does not warrant action by the Board.

4. *Technical Type Np Prescriptions Workgroup*
   Board members will recall that the Workgroup will consist of eight technical experts with strong technical backgrounds in physical, biological and forestry/operational aspects of headwater stream management. It will be guided by two co-chairs from the Policy committee: Jim Peters (NWIFC) and Darin Cramer (WFPA). The workgroup will generate buffering alternatives that address the results of numerous AMP and related external studies addressing riparian functions.

   Recent efforts by the Policy Committee, AMPA and staff have resulted in significant progress toward initiation of the Technical Type Np Prescriptions Workgoup:
   - Policy generated names, qualifications and caucus input on Workgroup nominees.
   - AMPA contacted Workgroup candidates, and all top-ranked candidates agreed to participate in the workgroup:

     Section VII. Membership

Workgroup Name	Focal Area	Role
Darin Cramer	Policy Liaison	Chair (non-voting)
Jim Peters	Policy Liaison	Vice Chair (non-voting)
Jeremy Groom	physical stream processes	Voting Member
John Stednick	physical stream processes	Voting Member
John Richardson	biological	Voting Member
Bob Bilby	biological	Voting Member
Steve Barnowe-Meyer	silviculture/field forestry	Voting Member
Chris Lunde	silviculture/field forestry	Voting Member
Heather Gibbs	AMP	Project Manager (non-voting)

   - AMPA and staff developed an improved plan for Workgroup member compensation, which was approved by Policy:

     Section VII. Compensation

Workgroup members will be selected using the Collaborative Research Approach to contracting. Specifically, all members of the Workgroup have been selected through the consensus process by Policy at the August 1, 2019 meeting.

All workgroup members, excluding Policy co-chairs will be compensated within the total budget of $200,000 for their active participation and adherence to the Charter. Compensation is intended to cover any expenses incurred during the duration of the project and to compensate members for professional contributions and time. As with all other contracts through the Adaptive Management Program, the Department of Natural Resources will award and manage these Collaborative Research Contracts.

Co-chairs will be compensated via reimbursement requests to DNR for expenses associated with travel, lodging, and/or per diem if necessary.

- AMPA updated expected delivery of key CMER research products in order to update the timeline in Section VI of the Charter. We recall that the potential for delays suggested by previous changes to this timeline were key concerns expressed by FPB members Bellon and Swedeen at the previous meeting:

Milestone/Task	**Earliest Expected**	**Reasonable Worse Case***
Informational: CMER-Approved **draft** BCIF Report to send to ISPR available	June 2018	N/A
Board acceptance of Policy Proposal	May 7, 2019	N/A
Receipt of **final** Buffer-Shade Amphibian Response Study Findings Report, and Direction ***from Policy***	Early spring 2019	N/A
Workgroup convened ***Informational:*** Receipt of ISP and CMER-Approved **final** Extensive Type N/F Temperature Report ***from CMER*** ***Informational***: CMER-Approved **draft** Hard Rock Phase II Extended Report to send to ISPR available	Oct 2019	Nov 2019 N/A Nov 2019
Receipt of **final** Extensive Type N/F Temperature Study, Findings Report, and Direction ***from Policy*** ***Informational***: CMER-Approved **draft** Type N Soft Rock Report (2yr post-harvest) to send to ISPR available	Nov 2019	Jan 2020 Jan 2020
Informational: Receipt of ISPR and CMER-Approved **final** BCIF Report ***from CMER*** (Changes from draft noted)	Jan 2020	Mar 2020
Receipt of BCIF Findings Report and Direction ***from Policy***	Feb 2020	Apr 2020
Informational: Receipt of ISPR and CMER-Approved **final** Hard Rock Phase II Extended Report ***from CMER***	May 2020	Jul 2020
Receipt of Hard Rock Phase II Extended Findings Report and Direction ***from Policy*** ***Informational***: Receipt of ISPR and CMER-Approved **final** Type N Soft Rock Report (2yr post-harvest) ***from CMER***	Jun 2020	Aug 2020
Workgroup develops “draft” Type Np water RMZ buffer prescription(s) for initial policy review	Jun 25, 2020	N/A

Receipt of Type N Soft Rock Findings Report and Direction ***from Policy***	Aug 2020	Oct 2020
Workgroup modifies proposed "draft" Type Np water RMZ buffer prescription(s) based on review of Type Np Soft Rock CMER study	3 mo post Soft Rock (est. Aug 2020)	3 mo post Soft Rock (est. Oct '20)
Final submission of deliverables to policy	6 mo post Soft Rock (Dec '20)	Jan 2021

- The present expectation of a product for PPB is now the end of 2020, somewhat sooner than the mid-2021 projection discussed at the last FPB meeting. Because this and previous timeline projections are estimates and rely on delivery of CMER products, Policy was not able to reach consensus that the latest projection should be formally approved. A motion was made by the County Caucus that Policy accept the Type Np charter as amended (reflective of updated timeline). This motion was seconded, and then failed to reach consensus: Conservation Caucus thumbs down; all other caucuses thumbs up.

5. *Small Forest Landowners' Low Impact Template*
   Having been granted an extension by Policy, the Template Group has been working toward a set of recommendations to be presented to Policy at the November meeting, scheduled for October 31. Although the workgroup output and initial discussion at Policy will not have occurred in time to be reported here, the Policy co-chairs can provide a verbal summary at the November Board meeting. However, Policy will need additional time into late 2019 to conduct ongoing discussions of workgroup materials and hopefully generate consensus recommendations.

   <u>The Board should anticipate a report from Policy on this topic at the February 2020 meeting.</u>

6. *Framework for Evaluating Extended Monitoring*
   To review, at the August 2018 Board Meeting the Board tasked Policy and CMER to jointly develop a proposal regarding how to evaluate proposals for extending the duration of monitoring at AMP projects. The impetus for this request was a lack of clarity on the process and rationale for extending the Type N Hard Rock study. A joint CMER-Policy workgroup was formed to explore a range of scenarios and develop a framework. The framework document was developed and has been formally approved by CMER and Policy as of the September 5, 2019 Policy Meeting with full consensus (Eastside Tribes and Federal Caucus absent) and is included in your materials package as Attachment 1.

   The proposed approach includes input and approval roles for CMER (e.g. methods, certainty), Policy (e.g. competing priorities, policy questions) and AMPA/Project Management staff (e.g. staff availability, timing). The approach generally relies on steps and documents that are already in use. The final approval of extension proposals will optimally be completed at the time of annual MPS review to allow consideration of implications of the extension (cost, staffing, timelines, added certainty) in context of impacts to other priorities.

   <u>Policy and CMER request that the Board review and approve the Extended Monitoring Framework document.</u>

7. *TFW Policy Improvement Initiative*
   As reported in Policy's previous report, the June 2019 Policy meeting included a joint CMER-Policy workshop to review and understand CMER's Protocols and Procedures Manual. During that workshop Policy members identified numerous opportunities to improve lacked efficiency and procedural clarity.

This effort has ben initiated and has begun with a review of written communication between CMER and Policy, specifically Findings Reports and related documents. A policy workgroup is making progress reviewing recent documents.

Policy expects to provide a report on this effort in 2020, depending on progress and competing priorities.

8. *Eastside Type N Riparian Effectiveness Project (ENREP)*

   With assistance from CMER and AMP staff, Policy has been evaluating the financial, inference and rule-making aspects of ENREP since earlier in 2019. Although the study design has been approved, the renewed attention was triggered by difficulties in site selection and the substantial cost increases projected for this project. Some caucuses expressed concern that study design limitations could undermine the usefulness of results to support future management decisions.

   Policy conducted an ENREP workshop at their May meeting and followed by requesting additional information from CMER. Additional questions focused on aspects of inference and the specific study components driving the cost increases. At the October Policy meeting, CMER and project scientists presented responses to 3 of the 4 questions, which were very helpful. However, CMER had not yet deliberated on a response to the over-arching fourth question but hopes to do so in time to inform Policy at their next meeting. If so, Policy co-chairs will brief you at the upcoming Board meeting.

   Policy will need addition time to evaluate the full CMER response and thus expects to provide a recommendation to the Board detailing any proposed changes to the ENREP study at the February 2020 meeting.

Other Updates on AMP Personnel

As Board members are likely aware, in August Mark Hicks became the permanent AMPA after the retirement of interim Howard Haemmerle. Among other tasks, Mark is working on filling numerous vacancies including Project Manager, Wetland Scientist, and Eastside Scientist.

With the impending retirement of Dave Schuett-Hames, Jenelle Black was hired as incoming lead CMER scientist, beginning with a brief overlapping period. The lead scientist conducts scientific work (research, writing and SAG support) and supervision of other CMER staff scientists. This is a major transition, as Dave has served CMER and the AMP for over 30 years. Black is a hydrologist and also was the original project manager hired by the AMP in the mid-2000s.

WORKGROUP REPORT ON EXTENDED MONITORING

Date: July 10, 2019 - draft v 3.3 (for CMER and Policy review);
Approved by Policy September 5, 2019

From: Extended Monitoring Workgroup: Doug Hooks, Harry Bell & Chris Mendoza (CMER members), Curt Veldhuisen, Darin Cramer & Chris Conklin (Policy members)

I. Background and Purpose

When research and monitoring projects are designed within the Adaptive Management Program (AMP), the study duration is an important component of the study plan. Given the number of CMER projects the Board funds biennially, and the limitations of human and financial resources, it's important that all funded projects are carried out in a manner which provides meaningful, defensible scientific results. Once project scoping and study design passes the various review steps (Independent Science Panel Review, CMER and TFW Policy) and has been implemented, preliminary results may suggest longer duration monitoring is needed to further reduce uncertainty, strengthen confidence in results, and better inform TFW Policy and the WA Forest Practices Board's (Board) decision making process.

Despite the potential benefits, extending monitoring beyond the original scope of a project will require expanded costs and staff demands, and could potentially delay consideration of results by Policy and the Forest Practices Board beyond important deadlines (e.g. meeting Ecology Clean Water Act milestones). The existing AMP project approval process is geared toward the initiation, implementation and completion of new projects but lacks a defined process for assessing such extensions. At their August 2018 meeting, the Board requested input on how extension proposals should be evaluated.

A work group was assembled of the CMER and Policy members listed above. This report explains their assessment of the issue and resulting recommendations.

II. Workgroup Efforts

Considerations and Discussion

Because work group members have extensive experience in the AMP, efforts utilized their personal knowledge to consider the following:

- Discussion of Extended Monitoring scenarios in past and future

- Circumstances beyond scope of Extended Monitoring Framework (i.e. major changes requiring a new design or minor changes that could be addressed by a memo of decision by PI or SAG to CMER).

- Review of existing procedural tools and timelines and applicability to extended monitoring.

- Considerations for developing new process: improvements vs additional effort required

- Need for involvement and approval by CMER, Policy, AMP Administrator, Forest Practices Board (FPB)

- How to evaluate consequences to AMP budget, staff, committee work loads

- Information needed to evaluate EM proposals

III. Recommendations

The Workgroup determined most of the documentation needs for extended monitoring are like those presently being used for development of new projects. For this reason, several of the document types CMER has developed are applicable to consideration of extended monitoring. The advantages of using existing documents include avoiding additional development effort and minimal learning curve effort for users over the long run.

The Workgroup anticipates some adaptations may be needed to accommodate differing circumstances. Once this approach has been implemented and refined, it may be incorporated into the Protocols and Standards Manual and/or Board Manual Section 23.

The Workgroup anticipates several scenarios when extended monitoring could be formally considered. They include:

1. **At project initiation** during project scoping, best available science review, preferred alternatives development and approval by TFW Policy. The decision to provide additional monitoring outside the scope of the initial study design doesn't necessarily need to occur at this time but needs to be discussed. If no decision about extended monitoring is made at this time, it may be revisited later in project implementation as needed (see below);
2. **Mid-stream of a Project** due to unforeseen circumstances that directly impact the ability of the project to be carried out as originally designed (delays in site selection, loss of treatment/reference sites, harvest timing out of sync with applied treatments, etc.);
3. **Near the end of the field component of a project** extended monitoring may be considered prior to last year of post-treatment field data collection, but ideally, before any field equipment is removed. Extending monitoring may be of interest due to the

magnitude of impacts, unexpected findings, and/or to learn more about long-term impacts from treatments (e.g., stream temperature, shade, wind throw, etc.) relative to the original project scope. This is the scenario the workgroup spent most of its time considering.

Some members of the Workgroup believe consideration of extended monitoring should be a standard requirement at a certain optimal stage of all relevant AMP projects. The group did not determine whether such a prescribed trigger would eliminate or coexist with the circumstance-driven scenarios described above. This question may benefit from further discussion during CMER and Policy review.

Extended Monitoring Decision Framework

Extended monitoring consideration generally consists of four steps and can be initiated by any AMP participant (PI, CMER, Policy, FPB).

1. PI and project team (SAG) develops brief extended monitoring proposal by updating the prospective findings report (rationale, benefits, link to AM, costs, etc.).

2. Extended monitoring proposal and updated prospective findings report are presented to CMER for review and approval.

3. Once approved by CMER, Policy considers extended monitoring proposal within the context of biennial MPS consideration.

4. If Policy approves extended monitoring, PI and project team (SAG) updates project charter which is reviewed and approved by CMER and Policy.

Note - Since extending monitoring beyond the scope of initial project study designs can affect AMP budget/priorities, the steps above need to occur well in advance of the annual budget process, which typically concludes at the May FPB meeting. Step 1 above should begin around the end of each calendar year in order to give CMER and TFW Policy adequate time to prepare and consider the information prior to the May FPB meeting (of the following year).

Attachments

Summary Form

Example prospective findings report

DEPARTMENT OF
NATURAL RESOURCES

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October 30, 2019

TO: Forest Practices Board

FROM: Marc Engel, Senior Policy Planner, Forest Practices Division

SUBJECT: Petition for Rulemaking Regarding the Northern Spotted Owl

The attached petition for rulemaking from the North Central Washington Audubon Society (Audubon) was received as complete on September 23, 2019. Board staff notified Audubon of receipt within the required five business days and, by November 21st, the Board must either accept the petition and initiate rulemaking or deny the petition in writing stating its reasons for denial specifically addressing Audubon's concerns. (WAC 222-08-100) If the Board issues a denial, its explanation may also indicate the alternative means by which it will address the concerns raised by the petitioner. (RCW 34.05.330(1))

The petition states that the rules for spotted owl special emphasis areas (SOSEA) east of the Cascade Crest are not achieving the protection measures intended for spotted owl habitat. The petition suggests the rules are failing in the recovery of the owl and thereby demonstrate that the rules or their application in eastern Washington need to be revisited and strengthened. Audubon requests the following:

> "Pursuant to WAC 222-10-041(6), North Central Washington Audubon requests a moratorium be placed on logging anywhere within SOSEA sites in Eastern Washington pending reconsideration of WAC 222-10-041 as it applies to them and confirmation that the rules as currently written have been and are being adhered to."

The petition specifically references the Board's SEPA policies for forest practices applications. WAC 222-10-041 *Northern spotted owls*, is designed to identify and address potential adverse impacts to the owl through an environmental analysis when specific forest practices, including harvest, are proposed within suitable spotted owl habitat.

Recommendations:

DNR staff recommends the Board deny the petitioner's request for a moratorium. There are two reasons for this recommendation. First, the Board, through the Commissioner of Public Lands, asked for a formal opinion of the Attorney General of Washington concerning its authority with respect to a proposed moratorium on forest practices applications submitted on potentially unstable slopes. This request followed the 2014 Oso landslide. The Attorney General's Opinion (2015 No. 1) stated that:

> Nothing in the Forest Practices Act expressly authorizes the Forest Practices Board to adopt a moratorium on the acceptance or approval of forest practices applications. Moreover, we find it unlikely that such a power should be implied because it would be contrary to the statutory directives regarding processing and approval or disapproval of such applications.[1]

The second reason comes from the rule proposal's structure. The rules in Chapter 222-10 WAC, such as the one cited in the petition, are SEPA policies that guide environmental analysis for individual proposals (i.e., to determine whether a proposal will have a probable significant adverse environmental impact, requiring further analysis through an environmental impact statement). Those rules are not designed or intended to establish hard and fast substantive standards dictating acceptable or unacceptable harvest practices or locations for harvest.

With regard to increasing the options for spotted owls, staff recommends the Board continue to support the development of a programmatic Northern Spotted Owl Safe Harbor Agreement (SHA). DNR has prepared draft legislation requesting authority to enter into a programmatic SHA with the U.S. Fish and Wildlife Service. Under the Endangered Species Act and rules, SHAs provide incentives for non-federal landowners to voluntarily restore, enhance, or maintain habitat for listed species and provides assurances that additional restrictions will not be imposed as a result of their voluntary conservation efforts.

At your upcoming November 13 meeting, staff will provide additional information regarding the process DNR uses to evaluate proposed applications involving spotted owl habitat, including determining classifications and updating habitat maps. Should you have any questions in the meantime, please feel free to contact me at 360-902-1309 or marc.engel@dnr.wa.gov.

SF

Attachment

c: Joseph Shramek, Marc Ratcliff, Sherri Felix, DNR
Hannah Anderson, Chris Conklin, Gary Bell, WDFW

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[1] This opinion is available at: https://www.atg.wa.gov/ago-opinions/authority-forest-practices-board-adopt-moratorium-forest-practices-applications-due (last visited Oct. 29, 2019).

North Central Washington
AUDUBON SOCIETY

North Central Washington Audubon Society
P.O. Box 2934
Wenatchee, WA 98807
www.ncwaudubon.org

September 23, 2019

Department of Natural Resources
Stephen Bernath, Forest Practices Board Chair
1111 Washington St. SE
PO Box 47012
Olympia, WA 98504-7012

Re: Petition to the Forest Practices Board Regarding the Spotted Owl in Eastern Washington

Washington State's Spotted Owl Special Emphasis Areas (SOSEA) represent a core strategy for preventing the continued decline of the Northern Spotted Owl on nonfederal lands in Washington over which the state has jurisdiction. North Central Washington Audubon Society contends that the rules applying to SOSEAs east of the Cascade Crest demonstrably are not achieving the protection of needed habitat. Simply put, they are failing the owl, and thereby show that the law, or at least its application in Eastern Washington, needs to be revisited and strengthened.

The following example, involving the only known breeding pair of Northern Spotted Owl remaining in Eastern Washington and Oregon, demonstrates the current rules are insufficient and thereby flawed, and/or they are not being adhered to.

Case in Point

We are aware of a pair of Northern Spotted Owls (NSO) occupying a SOSEA in Eastern Washington. In 2016 they returned to nest in federal timberlands that are part of a SOSEA that also contains private forest parcels in checkerboard fashion. The same year, the timber company that owns the private parcels applied for and received permits to log some of its lands lying within the 1.8-mile radius area (222-10-041 (4) refers to it as the "median home range circle") of the SOSEA. In the process of considering the requested permits, the Department of Natural Resources (DNR) and the Department of Fish and Wildlife determined the habitat quality within this zone did not meet defined standards that would allow them to deny the applications. Hence, the permits were granted.

With these permits approved, logging took place in the winter of 2016 and into the nesting season of 2017. Because it was so close to and disruptive of the owl's nest site, they abandoned the stand they've occupied for 13 of the last 16 years and moved east to a section of the privately-owned timberland within the median home range circle previously determined to be unsuitable for them. In 2017, they successfully fledged a chick while nesting on this supposedly unsuitable private timber land. In 2018, they returned to the historic nest on National Forest Land and successfully fledged 2 chicks. Importantly, this is the only documented NSO pair known to have successfully reproduced in 2018 in all of both eastern Washington and eastern Oregon. In 2019, possibly because of the loss of foraging habitat north of the historic nest site in 2016 and 2017, they nested again on the supposedly unsuitable private timber land parcel.

Applicable Law

We believe DNR must adhere to WAC 222-10-041 (2), (4), (6), and (7) in making decisions in this matter:

"(2) **In SOSEAs or areas of SOSEAs where the goal is dispersal support**, either suitable spotted owl habitat should be maintained to protect the viability of the owl(s) associated with each northern spotted owl site center or dispersal habitat should be managed, over time, to provide the dispersal support for that particular SOSEA as described in the SOSEA goals. Dispersal support is provided by a landscape which includes dispersal habitat at the stand level interspersed with areas of higher quality habitat. Stands of dispersal habitat should be managed to reduce gaps between stands and to maintain a sufficient level of dispersal habitat to meet the SOSEA goals over time."

"(4) **Within SOSEAs,** the following amounts of suitable habitat are generally assumed to be necessary to maintain the viability of the owl(s) associated with each northern spotted owl site center, in the absence of more specific data or a mitigation plan, as provided for in subsections (6) and (7) of this section respectively:

(a) All suitable spotted owl habitat within 0.7 mile of each northern spotted owl site center;

(b) Including the suitable spotted owl habitat identified in (a) of this subsection:

(i) For the Hoh-Clearwater/Coastal Link SOSEA - A total of 5,863 acres of suitable spotted owl habitat within the median home range circle (2.7-mile radius).

(ii) For all other SOSEAs - A total of 2,605 acres of suitable spotted owl habitat within the median home range circle (1.8-mile radius)."

"(6) The assumptions set forth in subsection (4) of this section are based on regional data. Applicants or others may submit information that is more current, accurate, or specific to a northern spotted owl site center, proposal, or SOSEA circumstances or goals. The department shall use such information in making its determinations under this section where the department finds, in consultation with the department of fish and wildlife, that the information is more likely to be valid for the particular circumstances than the assumptions established under subsection (4) of this section. If the department does not use the information, it shall explain its reasons in writing to the applicant."

"(7) The department shall consider measures to mitigate identified adverse impacts of an applicant's proposal. Mitigation measures must contribute to the achievement of SOSEA goals or to supporting the viability of impacted northern spotted owl site centers."

Discussion

These habitat calls and approval of harvest in a circle already deficient in suitable spotted owl habitat raise the question of whether WAC 222-10-041 (2), (4), (6), and (7) were, or are, being followed. If a SOSEA has less than the 2,605 acres of suitable spotted owl habitat within its median home range circle and additional unsuitable habitat is allowed to be harvested, the circle will remain deficient and the achievement of SOSEA goals will thereby never be met. This is contrary to (2) above.

The fact that this owl pair subsequently chose to nest, and did so successfully, in the habitat previously determined not to be of high enough quality to support them, proves that the law, as it applies to Eastern Washington SOSEA median home range circles is flawed, not being followed, or both. DNR should be required to consider and use this information in accordance with (4) and (6) above. It is also known that the Northern Spotted Owl in Eastern Washington is in continuing decline and facing almost certain extirpation if stronger measures are not taken.

Approval of the permits cited in the case above were certain to have negative impacts within the median home range of the owl circle and thereby on the SOSEA itself. WAC 222-10-041 (7) clearly states that DNR must consider mitigation measures for the adverse impacts approval of these permits allowed. We are, however, unaware of any such action having been taken.

Recently the timber company announced that they will reserve 100 acres around this nest tree on their land. This mitigation measure is entirely inadequate given that the circle is already below threshold. The integrity of the SOSEA must be maintained if extirpation of the northern spotted owl there is to be prevented. For this to occur, the rules and administration of the law as they apply to SOSEAs east of the Cascade Crest warrant reconsideration.

Also of concern is the well documented threat the Barred Owl poses to the continued existence of the NSO. Habitat fragmentation is known to be a primary factor contributing to the Barred Owl's interface with, and thereby negative impact upon, the NSO. It should be obvious that actions that increase fragmentation within SOSEAs are contrary to the goals they are intended to achieve.

Our Request

Pursuant to WAC 222-10-041(6), North Central Washington Audubon Society requests a moratorium be placed on logging anywhere within SOSEA sites in Eastern Washington pending reconsideration of WAC 222-10-041 as it applies to them and confirmation that the rules as currently written have been and are being adhered to.

Sincerely,

Arthur Campbell

Arthur Campbell
President, North Central Washington Audubon Society

CC Hillary Franz, Commissioner of Public Lands
Todd Welker, Region Manager, DNR Southeast Region
Jim Brown, Director, Washington Department of Fish & Wildlife Region 2
Trina Bayard, Director of Bird Conservation, Audubon Washington

DEPARTMENT OF
NATURAL RESOURCES

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October 17, 2019

TO: Forest Practices Board

FROM: Marc Engel, Assistant Division Manager, Policy and Services
Forest Practices

SUBJECT: Northern Spotted Owl Conservation Advisory Group Update

The Forest Practices Board is required, per WAC 222-16-010, to annually evaluate the need to maintain the Northern Spotted Owl Conservation Advisory Group. This group is convened when the Washington Department of Fish and Wildlife (WDFW) approves a northern spotted owl protocol survey demonstrating the absence of owl detections within the habitat supporting an owl site center. When convened, the group evaluates if the owl habitat is to be maintained in support of northern spotted owl recovery.

Since the August 2018 status report there were no northern spotted owl surveys submitted to WDFW for review and approval; as such, the group was not convened.

I will be requesting you confirm the Board’s support of the Northern Spotted Owl Conservation Advisory Group at the upcoming November meeting.

Should you have any questions please feel free to contact me at 360-902-1309 or marc.engel@dnr.wa.gov.

ME

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October 30, 2019

Memorandum

TO: Forest Practices Board members

FROM: Joe Shramek, Forest Practices Division Manager

SUBJECT: Adaptive management program fiscal audit for 2017-19 biennium

I'm pleased to transmit the fiscal audit report of the adaptive management program for the 2017-19 biennium. This report was prepared in partial fulfillment[1] of requirements of WAC 222-12-045(2)(e), which calls for "biennial fiscal and performance audits of the program by the department or other appropriate and accepting independent state agency." The fiscal audit was conducted by Jennifer Woods, the internal auditor for the Department of Retirement Services, under contract with the DNR.

Subject to the audit, DNR awarded contracts totaling approximately $14.5 million during the 17-19 biennium to complete work necessary to support the adaptive management program. The audit found that "the program has generally implemented a process to protect state funds and to be compliant with state laws and regulations."

The audit resulted in a single key finding: that the department had not included in competitive "request for proposal" (RFP) solicitations a clear process for complaints and protests as required by RCW 39.26.170 and Department of Enterprise Services' policy. This came about because the DNR's standard RFP template had not been updated to include a reference to a compliant process. DNR has corrected this deficiency.

I will be available at the November 2019 Board meeting to present highlights and respond to questions about the fiscal audit.

Attachment: Adaptive Management Program Fiscal Audit for 2017-2019 Biennium. October 18, 2019 memo to Stephen Bernath from Jennifer Woods, CPA, CIA, CFE, CRMA. 8p.

cc: Mark Hicks, Adaptive Management Program Administrator
Dawn Hitchens, DNR Forest Practices Division Assistant Manager for Business

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[1] A seperate *performance audit* is currently being conducted by the Office of the State Auditor.

October 18, 2019

MEMORANDUM

TO: Stephen Bernath, Deputy Supervisor for Forest Practices

FROM: Jennifer Woods, CPA, CIA, CFE, CRMA

SUBJECT: Adaptive Management Program Fiscal Audit for 2017-2019 Biennium

EXECUTIVE SUMMARY

The Adaptive Management Program (AMP) was created to provide science-based recommendations and technical information to assist the Forest Practices Board in determining if and when it is necessary or advisable to adjust rules and guidance. The Department of Natural Resources (DNR) awarded approximately $14.5 million to governmental agencies, not-for-profit organizations, contractors and tribes during the 17-19 biennium to complete work necessary to support the AMP.

Biennial fiscal and performance audits of the AMP are required by the forest practices rule, WAC 222-12-045(2)(e). The most recent fiscal audit of the AMP was completed in October 2017.

The purpose of this audit was to provide DNR management with reasonable assurance that:

1. AMP science contracts awarded during the 17-19 biennium were procured in accordance with applicable laws, rules and regulations.
2. Deliverables agreed upon in AMP participation grants for non-governmental organizations awarded during the 17-19 biennium were provided and that only allowable costs were reimbursed.
3. Deliverables agreed upon in AMP tribal participation grants for one-time funding for cultural resources projects awarded during the 17-19 biennium were provided and that only allowable costs were reimbursed.

Overall, I found that the department has generally implemented a process to protect state funds and to be compliant with state laws and regulations. As to be expected of any program with many varied participants, there are opportunities to improve processes. The “Key Finding” section of this report contains a summary of audit recommendations.

SCOPE & METHODOLOGY

The scope of this audit included AMP science contracts, participation grants for non-governmental agencies and tribal participation grants entered into during the 17-19 biennium.

To carry out this audit, I reviewed documents, including contracts, correspondence, invoices, and reports and interviewed staff to gain an understanding of the procurement and contract management process. A random sample of 50% of the population of contracts for each objective was selected for testing.

This audit was conducted in accordance with the *International Standards for the Professional Practice of Internal* Auditing contained in the *International Professional Practices Framework* issued by the Institute of Internal Auditors.

In my professional judgement, sufficient and appropriate audit procedures were completed and appropriate evidence gathered to support the accuracy of the conclusions reached and contained in this report.

OVERVIEW

Objective #1

Every biennium, the department enters into contracts with governments, non-governmental agencies and tribes for work to support the AMP. Depending on the goods or services required, the department will use either a competitive solicitation, direct buy, or sole-source procurement method.

I identified the state laws, rules and regulations applicable to goods and services procurement and reviewed each selected contract file to determine compliance.

Collaborative research was the purpose of the majority of the AMP science contracts reviewed. The WA State Department of Enterprise Services (DES) exempts contracts related to collaborative research from sole source requirements (e.g. DES approval and providing a public inspection period). The department cited the collaborative research exemption appropriately for each contract reviewed.

Additional contracts that were procured using the direct buy and the competitive solicitation (request for proposals (RFP)) methods were also reviewed. No issues were identified through review of the contract procured using the direct buy method. I reviewed documentation, including the RFP and department procedures, for the contracts procured using the competitive solicitation method and identified the lack of a clear and transparent complaint process as required by RCW 39.26.170 and Department of Enterprise Services Policy #DES-170-00. See issue in the “Key Finding” Section.

Objective #2

Allowable costs and deliverables required in the AMP participation grants were identified for each agreement reviewed. Agreement files including correspondence, invoices and progress reports were reviewed to determine whether only allowable costs were reimbursed and that all deliverables were received prior to payment. Overall, the department received required deliverables and reimbursed allowable costs. Minor recommendations related to travel expenses, contract deliverables, contract revisions and allowable expenses were communicated to management.

Objective #3

Allowable costs and deliverables required in the AMP tribal participation grants were identified for each agreement reviewed. Agreement files including correspondence, invoices and progress reports were reviewed to determine whether only allowable costs were reimbursed and that all deliverables were received prior to payment. Overall, the department received required deliverables and reimbursed allowable costs. Minor recommendations related to allowable costs and indirect cost rates were communicated to management.

KEY FINDING

Description of Condition

State law requires the department to have a clear and transparent complaint and protest process for competitive solicitations. The Department of Enterprise Services Policy #DES-170-00 defines the minimum requirements for the complaint and protest process. The department used the competitive solicitation process to procure at least three contracts for services in the total amount of $438,385 during the 17-19 biennium.

The department includes a description of the protest procedure in the RFP and Request for Quotes and Qualifications (RFQQ) templates. However, a clear and transparent complaint process meeting the minimum requirements of RCW 39.26.170 and Department of Enterprise Services Policy #DES-170-00 was not included in the RFPs reviewed.

The most recent RFQQ template dated 8/9/2019 includes a complaint process that meets the minimum requirements. This template was used for the most recent RFQQ posted (RFQQ 20-14).

Cause of Condition

The department followed standard processes to procure the contract. However, the RFP and RFQQ templates in use during the time period under review were not updated to include reference to a complaint process.

Effect of Condition

The department cannot demonstrate it has a clear and transparent complaint process that includes the minimum requirements defined by DES.

Recommendation

Continue to use the most current RFQQ template that includes a complaint process in future solicitations. Ensure the RFP template is updated to include the complaint process and use the updated template in future solicitations.

APPLICABLE CRITERIA

RCW 39.26.170

Complaints—Protests.

(1) All agencies that have original or delegated procurement authority for goods or services must have a clear and transparent complaint process. The complaint process must provide for the complaint to be submitted and response provided before the deadline for bid submissions.

(2) All agencies that have original or delegated procurement authority for goods or services must have a clear and transparent protest process. The protest process must include a protest period after the apparent successful bidder is announced but before the contract is signed.

(3) The director may grant authority for an agency to sign a contract before the protest process is completed due to exigent circumstances.

[2012 c 224 § 19.]

Washington State Department of
Enterprise Services

POLICY # DES-170-00	**COMPLAINTS AND PROTESTS (RCW 39.26.170)**
1) Purpose:	This policy provides the following information: 1) Minimum requirements for a complaint process and a protest process. 2) The criteria for filing a complaint or protest. 3) Agency response requirements and timelines. 4) How to request authority to sign a contract before the protest process is completed.
2) Enabling Legislation: RCW 39.26.170	Beginning January 1, 2013, agencies with original or delegated authority must have a procurement complaint process and protest process, both of which are clear and transparent. In addition: 1) The complaint process, including the agency response to complaints, must occur before the deadline for bid submissions. 2) The protest process must include a protest period after the apparent successful bidder is announced but before the contract is signed.
3) Complaint Process Purpose and Requirements:	The complaint process occurs early in the procurement process. The purpose of a complaint process is to settle unresolved vendor issues or concerns that either were not or could not be resolved during the question and answer period. The complaint process allows vendors to focus on the solicitation requirements and evaluation process and raise issues with these processes early enough in the process to allow an agency to correct a problem before bids are submitted and time expended on evaluations. A good complaint process can help reduce or eliminate the number of protests that would later be filed. The agency's procurement complaint process must meet the following minimum requirements: 1) Vendors must be given an opportunity to submit a complaint to the agency based on any of the following: a) The solicitation unnecessarily restricts competition; b) The solicitation evaluation or scoring process is unfair or flawed; or c) The solicitation requirements are inadequate or insufficient to prepare a response. 2) Vendors must be allowed to submit complaints up to 5 business days

	prior to the bid response deadline. In addition, agencies can require vendor complaints to meet the following requirements: a) Must be in writing. b) Must be sent to the procurement coordinator, or designee, in a timely manner. c) Should clearly articulate the basis for the complaint. d) Should include a proposed remedy. 3) The procurement coordinator or designee must respond to complaints in writing. 4) The response to complaints including any changes to the solicitation must be posted on WEBS. 5) The agency head is to be notified of all complaints and be provided a copy of the agency's response. 6) The complaint may not be raised again during the protest period. 7) The agency complaint process does not need to include an appeal process.
4) Protest Process Purpose and Requirements:	The protest process occurs after the bids are submitted and evaluated. This allows bidders to focus on the evaluation process to ensure its integrity and fairness. Protests can raise issues related to the evaluation process as set out in the solicitation or how it the process was executed. This allows an agency to correct evaluation process errors and problems before a contract is executed. The agency's procurement protest process must meet the following minimum requirements: 1) After the announcement of the apparent successful bidder (ASB), agencies must offer a debriefing conference to any bidder upon request. 2) Agencies must give bidders a minimum of at least 3 business days after the ASB is announced to request a debriefing conference. 3) Agencies can require bidder participation in a debriefing conference as a prerequisite for submitting a protest. 4) Agencies must give bidders at least 5 business days after their debriefing conference to file a protest. 5) The protest process as a minimum, must allow vendors an opportunity to submit a protest based on any of the following: a) A matter of bias, discrimination, or conflict of interest on the part of an evaluator;

	b) Errors in computing the scores; or c) Non-compliance with procedures described in the procurement document or agency protest process or DES requirements. 6) Agencies should assign a neutral party that had no involvement in the evaluation and award process to investigate and respond to the protest. 7) Agencies must issue a written protest response no more than 10 business days from receipt of the protest, unless additional time is needed. The agency should notify the protesting bidder if additional time is needed. 8) The agency protest decision is final and no appeal process will be required. If a protesting bidder does not accept the agency protest response, the bidder may try to seek relief from superior court. 9) At the time that the agency protest response is issued, the agency head and the Department of Enterprise Services Director must be provided a copy of the original protest and the agency's response. 10) Small and micro agencies that lack staff to address a protest may request assistance from DES.
5) Additional Requirements	1) Consistent with RCW 39.26.170, all competitive procurements must include an announcement of the ASB(s). 2) Consistent with RCW 39.26.030, following the announcement of the ASB(s), bid submissions and bid evaluations must be available for public inspection.
6) Compliance:	Agencies are expected to exercise sound professional judgment in implementing an objective and transparent complaint process and protest process. The agency's record of compliance will be factored into the agency risk assessment.
7) Exemptions: RCW 39.26.170(3)	The agency may not sign a contract before the protest process is completed except when the Enterprise Services Director grants the agency the authority to do so. Authority will only be granted if there are exigent circumstances that necessitate the contract to be signed. To request an exemption, the agency head must submit the request to the Enterprise Services Director. The request should explain the exigent circumstances and why it would be in the best interest of the state to grant the request.
8) Definitions:	"Apparent Successful Bidder" is the lowest responsive and responsible Bidder as determined by the bid evaluation process and prior to Bidder negotiations. (See RCW 39.26.160(6)) "Bid" means an offer, proposal, or quote for goods or services in response

	to a solicitation issued for such goods or services by the department or an agency of Washington state government. (See RCW 39.26.010(2))
9) FAQs:	Frequently Asked Questions
Previous Version	REV 01-08-15 - Added Section Numbering. - Added Revision Date. - Minor Formatting. - Move FAQs to centralized webpage.

DEPARTMENT OF
NATURAL RESOURCES

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October 29, 2019

TO: Forest Practices Board

FROM: Marc Engel, Senior Policy Planner, Forest Practices Division

SUBJECT: Recommendation on Critical Habitat (state) for the Mountain (woodland) Caribou *(Rangifer tarandus caribou)*

On October 2, 2019 the United States Fish and Wildlife Service (USFWS) published in the Federal Register their final rule listing the southern mountain caribou distinct population segment (DPS) of woodland caribou as endangered under the Endangered Species Act. This rule defines the DPS as 17 subpopulations of woodland caribou, including the currently endangered southern Selkirk subpopulation known to move between Washington, Idaho and British Columbia. Also, the rule reaffirms the previous critical habitat designated for the southern Selkirk subpopulation as the US portion of the new DPS.

Forest practices rules require the Department of Natural Resources (department), within 30 days of a Federal Register publishing date of a final listing and/or final critical habitat rule, to (1) consult with the Washington Department of Fish and Wildlife (WDFW) then (2) submit to the Board recommendations on whether to amend its current protections under WAC 222-16-080 *Critical habitats (state) of threatened and endangered species*. Specific forest practices involving the species in this rule are Class IV-special applications requiring review under the State Environmental Policy Act.

Background. The southern Selkirk subpopulation of the woodland caribou was state listed as endangered in 1982, federally listed as endangered in 1984, and federally designated critical habitat in 2012. USFWS's 2014 proposal to relist this caribou as threatened and reaffirm the same critical habitat resulted in a court order reopening the public comment period for the 2012 rule. Comments received from both public comment periods are addressed in this 2019 final rule.

The critical habitat designated in 2012 and reaffirmed by this final rule applies to approximately 30,010 acres in Washington and Idaho. The habitat within Washington occurs on federal land within the Colville National Forest in the far northeast corner of the state.

Recommendation. Upon consultation with WDFW, the department recommends the Board take no action to amend its current rule for the mountain (woodland) caribou. The department's reasoning is based on WDFW's assessment of the caribou's status as stated in the attached October 21, 2019 letter to the department. The reasoning is that the sole remaining caribou in Washington has been relocated to British Columbia and WDFW believes the South Selkirk herd is unlikely to occupy habitat in Washington within the near future, which precludes any need for modification to the existing rule at this time.

If you have any questions, please feel free to contact me at marc.engel@dnr.wa.gov or 360-902-1390, or Gary Bell at 360-902-1412 or gary.bell@wdfw.wa.gov. We will also be available at your upcoming November 13 meeting.

SF
Attachment

c: Joseph Shramek, Marc Ratcliff, Sherri Felix
Hannah Anderson, Terra Rentz, Chris Conklin, Gary Bell

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State of Washington
DEPARTMENT OF FISH AND WILDLIFE
Mailing Address: P.O. Box 43200, Olympia, WA 98504-3200 • (360) 902-2200 • TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia, WA

October 21, 2019

To: Joe Shramek, DNR Forest Practices Division Manager

From: Chris Conklin, WDFW Forest Habitats Section Manager

Subject: WDFW Recommendations for the Southern Mountain Caribou Distinct Population Segment as Pertains to the Recent Federal Amendment to Endangered Listing

On October 2, 2019, the US Fish & Wildlife Service (USFWS) published an amendment to the listing for the southern mountain caribou Distinct Population Segment (DPS) of woodland caribou. The amendment defines and clarifies the southern mountain caribou DPS, which includes the currently listed South Selkirk subpopulation that has historically used habitat in Washington (WA), Idaho, and British Columbia, Canada. It also confirms the listing status of the southern mountain DPS as Endangered and reaffirms the previous designation of approximately 30,010 acres of national forest lands (above 5000 feet elevation) as critical habitat (CH) for the southern mountain DPS.

Woodland caribou (*Rangifer tarandus caribou)*, a subspecies of caribou, occur across the boreal regions of North America and are comprised of eight recognized populations. The southern mountain caribou population consists of 17 subpopulations (herds) with the South Selkirk herd being one of these. Southern mountain caribou are distinguishable from other populations of woodland caribou by their inhabitation of mountainous areas with deep snow accumulations and their winter diet of primarily boreal lichens.

Predation is considered the most immediate threat to the South Selkirk subpopulation. Past conversion of old-growth forests to earlier successional stages have brought higher densities of deer, moose, and elk, and their predators (i.e. wolves, cougars, and bears), into closer proximity to herd members, resulting in greater predation risk to caribou. Other threats include highway collisions, human disturbance associated with winter backcountry recreation, small population size coupled with isolation from neighboring subpopulations, wildfires and climate change.

Overall abundance of southern mountain caribou has declined 45% since the late 1980s and was estimated at 1,544 animals during 2008-2014. The South Selkirk subpopulation has ranged between 33 and 51 animals from 1991-2009, but declined rapidly to just 12 individuals as of 2016. Most recently, the herd has continued to decline to the point that the sole remaining caribou was relocated to British Columbia in 2019 for potential conservation actions (i.e. captive breeding and rearing). At this time, the South Selkirk subpopulation could be considered to be functionally extirpated in Washington.

WDFW is not recommending any changes to the current forest practice rule (WAC 222-16-080) regarding Critical Habitat (State) for woodland caribou at this time. The fact that the South Selkirk herd is unlikely to occupy habitat in Washington within the near future precludes any need for modification of the existing rule at this time. If and when southern mountain caribou are to reoccupy their range in Washington, WDFW may consider reevaluation of the rule at that time. In the meantime, WDFW will continue to support conservation and recovery efforts for the South Selkirk subpopulation in collaboration with various partners including USFS, USFWS, Idaho Fish & Game, and British Columbia.

Cc: Hannah Anderson
Janet Gorrell
Penny Becker
Terra Rentz
Gary Bell
Marc Engel
Sherri Felix

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MEMORANDUM

October 18, 2019

TO: Forest Practices Board

FROM: Mark Hicks, Adaptive Management Program Administrator

SUBJECT: Adaptive Management Program Quarterly Report

This memo highlights work completed and progress made in the Adaptive Management Program (AMP) since your last update on August 1, 2019.

Cooperative Monitoring, Evaluation and Research Committee (CMER) Update

The Uplands Processes Science Advisory Group (UPSAG) continues to work on scoping the first project in the Deep-Seated Landslide Research Strategy. This scoping document is for the Landslide Mapping and Classification Phase and is expected before the end of the current Fiscal year.

The Unstable Slopes Criteria Project team has responded to the Independent Scientific Peer Review (ISPR) comments they had received on the draft study design. If the changes are accepted by ISPR reviewers and CMER this portion of the project will be ready for implementation.

The Road Prescription Scale Effectiveness Monitoring Project is in its field phase and setting up the experimental sites and monitoring equipment. Full implementation of the project is expected by the end of November 2019.

The Science Advisory Group for the Eastside (SAGE) continues to work on a best available science and alternatives analysis document in support of moving forward on the Eastside Timber Habitat Evaluation Project. The current goal is to complete project scoping by February 2020.

SAGE's Eastern Modeling Effectiveness Project has been sent to ISPR to get their approval that changes made to the draft report meet their acceptance. It is expected this will occur and a Findings Report delivered to TFW Policy in early spring 2020.

The Eastside Type N Riparian Effectiveness Project (ENREP) project team is in the first year of pre-harvest monitoring on 3 pairs of study sites in Northeast Washington, and has confirmed applicability and availability of 2 more pairs of study sites along the east slope of the Cascades. Monitoring at these 2 additional pairs can begin once the equipment has been installed. This will occur after the snow melts next year.

The Eastside Type F Riparian Effectiveness Bull Trout Add-On Study, examining changes to riparian stands after harvest, has been approved by ISPR and the project's authors have begun developing a Findings Report for TFW Policy. This project is expected to be done by December 2019 or January 2020.

The Riparian Science Advisory Group (RSAG) has also received ISPR approval for the Westside Type N Buffer Characteristics Integrity and Function Report, which examines changes in forest stands in western Washington after harvest. This study report still needs final CMER approval before a Findings Report can be provided to TFW Policy. This is expected to occur by December 2019 or January 2020.

RSAG completed the Extensive Monitoring Status and Trends – Temperature Report. CMER approved and passed along the Findings Report to TFW Policy for approval.

RSAG also has passed along to CMER for their review and approval a report beginning to address another phase of the Extensive Monitoring Status and Trends - Vegetation Pilot Study. This effort tested the transferability of a Light Detection and Ranging (LiDAR) remote sensing-based model initially developed for a watershed in the western slopes of the Cascades to sites in the Olympic Peninsula.

RSAG has begun scoping a Large Woody Debris Recruitment Study. This effort is being done by cooperators with the intention to promote it as a formal study to be added to the Master Project Schedule.

RSAG has completed the Hardwood Conversion Case Studies Report, and the associated CMER-approved Findings Report is expected to be delivered to Policy by December 2019.

RSAG continues to work on the Type F Effectiveness Monitoring Project Phase I Pilot Study. This project is in the data analysis and initial report writing stage. The results of the pilot study will be used to design a full study on the effectiveness of the Type F riparian rules.

RSAG continues to work with outside contractors to develop a study design to implement the Riparian Characteristics and Shade Study. This study will examine the effects of various buffer widths and intensities of riparian management on shade across the state.

The Type N Soft Rock Study Report is in its second round of CMER reviews. If successful in accommodating CMER comments, the report should be ready to send to ISPR in early 2020.

The Landscape and Wildlife Advisory Group (LWAG) has completed the Type N Hard Rock Amphibian Genetics Report. The Findings Report was approved by CMER and accepted by TFW Policy.

LWAG is in the initial stages of developing a charter to guide scoping for the Amphibians in Intermittent Streams Study.

CMER approved the LWAG draft Type N Hard Rock Phase II Extended Monitoring Report, and it was sent to ISPR. This is expected to take 4-6 months to move through the ISPR process before it can return to CMER for final approval.

The Wetlands Scientific Advisory Group (WetSAG) has drafted a study design for a phase I pilot study that will be used to design a full Forested Wetlands Effectiveness Monitoring Study.

WetSAG has also begun the scoping process for the planned Wetland Management Zone Effectiveness Monitoring Study which will examine rule effectiveness on non-forested wetlands.

WetSAG is additionally nearing completion of their efforts to develop a LiDAR-based wetlands identification Tool.

TFW Policy Committee (Policy) Update

The Policy workgroup tasked with reviewing the Washington Farm Forestry Association Alternative Plan Template Proposal has completed its work. The workgroup has developed non-consensus recommendations which will be brought to the full Policy committee October 31, 2019.

Policy approved the members and updated the charter for the Type Np Prescriptions Workgroup. The first meeting of this workgroup is scheduled for October 28, 2019.

Policy accepted the findings for the Buffer-Shade and Integrity (Amphibians) Study and agreed by consensus the study results do not warrant action by the Forest Practices Board.

Policy accepted the findings for the Type Np Hard Rock Study Amphibian Genetics Report and agreed by consensus the study results do not warrant action by the Forest Practices Board.

Policy received a presentation on the findings for the Extensive Riparian Status and Trends Temperature Monitoring Study. They are scheduled to make a decision on whether to recommend the Board take action in response to these findings at their October 31, 2019 meeting.

In response to concerns over increased projected costs for the Eastside Type N Effectiveness Monitoring Study (ENREP), Policy asked CMER and the study authors a set of questions intended to help determine if changes should be made to the study to reduce its cost or change its scope. Policy intends to make a decision at their October 31, 2019 meeting.

As requested by the Board, Policy has developed a possible process to use when considering authorizing extended monitoring for projects.

This has been a very busy period for the Adaptive Management Program and this update has only touched on the highlights of the work. If you have any questions, please feel free to contact me (mhic461@ecy.wa.gov or 360-902-1909).

MEMORANDUM

TO: Forest Practices Board

FROM: Garren Andrews, Compliance Monitoring Program Manager

SUBJECT: Current status of the Compliance Monitoring Program

Peter Grebowski officially began his duties as the Compliance Monitoring Field Coordinator on August 16th 2019.

Field work for the Unstable Slopes prescription commenced September, 17th 2019.

2018/2019 biennial standard sample data collection has been completed. Data will be complied and analyzed November 2019.

If you have any questions please contact me at (360) 902-1366 or garren.andrews@dnr.wa.gov

GA/

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October 3, 2019

TO: Forest Practices Board

TM

FROM: Tami Miketa, Manager, Small Forest Landowner Office – Forest Practices

SUBJECT: Small Forest Landowner Office and Advisory Committee

Small Forest Landowner Office Advisory Committee
Since my last report, the Small Forest Landowner Office Advisory Committee held two meetings, one on July 23, 2019 and one on September 25, 2019. Discussions focused on the following topics:

- Potential Low Impact Harvest Prescriptions
- FPA Forms and Updates
- Update of Small Forest Landowner Office Advisory Committee Action Plan.

SFLO Program Updates
This past year, DNR established a new Division titled the Forest Health & Resiliency Division. This past August, the Forest Stewardship Program moved from the Forest Practices Division's Small Forest Landowner Office to this new Division. Moving the Forest Stewardship Program to the Forest Health & Resiliency Division will better align the services available to small forest landowners, placing forest management assistance programs under the direction of one Division – a Division overseen by our State Forester. It will also improve the cohesion between DNR's existing Forest Health Assistance Program in eastern Washington, the Forest Health Strategic Plan for central and eastern Washington, the statewide Forest Action Plan, and DNR's statewide Wildland Fire Protection Strategic Plan, all of which depend on working closely with Washington's small forest landowners.

The Forest Health & Resiliency Division will continue to provide the following services to small forest landowners:

- Provide holistic forest management advice, technical and cost-share assistance to encourage landowners in active management to improve overall productivity of their forests which will lead to a healthier and more resilient environment.
- Assist landowners in developing a personalized management plan that protects, improves and restores the health, productivity and sustainability of their forests.

- Administer cost-share incentive programs for forest health and fuels mitigation in central and eastern Washington, which reduces unhealthy and unnatural wildfire fuels.
- Partner with WSU Extension in providing education to small forest landowners.

The Forest Practices Division will remain a resource for small-forest landowners who want help navigating forestry regulations and accessing Small Forest Landowner Office programs. The Forest Practices Division will continue to:

- Staff the Small Forest Landowner Office, which focuses on helping small-forest landowners understand how to complete forest practices applications and access the following programs to conserve fish and wildlife habitat and water quality: the Family Forest Fish Passage Program (FFFPP), the Forestry Riparian Easement Program (FREP), and the Rivers and Habitat Open Space Program (RHOSP).
- Provide Regulation Assistance Foresters, who offer technical guidance related to the state's forest practices rules, the Forest Practices Application and the programs available through the Small Forest Landowner Office.

The two Divisions will work in close coordination to provide the services needed to small forest landowners.

Additionally, the Small Forest Landowner Office recently hired a state-wide Regulation Assistance Forester, Todd Olson, who will begin his duties as of October 16, 2019. Todd comes into this position with extensive experience in DNR with 16 years in the Forest Practices Program as a Forest Practices Forester and Compliance Monitoring Field Coordinator, and 6 years as a State Lands Forester. Todd will be located in Olympia, but will help serve small forest landowners across the state in providing technical guidance related to the state's Forest Practices Rules and the Forest Practices Application process.

Long Term Applications (LTA)

There are a total of 277 approved long term applications, which is an increase of 5 approved applications since the end of the last reporting period (07/03/2019).

LTA Applications	LTA Phase 1	LTA Phase 2	TOTAL
Under Review	7	2	**9**
Approved	5	277	**282**
TOTAL	**12**	**279**	**291**

Upcoming Landowner Events

Forest Health Seminars

Forest health is a complex concept and tree death is a natural part of it, which can make it difficult to know when a dead or dying tree is truly a bad thing. This seminar will help landowners understand when to be concerned, what to look for, and what they may be able to do about it on their own property. They will also receive a wealth of information on resources available in their area that can help them learn and do more.

What's covered:
- Forest health concepts and learning how to identify a problem
- Identifying and managing common tree insects and diseases
- Identifying damage from environmental stressors
- Understanding wildfire risk and adaptation in western Washington
- Resources available in your area to help you with your management

Morton Forest Health Seminar
Tuesday, November 5, 2019

Stevenson Forest Health Seminar
Thursday, November 14, 2019

Monroe Forest Health and Fire Seminar
Tuesday, November 19, 2019

Forest Stewardship Coached Planning Short Courses

WSU Extension's flagship course will teach landowners how to assess their trees, avoid insect and disease problems, attract wildlife, and take practical steps to keep their forest on track to provide enjoyment and even income for years to come. In this course landowners will develop their own Forest Stewardship Plan, which brings state recognition as a Stewardship Forest and eligibility for cost-share assistance, and may also qualify them for significant property tax reductions.

Online Forest Stewardship Coached Planning Short course (Northwest Section)
Tuesdays, Starting January 28, 2020

Online Forest Stewardship Coached Planning Short course (Southwest Section)
Tuesdays, Starting January 28, 2020

Foresters Roundtable

Spokane, WA

Thursday, January 23, 2020
WSU-UI Family Foresters Workshop
Coeur d'Alene, ID
Friday, January 23, 2020

Forest Owners Winter School
Colville, WA
Saturday, February 1, 2020

Western WA Forest Owners Winter School
Auburn, WA Saturday, February 29, 2020

For more information regarding these events go to http://forestry.wsu.edu/

Please contact me at (360) 902-1415 or tami.miketa@dnr.wa.gov if you have questions.
TM/

TIMBER FISH
& WILDLIFE

Timber, Fish and Wildlife Policy Committee
Forest Practices Board

PO BOX 47012, Olympia, WA 98504-4712

Policy Co-Chairs:
Terra Rentz, WA Department of Fish & Wildlife
Curt Veldhuisen, Skagit River System Cooperative

October 18, 2019

TO: Washington Forest Practices Board

FROM: Terra Rentz and Curt Veldhuisen

SUBJECT: TFW Policy Committee Report (August, September & October 2019)

SUMMARY OF POLICY RECOMMENDATIONS TO THE BOARD

Action Items

Accept policy's recommendation to accept the Extended Monitoring Framework as presented in Attachment 1.

Recommended Actions to be Presented by the AMPA

Accept Policy's recommendation that the following study does not warrant action by the Board: Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading.

Recommended Actions for February

Accept Policy's recommendation that the following study does not warrant action by the Board: Type N Experimental Buffer Treatment Study: Post-harvest comparison of genetic diversity and demographic findings for three stream-associated amphibians.

Informational Items

Policy has provided the following materials for the Board as they relate to current or recent action items:

1. Report on Extended Monitoring Framework (Attachment 1)

EXISTING PRIORITIES AND UPDATES

1. *Master Project Schedule - updated October 2019*
   Policy continues to work to maintain an up to date MPS reflective of current overages and underspending by projects. At this time, no additional formal review or approval is needed by the FPB since approval of the revised MPS in August. Policy continues to discuss the financial obligations of the ENREP study, per the Board's direction, and will provide any final recommended changes to the budget at the Board's February meeting.

2. *Stream-Associated Amphibian Response to Manipulation of Forest Canopy Shading*
   The report and associated documents were provided to the Board at your August meeting. Since then, at Policy's August 2019 meeting, Policy has determined that this study does not, by itself, warrant action by the FPB. However, this study will be among the studies considered by the Technical Type Np Prescriptions Workgroup process and the Charter will be modified accordingly. This vote passed with 6 thumbs up, 1 sideways, and Eastside Tribes and Federal Caucus absent. This Workgroup process is described further in the following topic.

Policy recommends that the findings of the Stream-Associated Amphibian Response do not warrant action by the Board at this time, however the technical implications and recommendations portion of the report warrant action by the Adaptive Management Program.

Additionally, Policy recommends that the study and findings be provided to the Technical Type Np Prescriptions Workgroup as a source of information.

3. *Amphibians Genetics Report (Type Np Hardrock)*
   In September, Policy was presented with findings and a presentation on the amphibian genetics component of the Type Np Hardrock study. Study findings did not indicate evidence of immediate effects of treatment on amphibian populations; however, the team qualified the study may not have had the power to detect slow and gradual changes over the long term. Therefore, they have limited ability to infer effects across further generations. The team recommended that the study could be further fortified by funding resamples several years into the future. Policy has determined that this study does not warrant action by the FPB. This motion passed with full consensus.

   The report for this study will be provided by the AMPA at a later meeting date.

   Policy recommends that the Amphibian Genetics Findings report does not warrant action by the Board.

4. *Technical Type Np Prescriptions Workgroup*
   Board members will recall that the Workgroup will consist of eight technical experts with strong technical backgrounds in physical, biological and forestry/operational aspects of headwater stream management. It will be guided by two co-chairs from the Policy committee: Jim Peters (NWIFC) and Darin Cramer (WFPA). The workgroup will generate buffering alternatives that address the results of numerous AMP and related external studies addressing riparian functions.

   Recent efforts by the Policy Committee, AMPA and staff have resulted in significant progress toward initiation of the Technical Type Np Prescriptions Workgoup:
   - Policy generated names, qualifications and caucus input on Workgroup nominees.
   - AMPA contacted Workgroup candidates, and all top-ranked candidates agreed to participate in the workgroup:

     Section VII. Membership

Workgroup Name	Focal Area	Role
Darin Cramer	Policy Liaison	Chair (non-voting)
Jim Peters	Policy Liaison	Vice Chair (non-voting)
Jeremy Groom	physical stream processes	Voting Member
John Stednick	physical stream processes	Voting Member
John Richardson	biological	Voting Member
Bob Bilby	biological	Voting Member
Steve Barnowe-Meyer	silviculture/field forestry	Voting Member
Chris Lunde	silviculture/field forestry	Voting Member
Heather Gibbs	AMP	Project Manager (non-voting)

   - AMPA and staff developed an improved plan for Workgroup member compensation, which was approved by Policy:

     Section VII. Compensation

Workgroup members will be selected using the Collaborative Research Approach to contracting. Specifically, all members of the Workgroup have been selected through the consensus process by Policy at the August 1, 2019 meeting.

All workgroup members, excluding Policy co-chairs will be compensated within the total budget of $200,000 for their active participation and adherence to the Charter. Compensation is intended to cover any expenses incurred during the duration of the project and to compensate members for professional contributions and time. As with all other contracts through the Adaptive Management Program, the Department of Natural Resources will award and manage these Collaborative Research Contracts.

Co-chairs will be compensated via reimbursement requests to DNR for expenses associated with travel, lodging, and/or per diem if necessary.

- AMPA updated expected delivery of key CMER research products in order to update the timeline in Section VI of the Charter. We recall that the potential for delays suggested by previous changes to this timeline were key concerns expressed by FPB members Bellon and Swedeen at the previous meeting:

Milestone/Task	**Earliest Expected**	**Reasonable Worse Case***
Informational: CMER-Approved **draft** BCIF Report to send to ISPR available	June 2018	N/A
Board acceptance of Policy Proposal	May 7, 2019	N/A
Receipt of **final** Buffer-Shade Amphibian Response Study Findings Report, and Direction ***from Policy***	Early spring 2019	N/A
Workgroup convened ***Informational:*** Receipt of ISP and CMER-Approved **final** Extensive Type N/F Temperature Report ***from CMER*** ***Informational***: CMER-Approved **draft** Hard Rock Phase II Extended Report to send to ISPR available	Oct 2019	Nov 2019 N/A Nov 2019
Receipt of **final** Extensive Type N/F Temperature Study, Findings Report, and Direction ***from Policy*** ***Informational***: CMER-Approved **draft** Type N Soft Rock Report (2yr post-harvest) to send to ISPR available	Nov 2019	Jan 2020 Jan 2020
Informational: Receipt of ISPR and CMER-Approved **final** BCIF Report ***from CMER*** (Changes from draft noted)	Jan 2020	Mar 2020
Receipt of BCIF Findings Report and Direction ***from Policy***	Feb 2020	Apr 2020
Informational: Receipt of ISPR and CMER-Approved **final** Hard Rock Phase II Extended Report ***from CMER***	May 2020	Jul 2020
Receipt of Hard Rock Phase II Extended Findings Report and Direction ***from Policy*** ***Informational***: Receipt of ISPR and CMER-Approved **final** Type N Soft Rock Report (2yr post-harvest) ***from CMER***	Jun 2020	Aug 2020
Workgroup develops "draft" Type Np water RMZ buffer prescription(s) for initial policy review	Jun 25, 2020	N/A

Receipt of Type N Soft Rock Findings Report and Direction ***from Policy***	Aug 2020	Oct 2020
Workgroup modifies proposed "draft" Type Np water RMZ buffer prescription(s) based on review of Type Np Soft Rock CMER study	3 mo post Soft Rock (est. Aug 2020)	3 mo post Soft Rock (est. Oct '20)
Final submission of deliverables to policy	6 mo post Soft Rock (Dec '20)	Jan 2021

- The present expectation of a product for PPB is now the end of 2020, somewhat sooner than the mid-2021 projection discussed at the last FPB meeting. Because this and previous timeline projections are estimates and rely on delivery of CMER products, Policy was not able to reach consensus that the latest projection should be formally approved. A motion was made by the County Caucus that Policy accept the Type Np charter as amended (reflective of updated timeline). This motion was seconded, and then failed to reach consensus: Conservation Caucus thumbs down; all other caucuses thumbs up.

5. *Small Forest Landowners' Low Impact Template*
   Having been granted an extension by Policy, the Template Group has been working toward a set of recommendations to be presented to Policy at the November meeting, scheduled for October 31. Although the workgroup output and initial discussion at Policy will not have occurred in time to be reported here, the Policy co-chairs can provide a verbal summary at the November Board meeting. However, Policy will need additional time into late 2019 to conduct ongoing discussions of workgroup materials and hopefully generate consensus recommendations.

   The Board should anticipate a report from Policy on this topic at the February 2020 meeting.

6. *Framework for Evaluating Extended Monitoring*
   To review, at the August 2018 Board Meeting the Board tasked Policy and CMER to jointly develop a proposal regarding how to evaluate proposals for extending the duration of monitoring at AMP projects. The impetus for this request was a lack of clarity on the process and rationale for extending the Type N Hard Rock study. A joint CMER-Policy workgroup was formed to explore a range of scenarios and develop a framework. The framework document was developed and has been formally approved by CMER and Policy as of the September 5, 2019 Policy Meeting with full consensus (Eastside Tribes and Federal Caucus absent) and is included in your materials package as Attachment 1.

   The proposed approach includes input and approval roles for CMER (e.g. methods, certainty), Policy (e.g. competing priorities, policy questions) and AMPA/Project Management staff (e.g. staff availability, timing). The approach generally relies on steps and documents that are already in use. The final approval of extension proposals will optimally be completed at the time of annual MPS review to allow consideration of implications of the extension (cost, staffing, timelines, added certainty) in context of impacts to other priorities.

   Policy and CMER request that the Board review and approve the Extended Monitoring Framework document.

7. *TFW Policy Improvement Initiative*
   As reported in Policy's previous report, the June 2019 Policy meeting included a joint CMER-Policy workshop to review and understand CMER's Protocols and Procedures Manual. During that workshop Policy members identified numerous opportunities to improve lacked efficiency and procedural clarity.

This effort has ben initiated and has begun with a review of written communication between CMER and Policy, specifically Findings Reports and related documents. A policy workgroup is making progress reviewing recent documents.

<u>Policy expects to provide a report on this effort in 2020, depending on progress and competing priorities.</u>

8. *Eastside Type N Riparian Effectiveness Project (ENREP)*

   With assistance from CMER and AMP staff, Policy has been evaluating the financial, inference and rule-making aspects of ENREP since earlier in 2019. Although the study design has been approved, the renewed attention was triggered by difficulties in site selection and the substantial cost increases projected for this project. Some caucuses expressed concern that study design limitations could undermine the usefulness of results to support future management decisions.

   Policy conducted an ENREP workshop at their May meeting and followed by requesting additional information from CMER. Additional questions focused on aspects of inference and the specific study components driving the cost increases. At the October Policy meeting, CMER and project scientists presented responses to 3 of the 4 questions, which were very helpful. However, CMER had not yet deliberated on a response to the over-arching fourth question but hopes to do so in time to inform Policy at their next meeting. If so, Policy co-chairs will brief you at the upcoming Board meeting.

   <u>Policy will need addition time to evaluate the full CMER response and thus expects to provide a recommendation to the Board detailing any proposed changes to the ENREP study at the February 2020 meeting.</u>

Other Updates on AMP Personnel

As Board members are likely aware, in August Mark Hicks became the permanent AMPA after the retirement of interim Howard Haemmerle. Among other tasks, Mark is working on filling numerous vacancies including Project Manager, Wetland Scientist, and Eastside Scientist.

With the impending retirement of Dave Schuett-Hames, Jenelle Black was hired as incoming lead CMER scientist, beginning with a brief overlapping period. The lead scientist conducts scientific work (research, writing and SAG support) and supervision of other CMER staff scientists. This is a major transition, as Dave has served CMER and the AMP for over 30 years. Black is a hydrologist and also was the original project manager hired by the AMP in the mid-2000s.

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November 13, 2019

MEMORANDUM

To: **Forest Practices Board**

From: **Gary Bell, Wildlife Biologist, Forest Habitats Section**

Subject: **Upland Wildlife Update**

The following provides a brief status update for ongoing or pending actions pertaining to priority wildlife species in forested habitats:

Woodland Caribou – South Selkirk Subpopulation

1982: State listed as Endangered
1983 Federally listed as Endangered (emergency rule)
1984: Federally listed as Endangered (final determination)
2012: Federal critical habitat designated by USFWS
2017: Periodic Status Review and State retention of Endangered Status

On October 2, 2019, the US Fish & Wildlife Service (USFWS) published an amendment to the listing for the southern mountain caribou Distinct Population Segment (DPS) of woodland caribou. The amendment defines and clarifies the southern mountain caribou DPS, which includes the currently listed Selkirk Mountains subpopulation that has historically used habitat in Washington (WA), Idaho, and British Columbia, Canada. It also confirms the listing status of the southern mountain DPS as Endangered and reaffirms the previous designation of approximately 30,010 acres of national forest lands (above 5000 feet elevation) as critical habitat (CH) for the southern mountain DPS.

Current Forest Practices (FP) Rule protects Critical Habitat (state) for Mountain (woodland) caribou (*Rangifera tarandus*), which addresses activities including *'Harvesting, road construction, aerial application of pesticides, or site preparation within 0.25 mile of a known active breeding area, documented by the department of fish and wildlife.'* Due to the fact that primary caribou habitat for the Selkirk herd lies within the Colville National Forest (US Forest Service lands) in the extreme northeast corner of WA, WDFW has never designated a "known active breeding area" for woodland caribou. Rather, conservation of woodland caribou and their habitat has relied on the location of suitable habitat within the national forest and the federal CH in order to protect the species. Unfortunately, due to factors including habitat modification and predation, the Selkirk herd could be considered functionally extirpated from its range within WA and the few remaining individuals were taken into captivity for conservation/recovery efforts in British Columbia in 2018.

Given these factors, WDFW has recommended to DNR that no changes to the current Critical Habitat (State) rule (WAC 222-16-080) for woodland caribou are necessary at this time. In the future, if woodland caribou were to reoccupy their range in WA, WDFW may consider reevaluation of the rule based on any new knowledge for avoiding disturbance of caribou. In the meantime, WDFW will continue to support conservation and recovery efforts for the Selkirk subpopulation in collaboration with various partners including USFS, USFWS, Idaho Fish & Game, and British Columbia.

Marbled Murrelet

1992: Federally listed as Threatened
1993: State listed as Threatened
1996: Federal critical habitat designated by USFWS
1997: FPB enacted State Forest Practices Rules
2017: State up-listed to Endangered

With a continued average population decline of approximately 4.4% since 2001, the status of the Marbled Murrelet in Washington has not improved since state listing in 1993. Given the 2017 uplisting to state endangered, the Washington Department of Natural Resources (WDNR), in consultation with Washington Department of Fish and Wildlife (WDFW), recommended that the Forest Practices Board (Board) support WDFW's initiation of a Marbled Murrelet forest practices rule (FP Rule) assessment involving a diverse group of stakeholders. WDFW established a Wildlife Working Group (WWG) to evaluate rule effectiveness in protecting murrelet habitat, identify weaknesses in rule language and on-the-ground implementation, consider potential habitat conservation incentives, and bring consensus recommendations regarding FP Rule improvements to the Board for their consideration.

The WWG held its most recent meeting October 8, 2019 (a meeting was also held November 12, 2019), furthering their work to evaluate the definition of Marbled Murrelet habitat using current best available science on murrelet habitat characteristics and selection. Information gathered is intended to provide updated knowledge on murrelet ecology and help the group evaluate if the current definition is appropriate or if other habitat characteristics are worth consideration in identifying murrelet habitat, and possibly better align the FP Rule with the Federal and Pacific Seabird Group definitions. Once this task is complete, focus will shift to evaluation of the FP Rule processes and implementation aspects associated with the recommended habitat definition (which may not change from what is now in FP Rule).

WDFW continues to monitor marbled murrelet populations at-sea in both Zones 1 (Puget Sound and Strait) and Zone 2 (Washington coast). Each zone is monitored in alternating years. Zone 2 was monitored in 2019. WDFW just start the eighth year of Navy funded non-breeding season surveys in Puget Sound. The 2018/2019 survey report will be available shortly. The NW Forest Plan Effectiveness Monitoring team is currently drafting the 25-year report, which is expected to be released in spring of 2020. And finally, WDFW Research Scientist Scott Pearson is currently drafting a manuscript summarizing the Navy funded survey results.

Canada Lynx

1993: State listed as Threatened
1994: FPB enacted voluntary management approach
2000: Federally listed as Threatened
2017: State up-listed to Endangered

Up-listing of the lynx from state threatened to endangered became effective on February 4, 2017. At that time, WDFW recommended to WDNR (and WDNR in turn to the Board) that no action be taken to add lynx to the forest practices rule designation for critical habitats (state). WDFW also recommended maintaining the voluntary protection approach for lynx while efforts continue to evaluate existing protection mechanisms and identify conservation options in collaboration with landowners, Canadian federal and provincial entities, US Fish & Wildlife Service (USFWS), US Forest Service (USFS), conservation organizations, tribes and academic partners. The goal is to refine recovery actions that can be implemented in the near- and long-term to benefit lynx conservation in Washington.

WDFW continues screening forest practices for potential impacts to lynx and coordinating with conservation partners to maintain awareness about the importance of protecting remaining habitat in the face of wildfires that may affect lynx. WDFW also continues active participation in the *Transboundary Lynx Work Group*, exploring conservation strategies which have included a feasibility assessment for translocating lynx into the Kettle Lynx Management Zone, as well as coordination with southern British Columbia conservation partners concerning demographic support for Washington's transboundary lynx population.

In November 2017 USFWS published a proposed rule to remove lynx from the federal list of threatened and endangered species, but the final rule to de-list has not occurred to date. The USFWS species status assessment determined that regulatory improvements addressed the threat that led to their original listing of the lynx distinct population segment (DPS).

Northern Spotted Owl

1988: State listed as Endangered
1990: Federally listed as Threatened
1996: FPB enacted State Forest Practices Rules
2012: USFWS designation of revised critical habitat
2016: State retention of Endangered status

Recognized as a state endangered species, the Northern Spotted Owl (NSO) population has continued to decline in recent years primarily due to ongoing competitive interactions with Barred Owls, as well as habitat changes from timber harvests, forest health issues, and wildfires. The Northern Spotted Owl Implementation Team (NSOIT) continues working to develop a programmatic Safe Harbor Agreement (SHA) for forest landowners that will provide federal assurances while protecting existing habitat and recruiting new habitat, although progress remains slow. The group is also exploring other opportunities for landowner incentives.

The North Central Washington Audubon Society recently submitted a petition to the Board regarding NSO in eastern Washington. The petition calls to question the effectiveness of the FP Rules in protecting NSO habitat and ultimately requests that a moratorium be placed on logging anywhere within Spotted Owl Special Emphasis Areas (SOSEAs) in eastern Washington, reconsideration of WAC 222-10-041 which addresses policies for forest practices subject to SEPA, and confirmation that the NSO rules are being implemented appropriately. The Board will consider the petition at its November 13, 2019 meeting.

Fisher

1998: State listed as Endangered
2016: Federal status: Final decision for west coast DPS - not warranted for listing (April 2016)
2018: Northern District Court of California ruling on 2017 USFWS fisher ESA listing withdrawal
2019: Federal publication of Candidate Notice of Review (October), including fisher

Fisher reintroductions into Washington continue by WDFW and its partners. To date, a total of 189 fishers have been relocated to the Olympic National Park (2008-2010), and other federal lands within the southern and northern Cascade Mountains. 73 fishers have been released at Mount Rainier National Park and the Gifford Pinchot National Forest since December 2015. And, beginning in December 2018, 26 Alberta fishers were translocated from the Calgary Zoo and released into the North Cascades Recovery Area. Additional fisher releases in the North Cascades will occur during winter 2020/2020.

Combined with the Candidate Conservation Agreement with Assurances (CCAA) program administered by WDFW, the reintroductions are assisting the species return to the state. Non-federal landowners can continue to enroll in the CCAA and receive federal regulatory assurances in the event that the fisher becomes listed under the ESA in the future. By signing on to the CCAA, landowners agree to follow basic conservation measures that protect fishers that may use private lands. To date, 60 landowners and 3,318,228 acres of non-federal forest lands are enrolled in the CCAA.

In September 2018, the Northern District Court for California ruled that the 2017 USFWS decision to withdraw their proposed rule to list fishers under the ESA was arbitrary and capricious. The result was that the fisher is once again a candidate for listing under ESA and USFWS was required to review their decision and publish updated findings in September 2019. On October 10, 2019, USFWS published their annual Candidate Notice of Review (CNOR), which includes fisher. With the CNOR, they are seeking supplementary information that will be considered in deciding whether or not to once again propose the fisher for listing as threatened under ESA. The CNOR does not include a specific end date for acceptance of supplementary information, nor does it provide an indication as to when they'll make an updated listing decision for fisher.

Future Updates to the Board

The forest practices rules require that when a species is listed by the Washington Fish and Wildlife Commission and/or the U.S. Secretary of the Interior or Commerce, DNR consults with WDFW and makes a recommendation to the Forest Practices Board as to whether protection is needed under the Critical Habitat (State) rule (WAC 222-16-080). WDFW and DNR continue coordinating to anticipate federal actions and to respond to changes in the status of any given species.

cc: Hannah Anderson (WDFW)
Taylor Cotten (WDFW)
Terra Rentz (WDFW)
Chris Conklin (WDFW)
Marc Engel (DNR)
Sherri Felix (DNR)
Joseph Shramek (DNR)

DEPARTMENT OF
NATURAL RESOURCES

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October 18, 2019

TO: Forest Practices Board

FROM: Marc Engel, Senior Policy Planner, Forest Practices

SUBJECT: 2020 Work Plan

Attached for your consideration at your November 13 meeting, is staff recommended priorities for your 2020 Work Plan (attached). The Work Plan incorporates TFW Policy Committee priorities, recommendations from the Adaptive Management Program, and recommendations for rule making and board manual development. The Work Plan also includes standing agenda items and/or tasks of the Board. Upon your approval, this Work Plan will establish the Board's priorities for completion of work by the Adaptive Management Program and Board staff in calendar year 2020.

The meeting dates for 2020 are February 12, May 13, August 12, and November 12, which occur on the 2nd Wednesday of those months. Staff will notify the Office of the Code Reviser of the dates for publication in the Washington State Register.

Also attached for your review is the work accomplished this past year.

Should you have any questions please feel free to contact me at 360-902-1309 or marc.engel@dnr.wa.gov.

ME

FOREST PRACTICES BOARD
2020 WORK PLAN

2020 Meeting Dates: February 12 / May 13 / August 12 / November 12

TASK	COMPLETION DATE/STATUS
Adaptive Management Program	
• CMER Master Project Schedule Compliance Review*	August
• CMER Master Project Schedule Review*	May
• CWA LWAG Type N Experimental Buffer Treatment – Genetics	February
• CWA Type N Experimental Buffer Treatment in Soft Rock Lithology	November
• Eastside Modeling Evaluation Project	May
• Hardwood Conversion Study	February
• Independent AMP Financial Audit	February
• Small Forest Landowner Western Washington Low Impact Template: TFW Policy Recommended Review Process & Timeline*	August
• State Auditor Performance Audit Report	November
• TFW Policy Committee Progress Report on Unstable Slopes Recommendations from the Board approved Proposal Initiation	November
• Type N Experimental Buffer Treatment in Hard Rock Lithology	November
• Type Np Prescriptions Workgroup*	On-going
• Water Typing Strategy	On-going
Annual Reports	
WAC 222-08-160 Continuing review of FP rules (Annual Evaluations), *by tradition the Board has received an annual evaluation of the implementation of cultural resources protections*	August
• Clean Water Act Assurances	August
• Northern Spotted Owl Conservation Advisory Group	November
• TFW Policy Committee Priorities*	August
• Western Gray Squirrel	August
Board Manual Development	August
• Section 23 (Part 1) Field Protocol to Locate Mapped Divisions Between Stream Types*	On-going
• Section 23 (Part 2) Perennial Stream Identification*	On-going
CMER Membership	As needed
Compliance Monitoring 2018-2019 Biennial Report	August
Critical Habitat - State/federal species listings and critical habitat designations	As needed
Field Tour	
Rule Making	
• Water Typing System	On-going
• Rule Clarifications	May
Committee Recommendations on Water Typing System Rule	On-going
Committee Recommendations on AMP Efficiency & Improvements	On-hold
Cultural Resources Recommendations from Facilitated Process (progress reports)	On-going

Italics = proposed changes
**= TFW Policy Committee*

Updated July 2019

FOREST PRACTICES BOARD
2020 WORK PLAN

Quarterly Reports	
• Adaptive Management Program*	Each regular meeting
• Board Manual Development	Each regular meeting
• Compliance Monitoring	Each regular meeting
• Clean Water Act Assurances	February
• Legislative Activity	February & May
• NSO Implementation Team	Each regular meeting
• Rule Making Activities	Each regular meeting
• Small Forest Landowner Advisory Committee & Office	Each regular meeting
• TFW Cultural Resources Roundtable	*To be determined*
• TFW Policy Committee Work Plan Accomplishments & Priorities*	Each regular meeting
• Upland Wildlife Working Group	Each regular meeting
• **Work Planning for 2021**	November

Italics = proposed changes
**= TFW Policy Committee*

Updated July 2019

FOREST PRACTICES BOARD
2019 WORK PLAN

2019 Meeting Dates: May 8 & 9 / August 14 / November 13

TASK	**COMPLETION DATE/STATUS**
Adaptive Management Program	
• Buffer/Shade Effectiveness Study (amphibian response)	November-COMPLETED
• CMER Master Project Schedule Review*	May-COMPLETED
• CMER Master Project Schedule Compliance Review*	August-COMPLETED
• Hardwood Conversion Study	Move to 2020 work plan
• TFW Policy Committee Progress Report on Unstable Slopes Recommendations from the Board approved Proposal Initiation	As needed
• Small Forest Landowner Western Washington Low Impact Template: TFW Policy Recommended Review Process & Timeline*	Move to 2020 work plan
• Hard Rock Extended Study	Move to 2020 work plan
• Type Np Prescriptions Workgroup	On-going
• Extended Monitoring and Reporting*	November-COMPLETED
Annual Reports	
• WAC 222-08-160 Continuing review of FP rules (Annual Evaluations), *by tradition the Board has received an annual evaluation of the implementation of cultural resources protections*	August
• Clean Water Act Assurances	November-COMPLETED
• Northern Spotted Owl Conservation Advisory Group	November - COMPLETED
• TFW Policy Committee Priorities*	August-COMPLETED
• Western Gray Squirrel	August-COMPLETED
Board Manual Development	
• Section 23 (Part 1) Field Protocol to Locate Mapped Divisions Between Stream Types*	Move to 2020 work plan
• Section 23 (Part 2) Perennial Stream Identification*	Move to 2020 work plan
CMER Membership	As needed
Critical Habitat - State/federal species listings and critical habitat designations	As needed
Field Tour	early fall
Rule Making	
• Water Typing System – CR102	Move to 2020 work plan
• Water Typing System – CR103	Move to 2020 work plan
Committee Recommendations on AMP Efficiency & Improvements	On-going
Cultural Resources Recommendations from Facilitated Process (progress reports)	**On-going**
Quarterly Reports	
• Adaptive Management Program*	Each regular meeting
• Board Manual Development	Each regular meeting
• Compliance Monitoring	Each regular meeting
• Clean Water Act Assurances	February

Italics = proposed changes
**= TFW Policy Committee*

Updated July 2019

FOREST PRACTICES BOARD
2019 WORK PLAN

TASK	COMPLETION DATE/STATUS
• Legislative Activity	February & May
• NSO Implementation Team	Each regular meeting
• Rule Making Activities	Each regular meeting
• Small Forest Landowner Advisory Committee & Office	Each regular meeting
• TFW Cultural Resources Roundtable	*To be determined*
• TFW Policy Committee Work Plan Accomplishments & Priorities*	Each regular meeting
• Upland Wildlife Working Group	Each regular meeting
Work Planning for 2020	November

Italics = proposed changes
**= TFW Policy Committee*

Updated July 2019