A Pilot Test of Systematic Review Techniques: Evaluating Whether Wood Placements in Streams of the Pacific Northwest Affect Salmonid Abundance, Growth, Survival or Habitat Complexity

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EXECUTIVE SUMMARY

A systematic review of evidence was conducted concerning the effects of large wood placement on salmonids. In contrast to a general literature review, a narrowly focused question was targeted. The question was formulated before the review commenced and specified the subject, treatment, and outcomes of interest. The primary review question was **"**Does instream wood placement affect salmonid abundance, growth, survival or habitat complexity?" Publications were found with a comprehensive, documented literature search and were selected for review based on explicit inclusion criteria. Two science reviewers evaluated the selected set of publications. The reviewers considered specific criteria to assess how relevant each publication was to the primary review question. Details for each publication considered in reviewing its relevancy, including factors that might have affected study conclusions, are reported. The overall strength of reviewed evidence is summarized in a narrative synthesis. Gaps in research are highlighted. Insights are provided into the process, feasibility, and utility of systematic reviews for assessing and synthesizing the science available to support forest management decisions and policymaking.

1. INTRODUCTION

Among the primary duties of the Oregon Department of Forestry (ODF) are regulation and oversight of forest practices in the state and management of state forest lands. This work involves identifying, assessing, and collating technical information about forest resources. Forest management stakeholders consistently agree that best available science should guide forest practices. Yet, conflicts over what is and is not "good" science, and the selective use of studies with different conclusions by competing interest groups, continue to pose major challenges.

Conflicts regarding best available science indicate a need for methods to identify knowledge gaps and synthesize technical information in a way that is readily accepted as objective and definitive. A promising tool for this is *systematic review* - a rigorous, transparent technique for reviewing technical literature developed and now widely used in the field of clinical medicine. In such systematic reviews, all relevant evidence is assessed regarding the efficacy of an active intervention, such as a particular surgical procedure or medication. A systematic review differs from a traditional literature review in having a narrow focus on a single question and using an explicit protocol for finding, screening, grading, and synthesizing primary research relevant to that question.

As its use in clinical medicine continues to grow, systematic review is now being explored as a means to consider scientific evidence in other disciplines such as natural resource conservation (Fazey et al. 2004, Pullin and Knight 2001). However, natural resource management and the science upon which it is based differ substantively from clinical medicine, and much remains to be learned about adapting systematic review techniques for assessing ecological research.

Recognizing the potential of systematic reviews for characterizing best available science, the ODF commissioned a pilot project to learn more about applying the approach to technical forest management questions. Systematic reviews in medicine tend to be exhaustive, time consuming, and expensive. Thus, an important concern was whether the systematic review process could be adapted to match the budgetary and human resources available to the ODF and still meaningfully assess scientific research about a topic of interest to the agency and its stakeholders.

Salmon and trout are integral components of stream ecosystems, and their conservation is of cultural and economic importance to Oregonians. Many landowners have engaged in stream restoration projects involving the placement of large wood. The ODF chose a question related to the effectiveness of wood placement because it is such a widespread practice and it was thought that a question could be developed appropriate to the desired scale of this prototype for examining the utility of systematic reviews.

2. OBJECTIVES OF THE REVIEW

2.1 Primary review question

The chief objective of the systematic review was to answer the question:

Does instream wood placement affect salmonid abundance, growth, survival or habitat complexity?

2.2 Secondary review question

The review also intended to evaluate differences among study locations that could help explain differences among study outcomes. Such variables are termed *effects modifiers* (Stewart et al. 2006). To the degree that relevant information was available in the reviewed studies, the following secondary question was addressed:

What influence do variables such as land use history, local geology, stream gradient and valley confinement, proportion of cobbles in substrate, degree of existing modification, stream size, drainage size, water flow, canopy cover, fish species present and other potential effects modifiers have on the impact of large wood placements?

3. BACKGROUND

In the Pacific Northwest, the logs, larger branches and roots of trees that fall into streams are primary determinants of channel form. Pools created by such large wood (LW or LWD, for large woody debris as is it often referred to in the literature) are important habitats for many fish species, including salmon and trout (Bilby and Bisson 1998). Streams with more large wood tend to have more and larger pools, as well as more variation in depth, substrate types, and amount of cover compared to streams with less large wood (Quinn 2005). Streams with more complex pool habitats tend to have more fish species and greater numbers of each species (Reeves et al. 2002). The presence of large wood also influences the transport and storage of sediment into and through streams (Bilby and Bisson 1998).

Because of its fundamental role in shaping salmonid habitat, large wood is a commonly used measure of habitat quality. Undisturbed streams in coastal Pacific northwestern forests typically contain large wood in great abundance. Past land use practices have substantially reduced large wood in many of the region's salmonid-bearing streams and rivers. After Euro-American settlement, large wood was often removed from streams to facilitate the practice of splash damming to transport logs from harvest sites downstream to sawmills. In the 1960's and 70's, federal and state programs were implemented to clear large wood from stream channels. This was in part motivated to eliminate perceived migration impediments for adult salmon caused by large instream accumulations of logging slash. Timber harvesting along streams has also reduced the amount of large wood available for recruitment into channels (Reeves et al. 2002).

Concern over declines and disappearance of several Pacific salmonid stocks (e.g., Nehlsen et al. 1991; National Research Council 1996) has resulted in major efforts to restore freshwater salmonid habitats. Active wood placement into streams is a basic component of many habitat restoration projects conducted in attempting to comply with federal statutes such as the Endangered Species Act (1973) and state statutes such as the Oregon Forest Practices Act (ORS 527.610 to 527.770, 527.990 (1) and 527.992) and the 1997 Oregon Plan for Salmon and Watersheds. Land managers, landowners, and citizens who invest public and private funds in restoration have an interest in knowing if, when, and where large wood placement projects are likely to be effective in recovering salmonid populations and restoring their freshwater habitats.

4. METHODS

A systematic review of evidence was conducted concerning the effects of large wood placement on salmonids and salmonid habitat complexity. A hallmark of systematic review is *a priori* development of a detailed methods protocol. Thus, for the systematic review of large wood placement, the protocol provided background on the review topic, stated review objectives and questions, established methods for identifying and evaluating literature, including details about the search strategy and plans for assessing, summarizing, and synthesizing studies (Behan 2008). In contrast to a general literature review, a narrowly focused question was targeted. A comprehensive, documented literature search was conducted to find and select publications for review (Appendix A). The selected set of publications was reviewed by K. Burnett and G. Giannico, hereafter referred to as science reviewers (biographical sketches in Appendix B). The science reviewers considered specific criteria to assess how relevant each publication was to the primary review question. Details considered in reviewing relevancy of each publication, including the rigor of study design and statistical analysis, are reported in Appendix C. The overall strength of reviewed evidence was synthesized in a narrative.

4.1 Question formulation

As used in clinical medicine, systematic reviews are designed to address questions regarding the efficacy of active medical interventions rather than a general topic of concern to medical policy or practice. The question should be answerable in scientific terms, be value-free to the extent possible, and specify the subject, treatment, and outcomes of interest.

Technical staff from the ODF (L. Dent and R. Mannix) developed a draft review question. The question was refined in consultation with the science reviewers, representative stakeholders (Ecotrust and Plum Creek Timber), and the review coordinator (J. Behan from the Institute of Natural Resources (INR) at OSU) to ensure its importance and appropriateness of scope for the prototype project. The primary question was finalized as:

Does instream wood placement affect salmonid abundance, growth, survival or habitat complexity?

Thus, studies that addressed the effects of only active placement of large wood on salmonids or their habitat were to be considered. This excluded the broader category of studies that address the ecological role of large wood in streams.

4.2 Search strategy

A key tenet of systematic review is use of a protocol that details in advance how the search will be conducted. The search strategy was drafted by the review coordinator with input from the ODF technical staff, science reviewers, and stakeholders. The draft was provided to a reference librarian (J. Webster), who finalized it using professional judgment and test searches. The final systematic search strategy (Appendix A) listed by name the electronic databases, meta search engines, and library collections to be searched. The systematic strategy also specified a list of key terms in each of three categories (species, environment, and treatment) and Boolean operators for use in searches. All publications found in each searched source were imported into a ProCite database, except for GoogleScholar where the first 100 of 3,820 results were reviewed for inclusion. Results with indeterminate information (e.g., incomplete citation) were discarded. After compilation, duplicate items and meeting abstracts were discarded.

Because disciplines related to stream restoration use diverse study designs and have little consensus on key terms, the systematic search was augmented with an ad hoc search to reduce the potential of omitting useful publications. In the ad hoc search, references contained in research syntheses located during the systematic search phase were examined (Lassettre 1999; Bayley 2002; Roni et al. 2005). Additionally, email queries were sent to Pacific Northwest fish biologists. The source of each reviewed publication is specified (Appendix C).

4.3 Inclusion criteria and procedures

A primary goal of ODF's for this prototype project was to limit the systematic review to a manageable scope. Consequently, specific inclusion criteria were developed and applied to publications found in the search. The criteria are:

- Studies that examined large wood placement were included. Studies that focused on interventions other than large wood placement were to be excluded.
- Studies that examined salmonids were included. Studies that targeted species other than salmonids were to be excluded.
- Peer-reviewed journal articles were included. Gray literature and abstracts from conference proceedings or annual meetings were to be excluded.
- Studies conducted in the Pacific Northwest - Oregon, Washington, Alaska and British Columbia - were included. However, a sample of studies from beyond this region was reviewed to evaluate whether limiting the geographic scope may have biased the conclusions.

With these criteria in mind, the review coordinator read all abstracts of publications found in the search and the full text when consistency with the criteria could not be determined from the abstract. Thus, a final set of publications was selected to be considered by the science reviewers.

4.4 Review strategy for retained studies

Each of the science reviewers evaluated approximately 50% of the selected studies. To determine consistency in summarizing and interpreting information, each reviewer independently assessed a subset of the publications considered by the other. Disagreements between reviewers regarding this subset of publications were to be resolved through discussion and consensus. Any publication authored by one of the science reviewers was to be summarized and evaluated by the other one.

Information about each reviewed publication was systematically and consistently documented by the categories listed in Table 1. The categories identified in italics were considered when evaluating the relevance of each publication to the primary review question (Appendix C).

Table 1. Categories of information documented for each publication

Publication title and principal investigator(s)	
Study dates and *study duration*	
Study location, settings where the intervention was applied	
Ecosystem type; plant association	

group	
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	
Species studied (if applicable)	
Study design, experimental controls	
Pretreatment data (yes/no)	
Intervention or management action	
Replications (if applicable)	
Sample sizes and results	
Nature of the outcome measures used, their relative importance and robustness	
Effects Modifier (confounding factors)	

The rigor of study design and statistical analyses were essential details assessed for each publication in reviewing its relevancy to the primary review question. Table 2 illustrates how such information was considered in determining relevancy.

Table 2. Hierarchy of study designs and outcomes considered when assessing relevancy of publications to the primary review question.

Study design	**Example Outcome**	**Level of Relevance**
Replicated sampling, replicated controls, sampling before and after rehabilitation	'The mean increase in frequency of pools was significantly greater in reaches treated with wood than in control reaches'	Higher
Unreplicated, controlled, sampling before and after rehabilitation	'The number of salmon increased after wood placement in the treated reach, but not in the control reach'	High
Unreplicated, uncontrolled, sampling before and after rehabilitation; OR Unreplicated, controlled, sampling after rehabilitation	'There were more salmon after wood placement than before'; OR 'After wood placement, there were more salmon in the control reach than in the treated reach'	Low
Unreplicated, uncontrolled, sampling after rehabilitation	'There was a gradual increase in the number of salmon in the two years after wood placement'	Lower
Unreplicated, uncontrolled, anecdotal observation after rehabilitation	'I saw lots of salmon after the wood placement'	Lowest

(Modified from a table in from Fazey et al. (2002), which was modified from Rutherfurd et al. (2000), *A Rehabilitation Manual for Australian Streams*, Vol 1, pp 164-73.)

The relevancy of each publication to the primary review question was determined based on the decision tree in Figure 1. Emphasis was placed on the research question addressed by each study, followed by the type of experimental design and statistical analyses used.

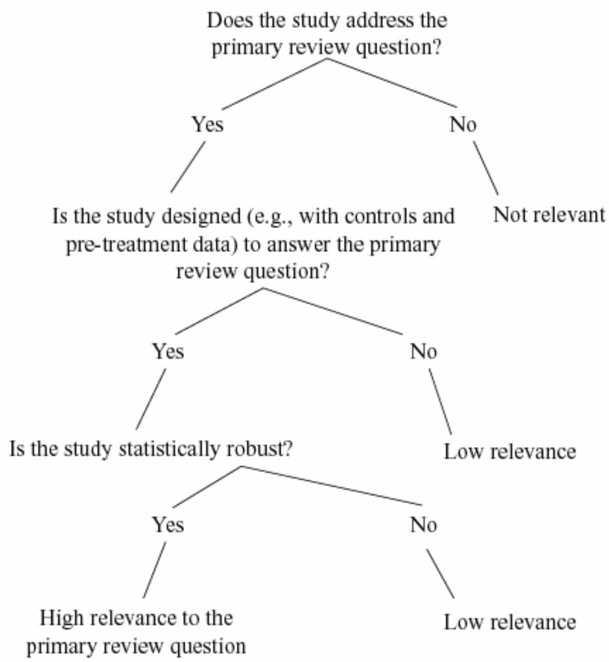

Figure 1 - Decision tree used to evaluate the relevance of publications to the primary review question.

5.0 RESULTS

The search found a set of 457 publications. Due to inconsistencies with keywords and terms and the need to utilize a search strategy that balanced inclusiveness with specificity, numerous publications found in the search were deemed inappropriate for full review.

Subsequently, applying the inclusion criteria that required all publications to be peer reviewed, focused on the effects of active placement of wood on salmonids, and restricted to the Pacific Northwest reduced the set to 22 (see summary tables in Appendix C). An additional 11 publications were selected that met the first two criteria but were from areas outside the Pacific Northwest. Of these 33 publications, about 80% were identified by the systematic search with the remainder being identified by another means in the ad hoc search.

Of the 33 publications reviewed, one science reviewer evaluated 16 and the other evaluated 17. Then, two publications from each reviewer were randomly identified and independently assessed by the other (Appendix C - Tables 11a and b, 18a and b, 26a and b, and 29a and b). The independent reviews proved to be consistent across all categories. Based on the high degree of consistency, reviewers' perspectives were considered comparable and their evaluations were combined in subsequent stages of the review.

Using the summary tables (Appendix C) and the decision tree (Figure 1), reviewers determined that seven publications had no relevancy and sixteen publications had low relevancy for addressing the primary review question (Figure 2, Appendix C). Ten publications were deemed as highly relevant to the primary review question. All of the high relevancy publications were identified by the systematic search (Appendix C).

Seven of the ten high relevance publications and half of the low-relevance publications were from the Pacific Northwest. Consequently, the narrative synthesis of findings drew from high relevance publications, regardless of study location. Of the ten high relevance publications: two provided evidence of wood placement effects on fish habitat, four on salmonids, and four on both (Figure 2, Appendix D). All of the high relevance publications were identified from the systematic search and not from the ad hoc search.

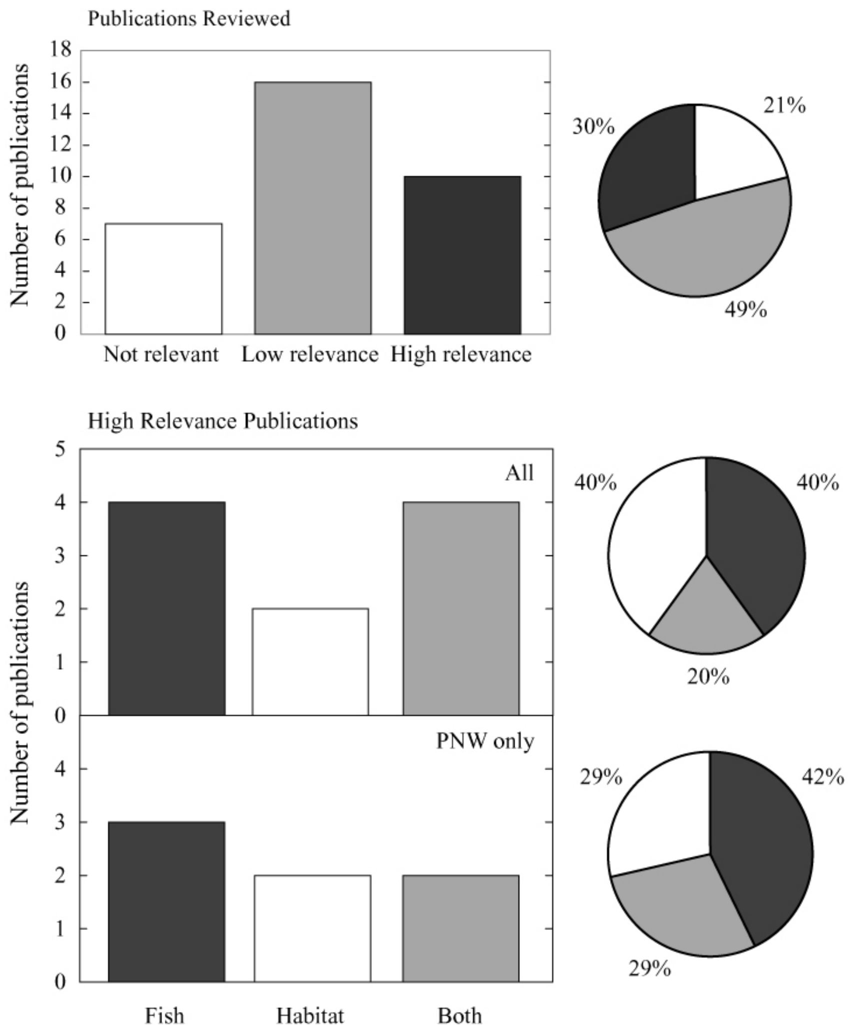

Figure 2 - Results from evaluating the relevance of publications to the primary review question.

5.1 Evidence regarding effects of in-stream wood placement on salmonid habitat

Very similar attributes were measured in all of the high relevance studies examining the effects of wood placement on stream habitat. These studies tended to focus on the amount and volume of wood, percentage of pool area and of fast water habitats, summer wetted area, and mean depth. Results generally suggest at least short-term improvements in habitat conditions consistent with objectives of placing wood in streams.

After wood addition, increases were found in the number of pieces of wood (Cederholm et al. 2002; Johnson et al. 2005; Roni and Quinn 2001), the volume of wood (Cederholm et al. 2002; Johnson et al. 2005), the percentage of pool area (Cederholm et al 2002.; Johnson et al 2005; Lehane et al. 2002; Roni and Quinn 2001), and the mean depth (Gowan and Fausch 1996; Johnson et al. 2005). In contrast, responses differed among studies for area in fast water habitats (Cederholm et al. 2002; Lehane et al. 2002; Roni and Quinn 2001; Solazzi et al. 2000) and for summer wetted area (Gowan and Fausch 1996; and Roni and Quinn 2001). Some studies observed physical responses to wood placement by season. For example, pool area increased in summer (Cederholm et al. 2002; Johnson et al. 2005; and Lehane et al. 2002) and in winter (Johnson et al.); whereas increases in total mainstem area (Johnson et al. 2005) and total habitat area (Solazzi et al. 2000) were reported only for winter.

Additional habitat variables closely related to those previously listed were also examined, however, only single publications referred to them. Most of the variables addressed in single studies responded to wood placement in ways that were consistent with the morphological and physical processes associated with the artificial increase of in-stream structure. Thus, increases were observed in the amount of slow-water area (Lehane et al. 2002) was well as the amount of cover and percentage fines in the substrate (Gowan and Fausch 1996).

5.2. Evidence regarding effects of instream wood placement on salmonids

Publications deemed to be of high relevance to the primary review question considered a variety of salmonid species (coho salmon, cutthroat trout, rainbow trout, brown trout, brook trout, and Dolly Varden), forms (resident and anadromous), and life-history stages (fry through adult) over a variety of seasons and spatio-temporal extents. Consequently, evidence regarding the effects of wood placement for any particular combination of these factors is limited. Results regarding the effects of wood placement on salmonids were either positive or not statistically significant. No publication of high relevance to the primary review question reported negative effects of wood placement on any salmonid species. However, Giannico (2000) found that juvenile coho salmon tended to use pools more when added wood was sparse than when wood was dense or absent.

Coho salmon was examined in more high relevance publications than any other species, but results varied depending on the spatio-temporal scales considered. For example, wood placement was not associated with significant changes in the abundance of coho salmon juveniles when considered at the habitat unit scale over a few days (9-11 days) (Bjornn et al. 1991). Longer-term studies did indicate positive responses of coho salmon to wood placement in terms of increased survival (Solazzi et al. 2000), abundance of summer juveniles (Roni and Quinn 2001; Solazzi et al. 2000; Giannico 2000), and smolt output (Roni and Quinn 2001; Solazzi et al. 2000).

5.3 What variables influence effectiveness? (Under what conditions are wood placements likely to be effective, and under what conditions are wood placements likely to be ineffective?)

Evidence presented in the high relevance publications is insufficient to answer this question in any specific detail. Not surprisingly, however, physical and biological responses to wood placement tend to be greatest in areas of degraded habitat with low levels of naturally occurring wood (Roni and Quinn 2001).

5.4 Information gaps and research needs: what kind of studies and information would be most effective in filling information gaps and improving our knowledge and effectiveness of wood placements?

The role of naturally occurring large wood in affecting physical and ecological characteristics of streams is well documented (e.g., Gregory et al. 2003), however a relatively few high relevance publications supply the basis to evaluate the effectiveness of wood placement in stream restoration. Evidence is stronger regarding the effects of wood placement on habitat than on fish populations.

Although substantial evidence indicates that wood placement can alter physical characteristics of streams in ways that may benefit salmonids, studies are needed that address the effectiveness of such treatments on habitat over longer periods and larger areas. Reviewed studies provided little guidance about how much area must be treated before wood placement projects are likely to affect habitat over spatial extents (stream network or basin) of interest to decision makers. Furthermore, little is known about the riparian or watershed context under which wood placement is most likely to achieve desired objectives. Thus, studies that consider landscape characteristics (e.g., hill slope, rock type, and forest age class) as covariates in evaluating the effects of wood placement on habitat may be particularly valuable.

For studies examining the effects of wood placement on salmonid species in the Pacific Northwest, none addressed bull trout and few considered Chinook salmon (Shirvell 1990; Roni et al. 2002). Clear associations between bull trout and naturally occurring wood have not been established (Dunham et al. 2003). For Chinook salmon, however, studies have shown that juveniles selected areas with relatively high densities of naturally occurring large wood (Burnett 2001) and densities of adults increased in areas treated with log jams (Roni et al. 2002). Given such findings, studies examining wood placement effects on Chinook salmon may be particularly useful.

Considering the focus on large wood placement as a restoration technique, surprisingly little evidence is available from the PNW, or elsewhere, that supports its efficacy for increasing the abundance, survival, or growth of any salmonid species. Only a few of the high relevance studies examined fish responses beyond the habitat unit or reach scale. Thus, what if any effect wood placement projects may have on fish populations remains largely unknown. Controlled, replicated, long-term experiments, such as Gowan and

Fausch (1996), can provide important understanding for decision makers. Gowan and Fausch (1996) examined how wood placement may affect salmonid populations and the demographic mechanisms by which it does so. Results for salmonids from one of the long-term experiments in western Oregon were equivocal due to circumstances beyond the researchers' influence (large volumes of storm-introduced wood into the control and study streams after habitat manipulation) (Johnson et al. 2005). Given potential for such circumstances to affect long-term studies, much can be learned from shorter-term, replicated studies with treatments and controls. Results from the only other long-term study were confounded by the fact that the effects of large wood and alcove construction were not reported separately (Solazzi et al. 2000). Indeed, several of the reviewed publications did not distinguish the effects of large wood placement from those of other types of treatments, limiting their relevance to the primary review question. Thus, any new study will benefit from a design that allows the effects of wood placement and other instream, riparian, or watershed treatments to be clearly discriminated.

6.0 LESSONS LEARNED

Some important lessons were learned about the process, feasibility, and utility of systematic reviews for assessing and synthesizing the scientific basis for forest management decisions and policymaking.

First, it is clear that systematic techniques from clinical medicine are useful in literature searches on stream restoration and probably other issues related to forest management. A systematic search offers the benefit of transparency but comes with the possibility of omitting significant publications. This possibility increases as conformity decreases in keywords and cataloguing of completed studies. Concern over missing significant publications on the effectiveness of wood placement drove our decision to augment a systematic search with other, more traditional strategies for locating literature. We, therefore, sacrificed some repeatability for an attempt at inclusiveness. The systematic search strategy, however, identified most of the studies that were selected for full review and all of the studies deemed of high relevance to the primary review question. In subsequent efforts, therefore, an ad hoc search may be helpful for ensuring important publications are identified but including the results may add unnecessary complexity to the review and reporting.

Second, few publications on the effects of wood placement met the highest standard of relevance. Use of formalized summary criteria (Table 1) and a decision tree (Figure 1) facilitated transparent and objective decisions on the relevancy of publications to the primary review question. Evaluation and documentation of evidence quality are defining traits of systematic review and help distinguish these from traditional literature reviews. In addition to evidence quality, the decision tree evaluated whether a publication addressed the primary review question. This step was necessary given the diversity of designs and outcomes in reviewed studies. Matching study results with the outcomes defined in a review question is expected to be more challenging for systematic reviews on topics related to forestry or forest-stream interactions than to clinical medicine. Much medical research is structured around systematic reviews to assess and integrate double blind, randomly controlled clinical trials on a specific intervention. In contrast, many peer-reviewed publications addressing stream restoration did not distinguish effects of wood placement from other interventions. Findings were based on case studies with limited or no replication and an unknown scope of inference. Long-term stream restoration studies are rare, particularly those with replicated sampling and controls and with sampling before and after intervention. Due to such considerations, the systematic review revealed that decisions about whether to implement and how to design in-stream wood placement projects are currently based on much less than definitive science. As future research is considered, studies with rigorous designs, which specifically target wood placement effects on salmon and their habitats, can advance the scientific underpinnings of stream restoration.

Third, evidence regarding the effects of wood placement is stronger for habitat than for fish populations. High relevance studies typically identified physical changes following wood placement in streams that are interpreted as habitat improvements (e.g., increased cover, pool area, and wood volumes). In contrast, the body of evidence is scant regarding the effects of wood placement on any particular species, form, or life-stage of salmonid, however more high relevance studies examined coho salmon than any other species. Effects of wood placement on salmonids tended to be either positive or not statistically significant. As is the case with systematic reviews in general, results of this effort may have been influenced by publication bias - the tendency of statistically non-significant results to be rejected from peer-reviewed journals. Thus, the screening criteria of including only peer-reviewed literature may have disproportionately disqualified from the review studies demonstrating no effect of wood placement. In addition to the benefit of systematically assessing and presenting available evidence, systematic reviews can help focus and set science agendas. Systematic reviews are valuable for illuminating information gaps that may be impeding development of science-based policies and for prioritizing research funding to fill these gaps.

Fourth, a systematic review provides benefits beyond those of a traditional literature review but may be less feasible for a natural resource agency to conduct. The transparent, documented processes of systematic reviews are particularly valuable to establish a scientific foundation for decision making on contentious issues. These processes, however, render a systematic review time consuming to plan and implement. Other than developing the review questions, expertise for this systematic review came from outside the ODF. A professional librarian designed and performed the systematic literature search, and two PhD-level fisheries biologists reviewed the evidence. Directing such expertise at a future systematic review is a substantial investment, regardless of whether the expertise comes from inside or outside the agency. Applying inclusion criteria made the scope of this systematic review manageable for the resources at hand. Such actions may have biased results of the systematic review. However, the potential for geographic bias was addressed by reviewing a sample of literature from beyond the Pacific Northwest and it is doubtful that excluding gray literature omitted studies reporting stronger effects than in the peer-reviewed studies.

In conclusion, the findings of this review should not be considered the last word either on the process of systematic reviews for forest management or on the effectiveness of in-stream wood placement. However, we think that this particular review is robust and offers useful information to ODF and the agency's stakeholders. Additionally, systematic reviews show promise in helping to objectively define best available science, identify knowledge gaps, and guide future research if sufficient human and financial resources are made available.

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Appendix A. Search Strategy

Theses electronic databases, listed by database name and host/administrator, were searched. ASFA and Fish & Fisheries cover international information, searching was not limited to US generated material or English language.

- Aquatic Sciences & Fisheries Abstracts: Cambridge
- Environmental Sciences and Pollution Management: Cambridge
- Forest Science: CAB Direct
- Treesearch: USDA Forest Service Research
- AGRICOLA: Ebsco
- Fish & Fisheries Worldwide: NISC
- Wildlife & Ecology Studies Worldwide: NISC
- Dissertation Abstracts: FirstSearch
- Web of Science: Science Citation Index

The following meta-search engine was searched.

- Google Scholar

The following library collections were searched:

- Oregon State Library (OCLC)
- Washington State Library (OCLC)
- Oregon State University Library (OCLC)
- University of Washington Library (OCLC)
- Washington State Library (OCLC)
- Streamnet Library Columbia Basin (OCLC)
- Sport Fish Division Reports: AK Dept. of Fish & Game (OCLC)
- WAVES Canada: Libraries of Fisheries and Oceans Canada

The following search strategy was used combining, when possible, these three sets of keywords:

Set 1: Species - These search terms were combined with OR. None were truncated as preliminary searches truncating 'salmon' returned too many irrelevant results.

- Oncorhynchus kisutch
- Coho salmon
- Oncorhynchus keta
- Chum salmon
- Oncorhynchus tshawytscha
- Chinook salmon
- Oncorhynchus gorbuscha
- Pink salmon
- Oncorhynchus nerka
- Sockeye salmon
- Oncorhynchus mykiss
- Salmo gairdneri

- Rainbow trout
- Oncorhynchus clarkii
- Cutthroat trout
- Salmo salar
- Atlantic salmon
- Salmo trutta
- Brown trout
- Hucho taimen
- Salmon
- Trout
- Char

Set 2: Environment – These broad search terms in conjunction with the treatment terms narrowed the search appropriately. These three terms were combined with OR.

- Stream
- River
- Channel

Set 3: Treatment - These terms were searched as phrases and combined with OR. Originally, broader treatment terms were used such as 'stream restoration', 'habitat restoration' and 'stream channel improvement.' This original strategy skewed the relevancy ranking of the results giving items with the most keywords from the search strategy the highest ranking. Consequently, more relevant items with only a few critical keywords could have been overlooked, especially if results had been limited to the first 100 or 200 hits. The terms listed below, while returning a smaller number of items, seemed to be more appropriate for the issue

- Wood placement
- Wood restoration
- Woody debris placement
- Woody debris restoration
- Large wood
- Logs
- Woody debris
- LWD

Three of the resources searched posed challenges for the chosen search strategy as the systems have intrinsic limitations.

- TreeSearch has a very limited search term capability and is a relatively small dataset. So, a simplified search strategy was used after some experimentation.

  Salmon **AND** "large wood" **or** "woody debris" **or** "habitat restoration" **or** "stream channel" = 9

- GoogleScholar limits search terms to 42 and is not transparent on phrase searching. So, a more general search strategy was used resulting in close to 4,000 hits. As GoogleScholar improves its advanced search engine, this problem of irrelevant and duplicated results may diminish.

(Phrases = "wood-restoration" or "large-wood" or "woody-debris" or wood placement **OR** (All words = logs or LWD)) **AND (**At least one word = salmon OR trout OR char)

- WAVES does not allow Boolean combining of multiple sets.

All items found in each source were imported except for GoogleScholar where the first 100 of 3,820 results were reviewed for inclusion. Those with indeterminate information (e.g. incomplete citation) were discarded. After compiling the results in a ProCite database, duplicates were removed as well as meeting abstracts.

Additional searching of pertinent conservation and statutory organization websites including the Oregon Department of Fish & Wildlife and the Washington Department Fish & Wildlife was considered, but discarded as neither had comprehensive publication lists. Pertinent publications by both agencies were retrieved with searches of regional library catalogues as Oregon State University and University of Washington are depositories for their respective state government publications. Both also collect non-depository items generated by the agencies as available. Some agency publications were retrieved via GoogleScholar.

In addition to the databases and catalogues searched, selected bibliographies of recent, relevant papers and book chapters recognized by experts as seminal or important were reviewed for further references. This helped identify additional references as well as reinforcing the validity of the initial search results.

Bayley, Peter. 2002. A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest: A report to the Washington State Independent Science Panel.

Lassettre, Neil S. 1999. Annotated Bibliography on the Ecology, Management, and Physical Effects of Large Woody Debris (LWD) in Stream Ecosystems. Department of Landscape Architecture and Environmental Planning University of California, Berkeley. http://www.cnr.berkeley.edu/forestry/curr_proj/woodydebris/woodbiblio02.html#113

Roni, P.; Hanson, K.; Beechie, T.; Pess, G.; Pollock, M ; Bartley, D.M. 2005 Habitat rehabilitation for inland fisheries. Global review of effectiveness and guidance for rehabilitation of freshwater ecosystems. FAO Fisheries Technical Paper, No, 484, Rome, FAO. 116 pp. [Reviewed Section 2.5: Instream Habitat Structures. Pp. 37-49]

Appendix B. Biographical sketches of science reviewers

Kelly M. Burnett
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Corvallis, OR 97331
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Education:
Ph.D., Fisheries Science, Oregon State University (2001)
M.S., Fisheries Science, Oregon State University (1986)
B.S., Biology and Chemistry, Berry College (1981)

Experience:
Research Fish Biologist, Pacific Northwest Research Station, Corvallis, OR. 2002-present
Assistant Professor (Courtesy), Department of Fisheries and Wildlife, Oregon State University, 2004 to present
Fish Biologist, Pacific Northwest Research Station, Corvallis, OR. 1988-2002
Research Associate, Caribbean Marine Research Center, Lee Stocking Island, Bahamas, 1987-1988

Selected Publications:
Clarke, S.E., K.M. **Burnett,** and D.J. Miller. In press. Combining digital and field data to model stream geomorphic attributes. Journal of the American Water Resources Association.
Miller, D.J., K. M. **Burnett**, and L.E. Benda. In press. Factors Controlling Availability of Spawning Habitat for Salmonids at the Basin Scale. American Fisheries Society Symposium.
Burnett, K.M. and D.J. Miller. 2007. Streamside policies for headwater channels: an example considering debris flows in the Oregon Coastal Province. *Forest Science* 53: 239-253.
Burnett, K.M.; G.H. Reeves, D.J. Miller, K. Vance-Borland, S.E. Clarke, and K.R. Christiansen. 2007. Distribution of habitat potential for steelhead and coho salmon relative to current and future land use and cover in the Oregon Coast Range. *Ecological Applications* 17(1):66-80.
Miller, D. J., and K. M. **Burnett**. 2007. Effects of forest cover, topography, and sampling extent on the measured density of shallow, translational landslides. Water Resources Research, 43, W03433, doi:10.1029/2005WR004807.
Burnett, K.M., G.H. Reeves, S.E. Clarke, and K.R. Christiansen. 2006. Comparing riparian and catchment-wide influences on salmonid habitat in Elk River, Oregon. Pages 175-196 in R.M. Hughes and L. Wang (eds), Influences of Landscapes on Stream Habitat and Biological Communities. American Fisheries Society Symposium 48. Bethesda, MD
Reeves, G.H., K.M. **Burnett**, and E. McGarry. 2003. Sources of wood in the mainstem of a fourth-order watershed in Coastal Oregon. Canadian Journal of Forest Research 33:1363-1370. (refereed)
Clarke, S. and K.M **Burnett**. 2003. Comparison of Digital Elevation Models for aquatic data development. Photogrammetric Engineering and Remote Sensing 69(12):1367-1375
Burnett, K.M. 2001. Relationships among juvenile anadromous salmonids, their freshwater habitat, and landscape characteristics over multiple years and spatial scales in the Elk River, Oregon. PhD Dissertation, Oregon State University, Corvallis, Oregon. 244p

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EDUCATION:
- Ph.D., Resource Management and Environmental Science, University of British Columbia, Vancouver, Canada. 1996
- M.Sc., Biology, University of Victoria, Canada. 1986.
- Licenciatura en Ecologia, Universidad Nacional de La Plata, Argentina. 1983

RECENT EMPLOYMENT HISTORY:
2001-present: Associate Professor and Extension Fisheries Specialist - Department of Fisheries and Wildlife, Oregon State University.
1999-2000: Research Associate - Institute for Resources and Environment, University of British Columbia, Vancouver, B.C., Canada.
1997-1999: Postdoctoral Research Fellow – Westwater Research Center, University of British Columbia, Vancouver, B.C., Canada.

REFEREED JOURNAL ARTICLES
Boxall, G.D., **G.R. Giannico**, and H.W. Li. 2007. Landscape topography and the distribution of Lahontan cutthroat trout (Oncorhynchus clarki henshawi) in two high desert streams. Environmental Biology of Fishes. ISSNP: 0378-1909 (Print) 1573-5133 (Online). DOI: 10.1007/s10641-007-9254-1.
Beechie, T., G. Pess, P. Roni, and **G.R. Giannico**. In press. Setting river restoration priorities: a review of approaches and a three-step process for identifying and prioritizing actions. North American Journal of Fisheries Management.
Giannico, G. R., and S. Hinch. 2007. Juvenile coho salmon responses to salmon carcasses and in-stream wood manipulations during winter and spring. Canadian Journal of Fisheries and Aquatic Sciences 64: 324-335
Giannico, G. R. , and S.G Hinch. 2003. The effect of wood and temperature on juvenile coho salmon winter movement, growth, density and survival in side-channels. River Research and Applications 19: 219-231.
Giannico, G.R. 2000. Habitat selection by juvenile coho salmon in response to food and woody debris manipulations in suburban and rural stream sections. Canadian Journal of Fisheries and Aquatic Sciences 57: 1804-1813.
Giannico, G.R., and M.C. Healey. 1999. Ideal free distribution theory as a tool to examine juvenile coho salmon habitat choice under different conditions of food abundance and cover. Canadian Journal of Fisheries and Aquatic Sciences 56: 2362-2373.
Giannico, G.R., and M.C. Healey. 1998. Effects of flow and food on winter movements of juvenile coho salmon. Transactions of the American Fisheries Society 127: 645-651.
Diez, J.M., **G.R. Giannico**, E. McLean, and E.M. Donaldson. 1992. The effect of somatostatins (SRIF-14, 25 and 28), galanin and anti-SRIF on plasma growth hormone levels in coho salmon (*Oncorhynchus kisutch*, Walbaum). Journal of Fish Biology 40: 887-893.

GRANTS & CONTRACTS
Total support received = $4,043,142. **Total support brought through OSU =** $3,699,922 **(this excludes 3 grants co-authored with colleagues from other universities for a total of** $559,220**).**

Appendix C. Peer-reviewed literature evaluated in addressing the primary review question "Does instream wood placement affect salmonid abundance, growth, survival or habitat complexity?" Publications marked with an asterisk are from the Pacific Northwest. A subset of studies from other areas was reviewed to provide assurances that findings from the Pacific Northwest are broadly representative. Studies labeled with a. and b. were evaluated by both reviewers. All publications were identified in the systematic search process except those for which the citation is followed by a reference to its source in brackets.

1.

Publication title and principal investigator(s)	Binns, N.A. 1994. Long-Term Responses of Trout and Macrohabitats to Habitat Management in a Wyoming Headwater Stream. North American Journal of Fisheries Management 14: 87-98.
Study dates and *study duration*	Summer fish and habitat evaluated in various years (1973, 1974, 1975, 1976, 1977, 1980, 1985, 1990) over an 18-year period; Structure condition and performance evaluated in 1990
Study location, settings where the intervention was applied	Beaver Creek, northeast Wyoming Black Hills National Forest, drains from the Bear Lodge Mountains into the Belle Fourche River
Ecosystem type; plant association group	Ponderosa pine
Watershed type (if applicable, e.g. 6^{th} field)	2^{nd} order creek (no map scale identified);
Research question(s), hypotheses	An experimental habitat management project to determine the responses of instream habitats and trout populations to habitat management and the durability and performance of habitat improvement structures.
Species studied (if applicable)	Brook trout (hatchery naturalized)
Study design, experimental controls	Study had a treatment reach as well as upstream and downstream control reaches. Effects on fish abundance, age class, biomass, and length, and on habitat features were examined.
Pretreatment data (yes/no)	No. Chemically treated to control non-game fish present in the reach. Stream was stocked with brook trout 1970 -1974.
Intervention or management action,	A variety of habitat manipulations, including large wood placement from 1973-1977.
Replications (if applicable)	No.
Sample sizes and results	Several desirable outcomes were suggested but results were considered over all types of habitat manipulations and could not be attributable to instream placement of large wood.
Nature of the outcome measures used, their relative importance and robustness	The only assessment specific to large wood placement was how long large wood remained in the channel and its role as cover (larger wood lasted and functioned as cover longer – 18 years).
Effects Modifier (confounding factors)	Grazing stopped in association with habitat manipulation.

2.

Publication title and principal investigator(s)	Binns, N.A. 2004. Effectiveness of Habitat Manipulation for Wild Salmonids in Wyoming Streams. North American Journal of Fisheries Management 24:911–921.
Study dates and *study duration*	30 years
Study location, settings where the intervention was applied	Wyoming streams
Ecosystem type; plant association group	Varied

Watershed type (if applicable, e.g. 6th field)	Stream orders 1-5 on 1:24,000 map
Research question(s), hypotheses	Documented costs of habitat manipulations and assessed if habitat manipulations affected trout: (1) number of trout of all sizes per mile (total trout), (2) number of trout 6in or greater in total length per mile (catchable trout), (3) biomass (lb/acre) of all trout, and (4) biomass (lb/acre) of catchable trout (not all indices were measured at every site, so some project evaluations included only one or two indices); habitat: cover, width, eroding banks and residual pool depth (RPD)
Species studied (if applicable)	Wild resident trout
Study design, experimental controls	Somewhat of a meta analysis of various studies. Evaluations included comparisons of pre-treatment sampling data to either post-treatment sampling data for a modified stream reach or an untreated control reach nearby. Both pretreatment samples and control stations were labeled as reference. Evaluations combined data from different trout species (including non-natives) and studies of different durations and different stream orders over 30 years.
Pretreatment data (yes/no)	Five projects had both control reach and pre-treatment sample data to compare with post-treatment data: Beartrap, Flat, Hell Canyon, Salt, and Spotted Tail Creeks.
Intervention or management action,	A variety of habitat manipulations, including large-wood placement in 10 of the projects
Replications (if applicable)	None. Statewide assessment.
Sample sizes and results	Statewide analysis of wild trout response to habitat improvement included 35 evaluations. Results suggested several desirable effects of enhancement for metrics of habitat and fish.
Nature of the outcome measures used, their relative importance and robustness	In each project, habitat manipulations in addition to large wood placement were used and so any effects due to large wood placement could not be discerned.
Effects Modifier (confounding factors)	None identifiable from the paper.

3.

Publication title and principal investigator(s)	Binns N.A. and R. Remmick. 1994. Response of Bonneville Cutthroat Trout and Their Habitat to Drainage-Wide Habitat Management at Huff Creek, Wyoming. North American Journal of Fisheries Management 14:669-680
Study dates and *study duration*	Monitoring from 1976 -1989, habitat treatment 1981-1983
Study location, settings where the intervention was applied	Huff Creek, Wyoming, flows north to join Coal Creek, a major tributary of the Thomas Fork Bear River
Ecosystem type; plant association group	
Watershed type (if applicable, e.g. 6th field)	1st and 2nd order streams
Research question(s), hypotheses	Monitored cutthroat trout population and fluvial habitat to document results of habitat management.
Species studied (if applicable)	Bonneville cutthroat trout
Study design, experimental controls	Habitat manipulated in one out of six reaches
Pretreatment data (yes/no)	Yes. Two years pre-treatment.
Intervention or management action,	Variety of habitat manipulations but not large wood placement
Replications (if applicable)	Habitat manipulations un-replicated
Sample sizes and results	Bonneville cutthroat trout population abundance, length, and weight; HQI; residual pool depth (RPD) all increased.

Nature of the outcome measures used, their relative importance and robustness	Nothing assessed related to specific effects of large wood placement.
Effects Modifier (confounding factors)	Grazing levels reduced and exclosures built in conjunction with habitat manipulations

*4.

Publication title and principal investigator(s)	Bjornn, T., S. Kirking, et al. 1991. Relation of Cover Alterations to the Summer Standing Crop of Young Salmonids in Small Southeast Alaska Streams. Transactions of the American Fisheries Society 120(5): 562-570.
Study dates and *study duration*	Summer 1982 and 1983
Study location, settings where the intervention was applied	Six small streams on the west side of Prince of Wales Island, Alaska
Ecosystem type; plant association group	All of the watersheds had been logged in the preceding 5-15 years, and the riparian zone of some streams had dense stands of young red alder.
Watershed type (if applicable, e.g. 6th field)	2nd -3rd order streams (map scale not identified)
Research question(s), hypotheses	The null hypotheses tested were that changes in riparian vegetation and four types of cover (woody debris, large-boulder substrate, undercut banks, and simulated overhead vegetation) would not change the standing crop of young fish.
Species studied (if applicable)	Coho salmon, steelhead, Dolly Varden
Study design, experimental controls	Effects examined before and 9-11 days after wood placement in treatment and control units. Changes in fish abundance due to cover additions (before versus after; cover addition versus no change) were evaluated with both ANCOVA and repeated-measures statistical procedures
Pretreatment data (yes/no)	Yes.
Intervention or management action,	Placement of logs up to 0.5 m in diameter and brush bundles in six units so that 50% of the area was affected. Also examined rate of recolonization after removing fish and effects of riparian canopy removal in different experiments.
Replications (if applicable)	6 treatment habitat units (10 – 52 m^2) and 6 control habitat units (4-35 m^2)
Sample sizes and results	Abundance of fish (age 0 coho salmon or of all juvenile salmonids) did not change significantly in response to large wood placement
Nature of the outcome measures used, their relative importance and robustness	Conclude that adding large wood did not change the carrying capacity of habitat units for age-0 coho salmon above control units; Relevant to the REVIEW QUESTION question regarding short term, site-scale effects.
Effects Modifier (confounding factors)	None

*5.

Publication title and principal investigator(s)	Boss, S. M. and J. S. Richardson. 2002. Effects of Food and Cover on the Growth, Survival, and Movement of Cutthroat Trout (*Oncorhynchus Clarki*) in Coastal Streams. Canadian Journal of Fisheries and Aquatic Sciences 59(6): 1044-1053.
Study dates and *study duration*	Enclosures in place for 40 days in East Creek and 20 days in Spring Creek during summer- sampling

	overwinter in 1997
Study location, settings where the intervention was applied	Malcolm Knapp Research Forest (49°162N, 122°342W) within the Coastal Western Hemlock (*Tsuga heterophylla*) biogeoclimatic zone of British Columbia, Canada.
Ecosystem type; plant association group	Forests were harvested for the second time in the mid-1970s and replanted with Douglas-fir.
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Experimentally manipulated food and cover in enclosures containing individually marked trout in two natural streams. Predicted that (i) food addition would affect individuals primarily through increased growth, (ii) cover addition would primarily increase survival, and (iii) both would decrease emigration. To determine whether differences in body size result in differential growth or survival over winter, experimental trout were recaptured following their release from enclosures.
Species studied (if applicable)	Resident coastal cutthroat trout
Study design, experimental controls	A factorial experiment in East and Spring creeks with two levels of food and cover. The four treatments were (*i*) control (no food or cover added), (*ii*) food addition, (*iii*) cover addition, and (*iv*) both food and cover added plus (v) control – no enclosure. Five size-classes of 1-year-old cutthroat trout and attempted to match the density of fish in the enclosures to that of natural stream densities,
Pretreatment data (yes/no)	No.
Intervention or management action,	In East Creek, each enclosure assigned a cover treatment received three plank – cinder block structures, and in Spring Creek, which at the time of setup was twice the wetted width, each received six.
Replications (if applicable)	4 replicates of each treatment 9-m-long enclosed reaches of stream; over-winter trapping reach 113 m
Sample sizes and results	Summer - a randomized block ANOVA, where stream was the blocking variable and replicates were nested within blocks and treatments - Cover did not affect individual growth rates and no interaction between treatments; Although the main effect of cover did not indicate an effect on survival, the block (i.e., stream) by cover interaction was significant but n=2 in Spring Creek where primary effect was observed; The mean number of times that fish emigrated per enclosure was not affected by either food or cover; Cover – no affect on overwinter growth or survival
Nature of the outcome measures used, their relative importance and robustness	Relevant to the REVIEW QUESTION question – but cover was not large wood, short time frame, and small area. Small sample size.
Effects Modifier (confounding factors)	None

*6.

Publication title and principal investigator(s)	Cederholm, C. J., R. E. Bilby, et al. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17: 947-963.
Study dates and *study duration*	Wood placement 1990 and 91; spring, summer, and fall measurements over six years (1988 - 1994)
Study location, settings where the intervention was applied	North Fork Porter Creek (NFPC), located west of Olympia, Washington, in the state-owned Capitol Forest 46°59'N, 123°14'W;
Ecosystem type; plant association group	Capitol Forest logged from 1920 to 1940 and from 1975 on - riparian buffer (8-25m) of standing trees was retained starting in the early 1980s; 1970s about 35 km of stream cleared of nearly all LWD
Watershed type (if applicable, e.g. 6th field)	Third-order tributary (25 km2) to the Chehalis River

Research question(s), hypotheses	Do large wood inputs increase the size and frequency of pools and amount of LWD cover during winter, and positively influence the number of overwintering juvenile salmonids
Species studied (if applicable)	Coho salmon and steelhead
Study design, experimental controls	1,500-m study area separated into three, 500-m sites—reference (R) (upstream), engineered (E)(center), and logger's choice (LC)(downstream)
Pretreatment data (yes/no)	Yes – 1988-1991 (spring) (but, included years of wood placement)
Intervention or management action,	Evaluated changes in habitat and responses of juvenile coho salmon and steelhead to two approaches: placing logs in the channel using heavy equipment and securing the wood in place (E) (133 structures containing 200 logs); and cutting and felling trees (60) into the channel and cabling them to stumps (LC)
Replications (if applicable)	No.
Sample sizes and results	Sampled approximately 20% of each of the three treatment sites for fish. By 1994, the number of pieces of LWD in E was 8.9 times the pretreatment level, in LC was 3.6 times, and in R 2.3-times. Diameters didn't vary but lengths did after treatment in both sites. %Pool area increased more in E than LC site but decreased in R. Coho significantly less in pre than post-treatment for E and LC but only during winter; Age-0 steelhead significantly less in pre and post-treatment for E and R during winter but LC during spring was significantly less in post than pre-treatment; Age-1 steelhead no differences pre- or post- or among sites; no post-treatments varied significantly from R; coho salmon smolt abundance greater in pre-than-post treatment for E and LC; LC expected to affect habitat for only 5 yrs and insufficient trees next to the channel to sustain LC method at 5-year intervals.; E designed to last 25 yrs little sign of decay when study ended.
Nature of the outcome measures used, their relative importance and robustness	Relatively long-term with a reference site, but un-replicated treatments and inclusion of 1990 and 1991 treatment years as pre-treatment data. Thus, apparent fish responses may be difficult to interpret. Increases in wood and pools with large wood placement are likely more reliable.
Effects Modifier (confounding factors)	Activities associated with wood placement in 1990 and 91 may have artificially lowered pre-treatment abundances and thus affected pre-and post-treatment comparisons, particularly for juveniles. Pre-treatment juvenile estimates may have also been lowered due to sampling issues in E and high winter flows. Logs in E primarily conifer from outside riparian; logs in LC primarily red alder from riparian; population census of coho salmon juveniles in the spring and late summer of stocked (1989,1990, and 1991) versus unstocked years indicated that stocking of 19,000 fed coho salmon fry had no discernible effect on fish density;

*7.

Publication title and principal investigator(s)	Coe, H.J., P.M. Kiffney, and G.R. Pess. 2006. A Comparison of Methods to Evaluate the Response of Periphyton and Invertebrates to Wood Placement in Large Pacific Coastal Rivers. Northwest Science 80, No. 4. [Email solicitation]
Study dates and *study duration*	Samples collected September 2002; tiles sampled after 1 month in river;
Study location, settings where the intervention was applied	Elwha River (ER), Olympic Mountains, WA (dam upstream of study site); North Fork Stillaguamish River (NFSR), North Cascades, WA (free-flowing)
Ecosystem type; plant association group	ER – 80% National Park; NFSR- timber harvest and road-building in the headwaters reduced wood

	inputs.
Watershed type (if applicable, e.g. 6th field)	ER 692km^2; NFSR 684 km^2
Research question(s), hypotheses	Evaluate importance of placed wood for periphtyon and invertebrates in two large (bankfull width > 30m) Pacific Northwest coastal rivers using small stream sampling methods and a new method for collecting invertebrates and periphyton from wood in large rivers; compared invertebrate densities and communities and periphyton biomass on artificial substrates and on natural substrates including cobbles and wood.
Species studied (if applicable)	Periphyton and macroinvertebrates
Study design, experimental controls	Upstream reference reaches
Pretreatment data (yes/no)	No.
Intervention or management action,	ER -11 Engineered Log Jams (ELJs) were placed between rkm 3.7 and rkm 4.0 in Elwha River 1999-2001 and another 5 in 2002 - 2003.; NFSR four 5 ELJs were placed between rkm 35.3 and rkm 36.
Replications (if applicable)	1
Sample sizes and results	Tiles - 3 treatment and 2 reference in each river; natural substrates - 3 wood in each treatment and 2 cobble in each reference for each river; **Tile:** No significant differences in mean organic matter, chlorophyll content, or mean total invertebrate densities between reaches in either river; invertebrate community in both rivers primarily Chironomidae and 'other' invertebrates -ER,'other' dominated the treatment reach (> 50%), and Chironomidae the reference reach (> 80%) NFSR - treatment reach about 50% Chironomidae and 50%'other' but Chironomidae dominated (> 50%) the reference reach. **Natural substrates:** ER: No significant differences in mean organic matter or chlorophyll content; NFSR No significant differences in mean organic matter but chlorophyll content greater in reference reach. ER but not in NFSR, total invertebrate density was significantly higher on wood in the treatment reach than on cobble in the reference reach. ER 'other' dominated the treatment reach (> 50%) and Chironomidae dominated the reference reach (> 90%); NFSR 'other' dominated the treatment reach (> 80%) and Chironomidae dominated (> 80%) the reference reach.
Nature of the outcome measures used, their relative importance and robustness	Small sample size, study appeared designed primarily as a methods assessment, 1 replication but no pre-treatment data; the study has limited relevance to the specified primary review question.
Effects Modifier (confounding factors)	Differences in invertebrate density between cobble and wood substrates were likely underestimated as woodburrowing invertebrates were not sampled; natural substrate controls were cobble rather than wood.

*8.

Publication title and principal investigator(s)	Crispin, V., R. House, et al. (1993). Changes in Instream Habitat, Large Woody Debris, and Salmon Habitat After the Restructuring of a Coastal Oregon Stream. North American journal of Fisheries Management 13: 96-102.
Study dates and *study duration*	Survey in 1985 (pre) and 1990 (post) for summer habitat and wood; 1982-1988 (pre) and 1989-1992 (post) for coho salmon spawners
Study location, settings where the intervention was applied	Elk Creek, tributary of the Nestucca River, in Tillamook County, Oregon (severely degraded by logging, floods, and stream cleaning)
Ecosystem type; plant association group	Recently harvested and second-growth timberland
Watershed type (if applicable, e.g. 6th field)	26.6 km2

Research question(s), hypotheses	Quantify changes in summer and winter coho salmon habitat by examining physical characteristics of streams pre- and post-addition of large wood.
Species studied (if applicable)	Coho salmon
Study design, experimental controls	0.5km upstream control for habitat and large wood; 2 untreated Nestucca tributaries for spawner abundance
Pretreatment data (yes/no)	Yes. 1985 for habitat and large wood
Intervention or management action,	1986, 1987, and 1989 installed 106 full-spanning and 94 partial-spanning structures in 4.2 km of stream
Replications (if applicable)	No.
Sample sizes and results	Higher flows in 1990 increased surface area by 8% and volume by 37% in the untreated reach but 74% and 168% respectively in the downstream treated reach, Mean pool size in the treated reach increased from 22 to 92 m2 and in the untreated reach from 56 to 63 m2; mean average and maximum pool depths increased more in the untreated than treated reaches; Treatment reach - total number of habitat units decreased by 3% pools and off-channel riffles increased by 65 units and main-channel riffles decreased by 39 units. Untreated reach - total number of habitat units decreased by 56%. Large wood abundance in the treated reach remained about double that in the untreated reach but the mean diameter and length increased 60 and 96%, respectively, in the treated reach and only 30 and 31% in the untreated reach; suggestion of more coho spawners post- than pre-treatment
Nature of the outcome measures used, their relative importance and robustness	Mean pre- and post-treatment values were not compared statistically for any attributes and sd were given for few.
Effects Modifier (confounding factors)	Flow at pretreatment inventory was 0.11 m3/s and at posttreatment inventory 0.45 m3/s, likely confounding direct comparisons between total absolute estimates of habitat pre- and post treatment. Treated reach had a mature riparian area, untreated reach had a previously logged riparian area making it difficult to assess the effects of large wood placement on characteristics of wood in the channel; pre-treatment coho salmon abundance estimate included treatment years 1986 and 1987 and the post-treatment estimate included treatment year 1989

*9.

Publication title and principal investigator(s)	Frissell, C.A.and R.K. Nawa 1992 Incidence and Causes of Physical Failure of Artificial Habitat Structures in Streams of Western Oregon and Washington. North American Journal of Fisheries Management 12:182-197 [Bayley 2002]
Study dates and *study duration*	Summer of 1986
Study location, settings where the intervention was applied	Streams with slopes primarily <2% in southwest Oregon (mean acw 5.5 – 30m) and southwest Washington (mean acw 8.1 – 31.2 m).
Ecosystem type; plant association group	Forested systems
Watershed type (if applicable, e.g. 6th field)	Oregon - drainage area 1.2 – 51.4km^2; Washington 10.8 – 632km^2 (mean acw 8.1 – 31.2 m).
Research question(s), hypotheses	Evaluate the incidence and causes of physical damage (failure + impairment) to artificial stream structures at several projects following a flood at 2-10-year recurrence intervals within the first few years after construction. Evaluated how well these projects survived and functioned for their projected life spans.
Species studied (if applicable)	None.

Study design, experimental controls	Calculated failure and impairment (damage) rates for each structure type and for each of eight streams in southwest Oregon and seven streams in southwest Washington and related them to stream-specific data on flood-flow magnitude, mean channel width, slope, drainage area, and stream segment type
Pretreatment data (yes/no)	No.
Intervention or management action,	A variety of habitat structures – including cabled natural large wood or; transverse log weir; diagonal log weir; downstream-V log weir; lateral log deflector; multiple-log structure; individually placed boulders; clustered boulders.
Replications (if applicable)	Observational study for each structure type and for each of eight streams in southwest Oregon and seven streams in southwest Washington.
Sample sizes and results	Overall, failure and damage rates of structures were higher for streams in southwest Oregon than in southwest Washington; rates of damage and failure were higher in larger and wider streams in southwest Oregon but for southwest Washington, failure rate was not correlated with stream width but damage was. Relationships relative to slope for structure failure and damage were equivocal due to sampling of few streams with steep slopes. Of the eight structure designs, only two (cabled natural wood and placed boulders) had damage rates less than 50%. Cabled natural wood (n=19) damage rate was about 75% and for multiple-log structures (n=17) damage rate was about 60%. Regionally, structure damage rates appear higher where peak flows are higher, streambanks are more erodable, and rates of sediment inputs are high.
Nature of the outcome measures used, their relative importance and robustness	Simple cabling of logs or log jams seemed to have the lowest damage rates, but study did not distinguish among structure types for mechanism of failure or influence of slope, drainage area, channel width or stream type. Overall, study suggested that damage to structures was greater in wider streams, with high peak flows, and ample sediment supply. Study is not relevant to specific primary review question.
Effects Modifier (confounding factors)	None

*10.

Publication title and principal investigator(s)	Giannico, G.R. 2002 Habitat selection by juvenile coho salmon in response to food and woody debris manipulations in suburban and rural stream sections. Canadian Journal of Fisheries and Aquatic Sciences 57: 1804–1813.
Study dates and *study duration*	Summer of 1994; Experiment 1: trials lasted 72 hrs; Experiment 2: a sampling period in June, July, and August; Experiment 3: 11 trials between July and August.
Study location, settings where the intervention was applied	Spring Creek, Chilliwack, B.C., and Coghlan Creek, Langley, B.C.
Ecosystem type; plant association group	Agricultural land with interspersed residential areas
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Investigate the spatial distribution of juvenile coho in response to wood and food manipulations in stream habitat affected by suburban residential development and agriculture and determine whether such responses change over time. Three experiments were conducted in modified sections of two streams and were repeated throughout the summer. Two experiments manipulated wood and food abundance in the pools of an experimental stream section. The other experiment examined whether the spatial distribution of fish was affected by wood density or type (LWD versus FWD).

Species studied (if applicable)	Coho salmon
Study design, experimental controls	**Experiment 1**: Spring Creek – 2 replicates 4 pools in each (4.1m*2m); Evaluated whether juvenile coho use of pools was affected by wood availability and density, (ii) food abundance (food versus no-food channels) altered fish response to wood and (iii) fish response to wood changes over the summer. In both replicates, all pools were treated with no debris, sparse FWD, or dense FWD. For each trial, treatments were randomly assigned to pools (one treatment repeated at random). For each of the 10 early summer trials, 50 fish were released into each pool for each food treatment (food and no food). For each of the seven late summer trials for each food treatment - 25 fish were released into each pool. Design of this experiment corresponded to a split-plot factorial. Food was the main plot factor (with two levels: food versus no food) and wood was the subplot factor (with three levels: none, sparse, and dense). The experiment was replicated over time. **Experiment 2**: Colghan Creek sites A, B, C each divided into four pools that randomly received no debris, sparse LWD, sparse FWD, or dense FWD. 75-120 fish were released per pool. This experiment examined whether (*i*) juvenile coho salmon distribute among stream pools in response to wood density and type (LWD versus FWD) and (*ii*) fish response to wood changes over time. In the randomized block design (blocks were monthly replications) with two factors (debris and site) and data were examined using ANOVA. The effect of debris on fish distributions was also tested separately for each month using single-factor ANOVA. **Experiment 3:** Spring Creek - 2 replicates 4 pools in each examined whether wood or food alone or the combination of both factors controls the distribution of juvenile coho salmon among pools. 25 fish were placed in each pool for each of 11 trials. Two treatments and two levels: food versus no food and dense FWD versus no debris. Treatment combinations were randomly assigned to pools in each channel. This experiment had two factors (debris and cover) and a randomized block design. In contrast with Experiment 1, this experiment examined the main effects of both wood and food as well as their interaction on fish distribution. **Controls:** In Spring Creek, a an experiment replicated 10 times examined how juvenile coho salmon distributed among pools in the absence of any experimental treatments related to wood and food. Another control test determined whether the juvenile coho salmon of hatchery origin used in Spring Creek differed from the wild fish used in Coghlan Creek for habitat preferences in a common experimental channel.
Pretreatment data (yes/no)	Yes for Experiment 1 and 3 through control in Spring Creek. No for Experiment 2.
Intervention or management action,	Fine wood bundles introduced in all three experiments but large wood introduced in only Experiment 2.
Replications (if applicable)	Yes, the experiments were well replicated.
Sample sizes and results	**Experiment 1:** Fish response to wood did not change markedly over time in the absence of food. Most fish preferred pools with sparse or dense cover, both in early and in late summer. However, when food was added, coho salmon preferred pools with sparse or no FWD in early summer, whereas in late summer, the majority of fish chose pools with sparse FWD. **Experiment 2:** June, debris did not affect fish distribution among pools; in July, it did have a significant effect on pool choice by fish, with sparse FWD treated pools attracting a higher proportion of fish than the other pools; in August, the effect of debris on fish distribution was also significant and fish were equally attracted to pools with sparse debris density regardless of debris type. **Experiment 3:** results indicate that juvenile coho salmon responded primarily to food and that wood altered the response.
Nature of the outcome measures used, their	Food abundance alters the response of juvenile coho salmon to wood density, and this response changes

relative importance and robustness	over the summer. Pools with intermediate wood densities were chosen by relatively high proportions of individuals in most trials. The presence of food rather than cover seemed to be most important in determining juvenile coho salmon habitat preference. Effects of LWD and FWD not distinguishable in late summer. Site-level, summer effects of wood on pool use by juvenile coho salmon.
Effects Modifier (confounding factors)	Experiment 1 and 3 - Because the waterfall seemed to attract fish into the upstream pools in the absence of treatments, ANCOVA was used to separate the effect of this factor from those of food and wood on fish distribution. Two covariables were used: "distance" (between the centre of each pool and the upstream end waterfall) and "distance." Juvenile coho salmon of hatchery origin were used in Spring Creek and wild fish were used in Coghlan Creek but no difference in pool choice was observed between these two types of fish in the artificial channel.

11.a

Publication title and principal investigator(s)	Gowan, C and K.D. Fausch. 1996. Long-Term Demographic Responses of Trout Populations to Habitat Manipulation in Six Colorado Streams. Ecological Applications 6: 931-946.
Study dates and *study duration*	1987 – 1994; 8-year study
Study location, settings where the intervention was applied	500-m reaches of six high-elevation small streams with moderate gradients in northern Colorado broken into two groups based on elevation (>2700m) and trout species composition (primarily brook and cutthroat trout).
Ecosystem type; plant association group	Forested, Rocky Mountain.
Watershed type (if applicable, e.g. 6^{th} field)	Streams 2.9-5.8 m in mean width
Research question(s), hypotheses	Determine if trout populations respond to habitat manipulation at the stream-reach scale and quantify the demographic mechanisms responsible.
Species studied (if applicable)	Brook trout, Colorado River cutthroat trout, brown trout, rainbow trout
Study design, experimental controls	A **controlled** and replicated field experiment to test for cause and effect relationships among wood placement and trout abundance, biomass, growth, survival, and movement. Also examined whether variation in population abundance was concordant among streams and among reaches within streams to evaluate potential regional-scale effects. About half of each reach was a control, which was typically randomly located upstream or downstream of the treatment. Pool volume, wetted area, total cover during summer analyzed with a repeated measures split-plot ANOVA - streams were replicates (random effects); all other effects were fixed, stream section as the whole plot factor (control or treatment), and time as the subplot factor with post-treatment = 1993-1994); depth and fine substrate post treatment effects analyzed as one-way ANOVA. Summer fish density and biomass by age class (age 1 and age 2+): 1) examined pre-treatment differences among streams, and 2) a repeated measures MANOVA to test for differences between treatment and control sections during the six post-treatment years (1989-1994) - a significant effect indicates that the logs changed fish populations in treatments relative to controls. Examined four potential mechanisms that could cause abundance or biomass of adult trout to increase in treatments relative to controls: increased recruitment of juveniles, adult survival, growth (for biomass), or net immigration. Analysis of some variables was broken into pre-treatment, initial post-treatment [1989-1991], and final post-treatment [1992-1994]. Examined regional factors – concordance over time among

	sections (n = 40) and among streams (n=6) - for adult and juvenile fish separately.
Pretreatment data (yes/no)	Yes. 1987-1988 for fish and many habitat variables
Intervention or management action,	10 – 15 log-drop structures were installed in about half of each reach
Replications (if applicable)	Yes. Six.
Sample sizes and results	Streams differed significantly before treatment in trout density and biomass, but no significant differences in trout or habitat parameters between treatment and control reaches pre-treatment. Pool volume and total cover were significantly greater after treatment than before but not wetted area. Mean depth and percent fine substrate were greater in treatment than controls. After accounting for among stream differences pre-treatment, biomass and density differed significantly with addition of log structures for adult trout but not juveniles. Growth – in 11 of 12 possible comparisons between the treatment and control section indicated either no significant difference or higher growth in a control. Survival – varied by time and section in one stream but only by time in the other examined stream. Movement – Few immigrants came from nearby control reaches. In higher elevation streams - immigration of adults exceeded emigration, apparently peaking during 1989-1991. Immigration into treatments was higher than into controls during 1989-1991, but did not differ thereafter. In lower elevation streams - movement was not as common and immigration rates did not differ between treatment and controls in either post-treatment period. Trout abundance in treatments and controls within and among streams tended to fluctuate together more than expected by chance.
Nature of the outcome measures used, their relative importance and robustness	Log placements increased the number and biomass of adult trout in treated sections, mainly due to immigration, not increased survival, recruitment, or growth. This held across streams with four trout species and a range of elevations and habitat conditions. Habitat manipulation increased the habitat available to trout; populations responded via movement rather than by in situ processes. Although conducted at a reach scale, the study may have broader-scale implications about the effects of instream wood placement on fish given that movement was the primary response. Habitat manipulation may have positive effects beyond the treated reach, but only if fish dispersal remains unimpeded within a drainage. Highly relevant to the primary review question.
Effects Modifier (confounding factors)	Evaluated potential effects of angling on results and determined to be of minor importance.

11b.

Publication title and principal investigator(s)	Gowan, C and K.D. Fausch. 1996. Long-Term Demographic Responses of Trout Populations to Habitat Manipulation in Six Colorado Streams. Ecological Applications 6: 931-946.
Study dates and *study duration*	1987 to 1994. Seven years.
Study location, settings where the intervention was applied	Six high elevation streams (Colorado Cr., Walton Cr., North Fork Cache la Poudre River, Jack Cr., Little Beaver Cr., and St. Vrain Cr.) in Northern Colorado. Streams small (2.9 to 5.8 m in width) and with moderate gradient (1.2 to 2.7%).
Ecosystem type; plant association group	Headwater streams in Rocky Mountains. Forested.
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Determine if trout populations respond to habitat manipulations at the stream-reach scale in terms of fish numbers, biomass, growth, survival and movement.

Species studied (if applicable)	Brown, brook and rainbow trout.
Study design, experimental controls	Manipulations in 500-m long reaches that were poor in LWD and had few pools. Streams divided into two groups: four of them >2,700 m in elevation and dominated by brook trout with some cutthroat trout (first four listed above), and those <2,500 m in elevation that were either dominated by brown trout (Little Beaver Cr.) or with equal proportions of brown, brook and rainbow trout (St. Vrain Cr.). **Manipulations = placement of 10 log weirs in half of each 500-m reach. Hence, study relied on six 250-m-long treated sections and six 250-m-long control sections. Treatment sections were randomly assigned with condition that 50% were on the upstream half of the reaches and the other 50% on the downstream part.** One stream was the exception (St. Vrain) and had two 250-m control sections, one upstream and the other downstream of 375-m treatment section (which had 15 log weirs). Also, 60 m of the treated section in Little Beaver Cr. were divided into two channels. So smaller structures were placed and 13 weirs were used to provide similar habitat volume to treatments in other streams. Water depth, and substrate composition were measured during baseflow period. Pool volumes, and overhead cover (adding undercut banks, overhanging riparian veg., logs, boulders and wetted brush). Habitat measured in each creek every other year. Fish abundance estimates by 3-pass removal electrofishing. Fish measured, weighed and fin clipped. Fish >120mm individually tagged. Age classes were estimated. Liner models used for analyses. Four mechanisms that could potentially alter adult trout numbers and biomass in treated sections were explained, and ways to identify them in the results were identified in advance.
Pretreatment data (yes/no)	**Yes.** For habitat: pretreatment in 1987 and post treatment between 1993-and 1994. Pretreatment data on depth and substrate were collected differently and, therefore, not used in analyses. For fish: pretreatment 1987 and 1988; post treatment from 1989 through 1994 (6 years).
Intervention or management action,	LWD installation in late summer 1988. Log weir placements in 250-m-long stream sections (which were randomly selected and adjacent to 250-m-long control sections).
Replications (if applicable)	**Yes. Six replicates (streams were replicates) in space, and 8 replicates in time.**
Sample sizes and results	Sample size = 12 for each year, and 96 for entire study. Pool volume, mean depth, % fines and total cover increased with log weir placements; but wetted area did not. Manipulations also increased adult trout numbers and biomass. Once pre-treatment differences among streams accounted for, treatments produced similar population responses in all of them. However, juvenile trout did not seem to respond to log placements. Trout growth, survival, and recruitment responses to treatment were not consistent among streams. Hence, increased fish numbers and biomass attributed to immigration into treatment sites often from beyond adjacent reaches.
Nature of the outcome measures used, their relative importance and robustness	Long-term study measured field responses in habitat characteristics and fish populations after LWD placement. Treatments randomly applied within blocks (streams). Pre-treatment data. Control-treatment
Effects Modifier (confounding factors)	Different altitudes and species composition among creeks. Yet, findings may apply in general terms to small stream in the central Rocky Mountains). Different angling pressure in one of the streams. Authors were confident that they compensated for this by quantifying it through creel surveys and time-lapse photography. Possible regional level climatic effects were considered and tested a posteriori to detect concordance (in fish populations changes) between sections, and among streams. Tests found concordance in trout number changes across all streams.

12.

Publication title and principal investigator(s)	Hartzler. J.R 1983. The Effects of Half-Log Covers on Angler Harvest and Standing Crop of Brown Trout in McMichaels Creek, Pennsylvania. North American Journal of Fisheries Management 3:228-238.
Study dates and *study duration*	1977-1981
Study location, settings where the intervention was applied	
Ecosystem type; plant association group	15 km of McMichaels Creek, which is formed by three tributaries that drain part of the Pocono plateau in eastern Pennsylvania
Watershed type (if applicable, e.g. 6th field)	Second-growth deciduous forest shades the stream throughout most of its length, except for several open meadow sections.
Research question(s), hypotheses	Stream width averages 7 m
Species studied (if applicable)	This study was designed to measure the effects of half-log shelters on a brown trout population in a stream considered to have adequate cover. It tested the hypothesis that increasing the amount of only one physical feature, cover habitat, would result in both greater numbers and biomass of "catchable-size" (>200 mm) wild trout.
Study design, experimental controls	brown trout
Pretreatment data (yes/no)	Pre-treatment 1977 and 1978. 35 reaches, ranging from 240 to 1,000 m were electrofished (3-pass method) in August to obtain number and biomass estimates. 6 of 35 reaches with low standing crops of brown trout were treated and 6 randomly selected reaches were left as controls. These 12 reaches were electrofished again in 1979, 1980, and 1981. A complete record also was kept of the number of wild brown trout killed by anglers in each fishing area.
Intervention or management action,	Yes – 2 years
Replications (if applicable)	October 1978, 68 half-log cover devices (oak or aspen log 2.0-2.5 m long and 20-30 cm diameter was split lengthwise, placed on wooden blocks, and anchored in the stream bed) were added in six reaches over 2.3 km.
Sample sizes and results	Yes – 6 for treatment and 6 for control.
Nature of the outcome measures used, their relative importance and robustness	n=12 for treatments and n=6 for controls; Half-log devices did not produce a substantial change in the total number of brown trout creeled by anglers but the number harvested increased in five out of six treated reaches. Pre- and post treatment numbers and biomass of brown trout (≥200 mm)were not significantly different. Number and biomass of trout in the yearling (100-199 mm) group was significantly higher in the post-treatment period in both treated and control sections. The biomass of trout (≥100 mm) increased in treated reaches. Supplemental cover had little effect on the relative proportion of yearling or older trout in the population.
Effects Modifier (confounding factors)	Neither numbers nor biomass of larger brown trout were significantly affected by supplementary cover provided by half-log devices, suggesting cover was not limiting in the stream. Results are relevant to the primary review question regarding cover.
	High flows prevented sampling of all control reaches in both pre-treatment years - four reaches were electrofished in 1977 and two reaches in 1978. Effects of angling effort were considered. Population and

	abundance data tested for normal distribution and thus comparisons were conducted on ranks

*13.

Publication title and principal investigator(s)	House, R. and P. Boehne. 1986. Effects of Instream Structures on Salmonid Habitat and Populations in Tobe Creek, Oregon. North American Journal of Fisheries Management 6: 38-46.
Study dates and *study duration*	Summer 1982 and 1983
Study location, settings where the intervention was applied	0.52 km – 3.7 km upstream of the mouth of Tobe Creek, in the Alsea River drainage, Oregon Coast Range
Ecosystem type; plant association group	Riparian area of young alder downstream and 80-130-year-old mixed conifer and bigleaf maple upstream
Watershed type (if applicable, e.g. 6th field)	927 ha
Research question(s), hypotheses	Examine physical and biological differences between a stream section logged over 20 years ago (before and after stream enhancement to imitate the role of large wood) and a stream section in an unlogged coniferous forest area.
Species studied (if applicable)	Coho salmon, age 1+ steelhead, and trout (cutthroat and steelhead < 0.75mm long)
Study design, experimental controls	Fish populations and selected physical stream parameters were sampled at 16 stations, each was 30.5m long. Physical information collected at 10 x-sections at each station, large wood (> 10 cm diam and 3 m long) was counted and volumes estimated. Juvenile population and biomass estimates were obtained following 2-pass removal electroshocking at each station. Four spawning ground counts were made between 10 February and 15 March 1982 and 15 counts between 16 November 1982 and 4 April 1983. Numbers of adults and redds were counted in the 0.8-km stretch of improved stream.
Pretreatment data (yes/no)	Yes. 1982.
Intervention or management action,	Installed gabions (wire containers made of two wings of a "V" placed at a 30-45 ø angle oriented downstream from the bank) in 1982 after the summer survey.
Replications (if applicable)	Sampling at 16 stations (five were treated) – but results do not appear to be presented as means with some measure of variance and compared statistically between treated and untreated sections or before and after treatment.
Sample sizes and results	Observed differences pre- and post-gabion installation for habitat, juvenile salmonids, and adults.
Nature of the outcome measures used, their relative importance and robustness	Results regarding the effects of gabions have little relevance to the specific primary review question.
Effects Modifier (confounding factors)	Flows at the time of survey were substantially higher in 1983 than in 1982.

*14.

Publication title and principal investigator(s)	House, R. A., and P. L. Boehne. 1985. Evaluation of instream enhancement structures for salmonid spawning and rearing in a coastal Oregon stream. North American Journal of Fisheries Management 5:283–295. [Roni et al. 2005]
Study dates and *study duration*	July 1981, 1982, and 1983
Study location, settings where the intervention was applied	0.8 km reach located 1.5 km upstream from the mouth of East Fork Lobster Creek in the Alsea River drainage, Oregon Coast Range

Ecosystem type; plant association group	80% of forest is 0-50 years old alder and conifer
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Determine stability of structures and changes in stream width, depth, channel configuration, and bottom substrate resulting from the installation of structures; and (2) changes in adult salmonid utilization and juvenile density and biomass due to enhancement.
Species studied (if applicable)	Coho salmon , steelhead, cutthroat trout
Study design, experimental controls	Fish populations and selected physical stream parameters were sampled at 10 stations each was 30.5m long. Five stations (3, 5, 7, 8, and 10) were considered untreated controls. Habitat information collected at 10 x-sections at each station. Number of redds and adults were counted in 24 spawning ground counts between 21 October 1981 and 22 April 1982; 19 counts between 27 October 1982 and 4 April 1983. Juvenile population and biomass estimates were obtained following 2-pass removal electroshocking at each station. A small-mesh beach seine was used with the shocker in pools at stations 1, 2, 4, 8, and 9 in 1982 and 1983.
Pretreatment data (yes/no)	Yes. 1981.
Intervention or management action,	Installed August 1981 over 0.5km reach: a mix of gabions (wire containers made of two wings of a "V" placed at a 30-45 ø angle oriented downstream from the bank); logs dragged into channels, inserted into stream banks, and secured using clusters of boulders; and boulder clusters.
Replications (if applicable)	Examined one reach in one stream for habitat and juveniles, but three replicates for 2-V gabion treatments and five replicates for controls in this reach. Adults – no replication.
Sample sizes and results	Log structures floated during high flows releasing trapped gravel but remained anchored scouring pools. Although changes to physical habitat, number of spawning redds, and juvenile density and biomass were reported, results were not associated with log placement specifically.
Nature of the outcome measures used, their relative importance and robustness	Findings were generally not relevant to the primary review question. Stability of structures was the only outcome specifically associated with log placement.
Effects Modifier (confounding factors)	To supplement wild steelhead runs, the Oregon Department of Fish and Wildlife released 279 female and 237 male adult steelhead 16 km downstream in Lobster Creek in 1981 and another 274 females and 139 males in 1982, and 169 females and 139 males 1.6 km downstream in 1983. 1983 above-average summer rainfall increased mean summer flows.

*15.

Publication title and principal investigator(s)	Johnson, S. L., J. D. Rodgers, M. F. Solazzi, and T.E. Nickelson. 2005. Effects of an Increase in Large Wood on Abundance and Survival of Juvenile Salmonids (*Oncorhynchus Spp.*) in an Oregon Coastal Stream. Canadian Journal of Fisheries and Aquatic Sciences 62: 412-424.
Study dates and *study duration*	Examined summer rearing population for 10 years. Examined the ocean migrant population for 12 years to determine the smolt production and freshwater survival of the age-0+ steelhead sampled in the ninth and tenth years of summer sampling.
Study location, settings where the intervention was applied	Tenmile Creek (treatment) and Cummins Creek (control) Oregon Coast Range
Ecosystem type; plant association group	Conifer and mixed conifer/hardwood

Watershed type (if applicable, e.g. 6th field)	Tenmile Creek (60.7 km2) and Cummins Creek (24.6 km2) both empty directly into Pacific
Research question(s), hypotheses	Examine juvenile salmonids (summer rearing populations and smolt populations) in an entire control and a treatment stream before and after addition of large wood. Evaluating how a sudden increase in large wood affects juvenile salmonid production and survival within a watershed.
Species studied (if applicable)	steelhead, coastal cutthroat trout, and coho salmon
Study design, experimental controls	BACI – treatment and control streams but the two did not track each other prior to treatment and so data were analyzed separately. Annual summer population size, smolt abundance (annually March-June), and freshwater survival (defined as the percentage of age-0+ fish that survived to smolt), summer and winter habitat in one or more years pre- and post-treatment.
Pretreatment data (yes/no)	Yes. 5 years
Intervention or management action,	October 1996, placed 241 whole conifer trees (30–35 m length, 75 cm butt diameter) in the active channel to create a series of large jams throughout the upper half of the treatment stream. Trees were not cabled.
Replications (if applicable)	None.
Sample sizes and results	More large wood (pieces and volume) after than before treatment in both streams; percent summer pool area increased in two of four treated reaches but not in untreated reaches in either stream. In the reach where most of the habitat restoration trees were placed, the percentage of pool habitat associated with pools deep pools (>1m) increased significantly. In the untreated stream, the percentage of summer stream surface area classified as pool habitat did not change between pre- and post-treatment years. Results suggested an increase in winter % pool area, total mainstem habitat area, and total side channel habitat area in treated reach. Summer populations of st0+ increased in control but not treatment, smolt abundances increased in treatment and control, survival increased in treatment but not control; sea run cutthroat trout smolts increased in both treatment and control streams; neither coho salmon summer juvenile or smolt abundances differed between pre- and post treatment in either stream, but survival increased in treatment stream but was not analyzed in control
Nature of the outcome measures used, their relative importance and robustness	Freshwater survival of steelhead does appear to have been affected by addition of wood in the treatment stream. Summer rearing densities of coho salmon were generally lower posttreatment than pretreatment in treatment stream, and less density-dependent mortality may have contributed to the observed increase in freshwater survival post-treatment. Circumstances beyond the control of the researchers (see below) may have confounded the results and reduced the relevancy of the study for answering the primary review question. Although not replicated, the study was long-term, well designed, and considered multiple species and life-history stages.
Effects Modifier (confounding factors)	Large storm in February of 1996 (100 year event) added large volumes of wood to the treatment (primarily in the lower reaches) and control streams (primarily upstream of salmon habitats). 1996 US Forest Service decommissioned approximately 19 km of roads in the watershed, removing culverts and fill. Riparian areas were planted with approximately 2000 young conifer trees along approximately 1.6 km of treatment stream. Some streamside riparian areas dominated by hardwood were thinned to increase the growth of existing conifers. Pre-treatment winter surveys were in different years for the treatment and control streams – not sure how differing flows may have influenced habitat comparisons. Stricter fishing regulations put in place in mid-1990s

*16.

Publication title and principal investigator(s)	Keim, R. F., A. E. Skaugset, et al. 2002. Physical Aquatic Habitat II: Pools and Cover Affected by Large Woody Debris in Three Western Oregon Streams. North American Journal of Fisheries Management 22(1): 151-164.
Study dates and *study duration*	Treatment in Dec. 1992 – October 1994, specific dates depending on Creek; post-treatment surveys.
Study location, settings where the intervention was applied	Oregon Coast Range. Tyee formation. Bark (lowest gradient), Buttermilk, and Hudson (highest gradient) Creeks
Ecosystem type; plant association group	Western hemlock zone but riparian areas along all streams were alder dominated.
Watershed type (if applicable, e.g. 6th field)	Third order streams on 1:24,000 map, low gradient <1.2% pool-riffle
Research question(s), hypotheses	Investigate the effects of an integrated restoration of streams and riparian zones in the Oregon Coast Range. Expected that added LWD would (1) increase total amount of residual pool habitat during the summer low flow, (2) create deeper residual pools, and (3) increase cover for fish in pools.
Species studied (if applicable)	None.
Study design, experimental controls	Two treated reaches separated by an untreated reach in each of three streams. Data were collected pre-treatment, post-treatment and in 3 additional post-treatment years. Measured and mapped residual pool (>15cm deep) depth, width, and length then summarized volume at 15cm depth increments. Measured and mapped number and volume of all wood pieces (>2m long and 0.1 m diameter if any part fell in the wetted or active channel) then summarized data by size classes. Index of cover (m^2/m) as the sum of the products of the diameters and lengths of all pieces of wood in the boundaries of all pools, divided by the length of the surveyed reach.
Pretreatment data (yes/no)	Yes. Bark and Buttermilk Creeks in January 1993 and Hudson Creek in June 1994 for wood data. All streams were surveyed for pre-treatment morphology the fall after treatment.
Intervention or management action,	Two small riparian clear-cuts (90-m long, separated by 140-290 m buffers ranging in width from 8 to > 25 m) were made along experimental reaches, which were each approximately 0.5km long. Wood placed into experimental reaches was primarily alder or de-limbed Douglas fir as key pieces (4-11 pieces) or logging slash (41-118 pieces). Logs were 0.9-4.2 times the active channel width. Alder had rootwads attached and were longer than Douglas fir.
Replications (if applicable)	Yes. Three streams.
Sample sizes and results	By year 3, much of the wood in the studied reaches originated from upstream and most of the wood added by the treatments moved downstream. Total residual pool volume increased in treated and untreated sections in Buttermilk, in only the treated section of Hudson because the untreated section was primarily bedrock, and was unchanged in the treated section and decreased slightly in the untreated section of Bark. Adding wood increased the amount of residual pool area covered by wood.
Nature of the outcome measures used, their relative importance and robustness	Authors considered the study as evaluating three trials of a treatment rather than the effects of relatively small wood on streams. Wood from the treatments moved into untreated reaches. Strongest evidence relative to question posed by the systematic review is that residual pool area covered by wood increased after treatment.
Effects Modifier (confounding factors)	Authors identified several irregularities in the application of treatments that limited the scope of inferences. The large storm event in year three may have substantively influenced outcomes.

*17.

Publication title and principal	Lacey, R. W. J. and R. G. Millar. 2004. Reach scale hydraulic assessment of instream salmonid habitat

investigator(s)	restoration. Journal of the American Water Resources Association 40: 1631-1644.
Study dates and *study duration*	Treatment occurred in the summer of 1999
Study location, settings where the intervention was applied	Tamihi side channel (400 m long with mean bankfull width (15 m) and depth (1.5 m) in the Chilliwack River, British Columbia
Ecosystem type; plant association group	Northern Cascade Mountains
Watershed type (if applicable, e.g. 6^{th} field)	Bankfull capacity of the Tamihi side channel is $40m^3$/sec
Research question(s), hypotheses	Used a 2D depth averaged, finite element triangular mesh hydrodynamic model, River2D, to assess the hydraulic and morphological effects, as well as the habitat benefits of instream structures.
Species studied (if applicable)	Steelhead and coho salmon
Study design, experimental controls	Pre-flood (November 1999 – 5-yr return interval) and post-flood channel surveys were conducted in late September 1999 and mid-February 2000. 1-m horizontal resolution DEMs were created from field measurements (pre-flood and post-flood bathymetry with and without structures). Finite element meshes were generated for the four DEMs, and hydraulics were computed for each mesh at four discharges (40, 5.0, 0.5, and 0.05 m3/s). Used modeled velocity and depth to determine the weighted usable area (WUA) from species-specific habitat preference curves.
Pretreatment data (yes/no)	Yes. Appears that pre-flood, pre-structure data was modeled.
Intervention or management action,	11 structures (four multiple-wood triangular structures, four single-wood rootwads, one single-rock groyne, and two double-rock groynes) were installed.
Replications (if applicable)	None.
Sample sizes and results	The channel was uniform with very little variation prior to structure placement. Pools formed and channel shapes adjusted following structure placements, with the deepest sections adjacent to the apex of structures. Larger pools developed adjacent to multiple-wood triangular and rock-groyne structures. Fines deposited directly downstream and upstream of structures consistent with modeled backwater and sheltering effects of the triangular and single-piece rootwad structures. Percent increase in WUAwas flow and fish-age dependent and ranged -5 to 210%. The most beneficial aspect of instream structures was to increase preferred habitat areas during high flows for steelhead and coho fry, and juveniles.
Nature of the outcome measures used, their relative importance and robustness	Site-specific results indicate pools were formed and WUA for juvenile steelhead and coho salmon increased due to instream wood placement. Study seems most relevant in demonstrating the 2D model for determining the best locations and designs for instream structures to achieve desired channel and habitat effects.
Effects Modifier (confounding factors)	Instream structures were represented in the DEMs by modifying bathymetries to simulate structure dimensions as shelf like solid obstructions and water flow was restricted to overtop and around structures.

*18.a

Publication title and principal investigator(s)	M.G. Larson , D.B. Booth, and S.A. Morley. 2001. Effectiveness of large woody debris in stream rehabilitation projects in urban basins. Ecological Engineering 18: 211–226.
Study dates and *study duration*	Summers of 1998 and 1999
Study location, settings where the intervention was applied	Six alluvial plane-bed or pool-riffle channels in Puget Sound Lowland with perennial flow

Ecosystem type; plant association group	Various degrees of urbanization
Watershed type (if applicable, e.g. 6^{th} field)	2.2 – 53.6 km^2
Research question(s), hypotheses	Investigate effectiveness of large wood placement to reverse local effects of watershed degradation in the absence of systematic watershed-scale approaches to rehabilitation. 1) Does in-stream wood placement produce physical channel characteristics typical of streams in less disturbed watersheds? 2) Does biological condition improve immediately downstream of wood addition? 3) How can project designs be improved? And 4) Does watershed disturbance exert greater control over physical and biological recovery than the local in-channel conditions addressed by added wood?
Species studied (if applicable)	Benthic-IBI, composed of ten metrics of taxa richness and evenness, disturbance tolerance, and life history attributes of benthic invertebrates.
Study design, experimental controls	Two sections of stream, at least 20 times the bankfull width, were surveyed in each project and just upstream. When pre-project data were lacking, post-project conditions were compared with data in the literature for other Puget Sound Lowland streams and/or to reaches upstream of each project. Root wads greater than 0.02 m^3 and all pieces of wood $\geq$ 10 cm diameter and 1 m long in the bankfull channel were counted; sediment storage was described by characterizing bars as either 'self-formed' or 'associated with wood;' depth and total volume of sediment stored by wood was estimated; overall volume of sediment in each section was estimated as the total volume of alluvial bars in the channel. The influence of wood in controlling reach grade was estimated from a longitudinal profile of the channel thalweg. Benthic-IBI was assessed in four streams. In addition, **pre- and post-project** physical conditions were compared for three streams for movement of wood into the project area; pools (with a RPD of at least 25% of the bankfull depth and at least as long as 10% of the bankfull width) were counted and expressed as the distance between pools in units of bankfull channel widths; pools formed by wood and pools formed by some other mechanisms were identified; number of pieces of wood associated with a given pool was counted.
Pretreatment data (yes/no)	Yes. Physical data for three projects (Laughing Jacobs, Soosette, and Swamp Creeks),
Intervention or management action,	Placement of anchored and unanchored wood in urban streams from 2 – 10 years prior to the study.
Replications (if applicable)	Yes. Examined 6 wood placement projects.
Sample sizes and results	Wood loadings were highest, in the range of least degraded urban Puget Lowland streams, in unanchored projects. For projects where wood was anchored, wood loadings were lower and typical of moderate to highly degraded urban streams and clearcuts. Described several characteristics of the added wood (e.g., size, degree of contact with or obstruction of low-flow channel). Wood moved only in unanchored projects containing few or no key pieces. Post-project pool spacing was not correlated to wood loading. But, in the three project reaches with pre-project data, pool spacing narrowed after wood was added. 50-80% of pools were formed by added wood; 30–70% of added wood was associated with pools where anchored but 15–18% where unanchored. Pool depth differed little between pools formed by wood or by other obstructions, between plunge or scour pools, or between pools formed by natural or added wood. About one-third of estimated in-channel sediment storage was associated with wood at most sites but wood placements were basically unsuccessful at retaining sediment and reducing downstream sedimentation; added wood contributed most to grade control on the highest gradient streams where wood extended the full channel width but contributed little to grade control on the low-gradient streams. Adding wood had little effect on B-IBI, but B-IBI varied inversely with the increase in percent developed land.

Nature of the outcome measures used, their relative importance and robustness	The degree to which watershed conditions influence project effectiveness varies with specific project objectives. Although projects spanning several hundred meters may improve some measures of physical habitat (i.e. pool spacing) locally over time scales of 2–10 years, they had little influence on the benthic invertebrate community or on stabilizing or retaining sediment to reduce downstream sedimentation and associated flooding. No obvious detriments of adding wood to urban streams were found. Authors indicated that if problems originate from upstream or from watershed-scale disturbances, adding wood did not appear to solve or mitigate the problem. Authors offer recommendations for increasing effectiveness of large wood placement and considerations. Study relevant to primary review question.
Effects Modifier (confounding factors)	Wood placement in reaches from 210 to 430 m, except for one (1430 m), as smooth logs, root wads, and tops of trees. Five projects less than 4-years old and the sixth 10-years old. Degree to which the streams were constrained by human activities varied greatly between projects. At most sites, upstream reaches varied somewhat from pre-project conditions due to differences in valley width, slope, or encroachment. Could not determine what effects, if any, these may have had.

*18b.

Publication title and principal investigator(s)	M.G. Larson , D.B. Booth, and S.A. Morley. 2001. Effectiveness of large woody debris in stream rehabilitation projects in urban basins. Ecological Engineering 18: 211–226.
Study dates and *study duration*	Summers of 1998 and 1999. However, treatments evaluated ranged in age from 2 to 10 years
Study location, settings where the intervention was applied	Six perennial, alluvial plane-bed or pool-riffle streams within the Puget Sound lowland region.
Ecosystem type; plant association group	Coastal watersheds with varying degree of urban and suburban development
Watershed type (if applicable, e.g. 6^{th} field)	2.2 – 53.6 km2
Research question(s), hypotheses	Investigate effectiveness of in-stream placement of LWD to reverse local effects of watershed degradation in the absence of any systematic watershed-scale approaches to rehabilitation. To address this objective, the study aimed at answering the following four questions: 1) Does in-stream placement of LWD produce physical channel characteristics typical of streams in less disturbed watersheds? 2) Does biological condition improve immediately downstream of LWD addition? 3) How can LWD project designs be improved? And 4) Does watershed disturbance exert greater control over physical and biological recovery of the channel than the local in-channel conditions addressed by added LWD?
Species studied (if applicable)	Benthic-IBI, composed of ten metrics of taxa richness and evenness, disturbance tolerance, and life history attributes of benthic invertebrates.
Study design, experimental controls	Two sections of stream, at least 20 times the bankfull width, were surveyed both at each project's location and immediately upstream. All pieces of wood >10 cm in diameter and 1 m in any portion of the bankfull channel were counted. Root wads> 0.02 m^3 in volume were also counted. The diameter and length of every piece was estimated. Every five to ten pieces the lengths and widths were measured with tape to calibrate the visual estimates. Key pieces (those independently stable within the channel and able to retain other material) were also identified. Where pre-project data were available, the movement of LWD in the project reaches was estimated. Variables measured in the field included: residual pool depth, and pool numbers. These counts were converted to average pool spacing per reach to allow direct comparison

	among streams. Pools were classified based on whether they were formed by LWD or by other mechanism. Substrate bars were classified as either self-formed (without LWD) or associated with LWD. Depth and volume of sediments were measured where LWD trapped sediments. Longitudinal profiles were used to measure the influence of LWD in controlling grade. Benthic Index of Biological Integrity (B-IBI) was used to measured biological conditions at project sites. This index combined ten metrics of taxa richness and evenness, disturbance tolerance, and life history attributes of benthic invertebrates. Benthic samples were collected with Surber sampler in late summer at only four of the projects, both upstream and downstream of installed LWD.
Pretreatment data (yes/no)	Yes, but only for three projects (Laughing Jacobs, Soosette, and Swamp Creeks) with pre-project data
Intervention or management action,	In-stream LWD placement in urbanized watersheds. Projects differed in age (2-10 years), design (anchor and no-anchored) and type of LWD (logs, root wads, tops of trees).
Replications (if applicable)	Yes. Six LWD placement projects were compared.
Sample sizes and results	LWD loadings were highest in unanchored projects. Only one of the streams, however, had a LWD frequency considered ideal for a natural stream. At the projects were the wood was anchored, LWD loadings were lower and typical of degraded urban streams and clearcuts. Size of added LWD varied broadly between projects but showed no relationship either to the size of the stream or to whether the LWD was anchored. No large logs to qualify as "key pieces" were added to the widest streams examined. In contrast, four times the number of key pieces typically found in a forested system was added to the smallest stream. All sites experienced 2-year flows, and 3 sites experienced 10-year-flow events. No anchored wood moved in any of the sites, and where 50% of the unanchored LWD were key pieces there was also no significant movement of structures. In the projects with unanchored LWD and few or no key pieces movement was observed (in some cases tens of meters downstream). Post-project pool spacing was not correlated to LWD loading. In the three project reaches with pre-project data, pool spacing narrowing was documented after LWD placement. Where there was no pre-project data on pools, the influence of added LWD on pools was evidenced by having 50% to 80% of the pools formed by the presence of these structures. Anchored wood was more often associated with pools (30-70%) than unanchored wood 15-18%), but both types of LWD raised pool numbers to some degree. Almost 1/3 of the in-channel sediment storage was associated with LWD at most sites, and in all but one creek the amount of this sediment increased by 50-100% where LWD frequency increased. The authors noted though, that even when LWD could retain sediments in some channel positions, such "storage" was exceeded by the high sediment loads of the study systems. LWD addition had little effect on benthic community responses based on B-IBI scores. There was only a weak relationship between B-IBI and extent of bank erosion, median grain size, or bed stability. This indicator index was much better correlated to the percent of urban development in the local riparian zone. Although projects may have improved some physical habitat (pool frequency), they had little influence on the benthic communities over the 2-10 years evaluated in this study.
Nature of the outcome measures used, their relative importance and robustness	Overall watershed condition seemed to dominate local effect of LWD placement projects. Although there was some physical response to some of the LWD installations, the benthic community response was not distinctive. Limited information on statistical procedures used. Although authors findings suggesting that local level actions cannot compensate watershed scaled degradation are consistent with numerous

	other studies, the small sample size and wide variation of treatment conditions used in this study seriously limit its robustness and importance.
Effects Modifier (confounding factors)	Length of treated reaches ranged from 210 to 1430 m. Treatment designs were very different in type of large wood used and on whether the structures were anchored or not. Some of the projects were very recent (less than two years) while others were 10 years old. Differences in local characteristics and degree of watershed development made comparisons between sites difficult. Moreover, differences between some of the upstream (reference) and downstream treated sites added additional "noise" to this study. Authors did not seem to realize this was a serious problem.

19.

Publication title and principal investigator(s)	Lehane, B.M., P.S. Giller, J. O'Halloran, C. Smith, and J. Murphy. 2002. Experimental provision of large woody debris in streams as a trout management technique Aquatic Conservation Marine and Freshwater. Ecosystems. 12: 289–311
Study dates and *study duration*	March 1998 – Spring 2000 (2 years)
Study location, settings where the intervention was applied	River Douglas Basin in Cork County, Ireland. 21 km^2 watershed. Work focused on area of basin dominated by plantation forests (conifers).
Ecosystem type; plant association group	Plantation Conifer Forest (Native and Exotic). Riparian corridor dominated by Alder.
Watershed type (if applicable, e.g. 6^{th} field)	
Research question(s), hypotheses	Quantify changes in stream physical habitat and evaluate potential for salmonid stock enhancement through LWD placement in plantation forested streams
Species studied (if applicable)	Brown trout (*Salmo trutta*)
Study design, experimental controls	Two 200 m study reaches within 1 km stretch of River Douglas' mainstem. Each reach divided into 8 segments (25 m each). Third and sixth segments treated with partial debris dams, the other six segments used as control sites. Used univariate and multivariate statistics to test hypotheses.
Pretreatment data (yes/no)	**Yes**. Both on fish abundance, biomass and condition, and on habitat variables.
Intervention or management action,	Installation of rootwads combined with brashings to form three partial dams that extended ½ to 1/3 of channel width. Structures anchored and cabled.
Replications (if applicable)	**Yes**. 4 segments treated and 12 segments as control
Sample sizes and results	Sample size small. LWD treatment altered stream habitat. Over the 2-year period of this study pool area increased (doubled), riffle are decreased (by ~30%), and amount of eddies and slack water areas increased. Trout density and biomass in debris treated segments increased significantly 1 and 2 years after treatment. But trout condition did not change.
Nature of the outcome measures used, their relative importance and robustness	Study measured effects of systematically (non-random) applied treatments. Design included control sites, replication and before/after data. Sample size small.
Effects Modifier (confounding factors)	

*20.

Publication title and principal	Manga, M. and J.W. Kirchner. 2000. Stress partitioning in streams by large woody debris.

investigator(s)	Water Resources Research 36: 2373–2379
Study dates and *study duration*	September through October 1997 (2 months)
Study location, settings where the intervention was applied	Cultus River, Central Cascade Mountains, Oregon
Ecosystem type; plant association group	Spring-fed forested mountain creek
Watershed type (if applicable, e.g. 6^{th} field)	
Research question(s), hypotheses	Determine contribution of LWD to the reach-averaged total stress (flow resistance in channel) and discuss theoretical implications.
Species studied (if applicable)	**None. Therefore this study is not relevant to evidence review objectives**
Study design, experimental controls	**No.** Survey of water velocity, depth, substrate composition, and LWD location. Used theoretical models to estimate the partitioning of flow shear stress between woody debris and streambeds.
Pretreatment data (yes/no)	**No**.
Intervention or management action,	**None.**
Replications (if applicable)	**No**. One reach surveyed.
Sample sizes and results	Even when LWD is less than 2% of streambed, it provides about 50% of the total flow resistance. With addition of LWD, a growing fraction of shear stress is borne by it and the stress borne by the bed decreases resulting in finer substrate.
Nature of the outcome measures used, their relative importance and robustness	Combination of theoretical models with data from very unique field conditions (constant flow spring-fed streams) illustrated effect of added structures on streambed stress and, therefore, on substrate composition. Low relevance to primary review question due to limited range of conditions considered
Effects Modifier (confounding factors)	

*21.

Publication title and principal investigator(s)	MacCracken, J.G and A.D. Lebovitz. 2005. Selection Of In-Stream Wood Structures By Beaver In The Bear River, Southwest Washington. Northwestern naturalist 86:49–58
Study dates and *study duration*	August-September 2000
Study location, settings where the intervention was applied	Bear River, Willapa Bay, Washington State.
Ecosystem type; plant association group	78 km^2 forested coastal watershed covered by 2^{nd} and 3^{rd} growth stands of Douglas fir, and western hemlock. Riparian dominated by Alder.
Watershed type (if applicable, e.g. 6^{th} field)	
Research question(s), hypotheses	Determine why some LWD structures were used by beavers for dams and others were not. Hypothesis: there were characteristics of LWD and their immediate environment that influenced use by beavers.
Species studied (if applicable)	**Beaver. Therefore this study is not relevant to evidence review objectives**
Study design, experimental controls	**No controls.** Continuous census of all (55) LWD in a 7 km study reach. Collection of 13 variables: stream width, gradient, depth, riparian vegetation, floodplain width, slope of valley hill sides, proximity to logjams, tributaries, and debris jams,LWD distance to a bank den and to deep pool, channel confinement, structure height above water.
Pretreatment data (yes/no)	**No**.

Intervention or management action,	**No experimental manipulation.**
Replications (if applicable)	**No**. One reach surveyed
Sample sizes and results	Sample size small (particularly in relation to number of parameters). 55 LWD pieces evaluated, only 6 of those were used by beaver.
Nature of the outcome measures used, their relative importance and robustness	Best explanatory model consisting of 6 variables. Used information-theoretic approach (AIC) to address research hypothesis. Statistical model used: logistic regression. Not an important contribution to answering primary review question due to small sample size, lack of replication. Did not examine cause-effect relationships
Effects Modifier (confounding factors)	

*22.

Publication title and principal investigator(s)	Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski, and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43: 1521-1533 [Lassettre 1999]
Study dates and *study duration*	June 1982-March 1983
Study location, settings where the intervention was applied	Six creeks in islands of southeastern Alaska (Chichagof Is., Kuiu Is., Mitkof Is., and Prince of Wales Is.)
Ecosystem type; plant association group	Coastal forest watersheds with western hemlock and Sitka spruce.
Watershed type (if applicable, e.g. 6th field)	Second to fourth order streams, with low discharge and 0.1 to 3.0% gradient.
Research question(s), hypotheses	Assess short-term (<15 years) effects of cler-cut logging, with and without buffer strips, on density of juvenile salmonids in southeastern Alaska, and to identify the habitat features tha mediate these effects.
Species studied (if applicable)	Juvenile coho salmon, Dolly Varden, steelhead and cutthroat trout.
Study design, experimental controls	Extensive post-treatment comparison of fish densities and habitat in stream reaches with three types of treatment: undisturbed (the old-growth **reference** reaches), clearcuts with riparian buffer strips (buffered), and clearcuts without buffer (clear-cut). Study streams were chosen to fit a randomized complete block design. Each block consisted of a set of 3 streams, one of each treatment, preferably in the same or adjacent watersheds. The stream in each treatment was divided into 3 sections and one 30-m sample reach was randomly selected from each section. Regional variation was incorporated by selecting two blocks in northern islands, two in central and two in southern islands. Habitat measurements included: stream size and gradient, sediment, forest canopy, undercut banks, channel stability, pool volume, and volume of LWD. Primary and secondary production were also measured by recording standing crops of periphyton and benthos. Populations of fish in all reaches were estimated using mark-recapture method. Sample sections were closed with nets, and sampling was conducted combining seining, electrofishing and baited traps. Coho salmon were divided into fry (age 0) and parr (age >0). Linear models were used to detect the effects of logging on fish density and habitat (ANOVA with treatment, block and region as factors). Relationships between habitat variables and fish densities were identified with multiple regression.
Pretreatment data (yes/no)	**No.**
Intervention or management action,	Clear-cut logging with and without riparian buffer strips.
Replications (if applicable)	**Yes**. 6 independent replicates per treatment and 3 samples taken per replicate.

Sample sizes and results	Sample size medium (N = 54, although usually between 25 and 40 because reliable population estimates were not obtained from each reach). Fish densities differed between treatments, but the effects of treatments were inconsistent among blocks (watersheds). The treatment x region interaction was nearly significant for production type variables (which could be due to regional climatic differences). Clear cut reaches ended up with less undercut bank, canopy density, pool volume and debris as well as more periphyton than old-growth reaches. They were also less stable. Compared with that in old-growth reaches, debris volume was greater in buffered reaches but less in clear-ct reaches. Pool volume was related to debris volume. Periphyton biomass was 130% higher in clear-cut reaches than in old-growth, but the effect of the treatment varied among regions. Difference in periphyton between old-growth and buffered reaches was not significant. Benthic production variability among regions was high enough to mask any treatment effect when all three were considered. When only old-growth and clear-cut reaches were compared the treatment effect was significant (more benthos produced in the clear-cuts). In summer, coho salmon fry was more abundant in either logging treatment than in old growth reaches. In winter density of parr depended on amount of LWD. If debris was left in clear cut reaches or added in buffered reaches, coho salmon parr were abundant. If debris had been removed from clear-cut reaches parr were scarce. Thus, clear-cutting may increase summer fry abundance in some streams by boosting primary production, but may reduce abundance of parr in winterif debris is removed
Nature of the outcome measures used, their relative importance and robustness	Study indicates that use of buffer strips maintains or increases debris, protects habitat, allows increased primary production, and can increase abundance of fry and parr. Clear-cutting without buffer strips appeared to reduce winter carrying capacity for salmonid parr by removing debris, collapsing undercut banks, and destabilizing or embedding channel substrate. Leaving buffer strips thus appears advantageous. Study uses replication and controls, which increases power of tests. However, the geographic variation among watersheds and the difference in debris management among logging treatments restricts relevance of this study in answering primary review question.
Effects Modifier (confounding factors)	Detected inconsistencies could be attributed to variable stream characteristics as well as differences in logging practices among streams. In some cases all debris was removed in others it was left behind and this introduced great variation within the two types of logging treatments.

23.

Publication title and principal investigator(s)	Naslund, I. 1989. Effects of habitat improvement on the brown trout, *Salmo trutta* L., population of a northern Swedish stream. Aquaculture and Fisheries Management 20: 463-474.
Study dates and *study duration*	Pre-treatment Fall 1983 – Post-treatment follow up Fall 1984 and 1986 (3 years?)
Study location, settings where the intervention was applied	Lacktabacken Creek, central Lapland, Sweden.
Ecosystem type; plant association group	75 km^2 forested watershed.
Watershed type (if applicable, e.g. 6^{th} field)	
Research question(s), hypotheses	What are the effects of four commonly used types of in-stream structures
Species studied (if applicable)	Brown trout
Study design, experimental controls	One treatment (in-stream structure) with supposedly four different levels (structure types). Each

	treatment level applied to one stream segment, resulting in 8 segments receiving treatment all along the same stream reach. Four controls segments were available, but only immediately upstream of segments treated with deflector structures or dam structures. Physical stream variables recorded. Fish numbers and size and weight were recorded. Body condition, biomass and fish densities estimated. The latter using removal method with electrofisher. Control and dam or deflector treated segments underwent three successive removal passes. Boulder and dam/deflector combo treated segments underwent only one fish removal pass.
Pretreatment data (yes/no)	Yes ("…controls had similar conditions as altered sections before installation of structures….”). Also fish data collected before and after installation of structures.
Intervention or management action,	Construction of four types of in-stream structures: deflectors (one made only of boulders, the other of logs), boulder dams, boulder groupings, and combination of boulder deflectors and dams.
Replications (if applicable)	Yes. Eight replicates for the treatment, but in theory only two per treatment level. Problem is that for one level of the treatment, "deflector", both installed structures were different. One was made of boulders the other of logs. Hence, this level is not truly replicated.
Sample sizes and results	Small. Two replicates for 3 of the treatment levels. No replicates for two other levels, which the authors seemed to consider as equal (?). Physical channel features were modified by structures installed. Nature of changes differed among types of structures (e.g., dams increased % pool area and mean depth; deflectors increased depth but reduced wetted width; boulders caused various different minor changes). Effects of deflectors on age 2+ trout densities were very ambiguous. However, trout biomass increased in response to the log-deflector (but this was not replicated). Dam structures did increase both trout densities and biomass. Boulder groupings did not affect trout densities or biomass; but the dam/deflector combos increased trout biomass (larger trout). Older/larger fish seemed to have been primary beneficiaries of these manipulations, but this is a conclusion based on very poor data for young-of-the-year trout.
Nature of the outcome measures used, their relative importance and robustness	Unbalanced design with actually 5 levels of treatment, 3 of those levels were replicated twice, but what they considered as a fourth replicated treatment level were two different un-replicated levels (boulder deflector and log made deflector structures). Problem comparing population estimates among sites because different removal efforts were used (this is not well compensated by estimating common catch probability from 3-pass segments and applying it to population estimates in 1-pass segments). Great uncertainty of these estimates forced authors to eliminate one entire age class (0+) of trout from study.
Effects Modifier (confounding factors)	Annual variation in age 0+ trout numbers, combined with poor population estimates, prevent study from concluding anything about the response of the youngest fish in the reach.

*24.

Publication title and principal investigator(s)	Nickelson, T.E., M.F. Solazzi, S.L. Johnson, and J.D. Rodgers. 1992. Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon

	(Oncorhynchus kisutch) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49: 790-794 [Bayley 2002]
Study dates and *study duration*	1986 to 1989 (three years)
Study location, settings where the intervention was applied	Two. The other is a companion paper in same journal by same authors.
Ecosystem type; plant association group	21 coastal streams in Oregon
Watershed type (if applicable, e.g. 6th field)	Forested coastal streams
Research question(s), hypotheses	
Species studied (if applicable)	To (1) examine the types of rearing habitat created by various habitat improvement techniques, (2) compare the relative effectiveness of the habitat created by these techniques to support juvenile coho salmon during summer and winter, and (3) compare the density of juvenile coho salmon in constructed habitats with that of juvenile coho salmon in natural habitats of the same type. In addition, a manipulation was conducted to test whether placement of bundles of small trees (brush bundles) in constructed pools would increase the winter carrying capacity of those pools for coho salmon.
Study design, experimental controls	Juvenile coho salmon
Pretreatment data (yes/no)	Sampling of 199 pools in 21 streams took place during the summer low-flow periods of 1986-89. For winter a subset of summer pools (181 pools in 19 streams) were sampled during the 1986-89 period. An effort was made to eliminate underseeded streams from the study to reduce the chances of underestimating the potential carrying capacity of a pool associated with a particular type of structure. Fish populations were estimated by using the mark-recapture method (pools were blocked off with nets). Pools were classified into various types (plunge, dammed, scour, alcove, etc.) and their areas estimated to calculate fish densities. The analyses were limited to constructed alcoves, and to dammed and plunge pools because these were most common and were the only habitats constructed in more than one stream. ANOVA was used to compare the means of juvenile coho salmon density among types of constructed pools in summer. Sample size in many cases was not large enough to do this same kind of analysis on winter data. After two summers and one winter of fish sampling, brush bundles would be placed in a subset of pools and these would be re-sampled in winter. The experiment included 24 pools treated with brush and 17 control pools located in 7 streams (all these pools were of different types and formed by different kinds of weirs). These data were analyzed using ANCOVA with pre-treatment densities being the covariate.
Intervention or management action,	Yes, but only for secondary part of study: brush manipulation.
Replications (if applicable)	Treatment (a) structures that spanned the channel width (weirs made of rock-filled gabions, logs, boulders, a combination of logs and boulders or concrete). These weirs were arranged perpendicular to the channel, diagonal to it or in a downstream 'V'. Treatment (b) constructed alcoves (dug into the banks), and (c) pools formed by boulders, log deflectors or rock blasting.
Sample sizes and results	Yes. However, true replicates are limited in number.
Nature of the outcome measures used, their relative importance and robustness	Sample size = 199 for summer and 181 for winter, but exact number of each type of pool was hard to determine. Mean densities of juvenile salmon did not differ among types of constructed pools in summer. The mean densities in these pools was similar reported for natural pools in companion paper (see above). It seems that constructed alcoves support higher densities of coho parr during winter than do either

	constructed plunge or dammed pools. In winter, mean densities in constructed pools did not differ from natural pool densities either. The comparison of density data between pools with and without brush showed that there were more coho parr in dammed pools with brush bundles in winter, but not in plunge pools.
Effects Modifier (confounding factors)	The development of off-channel habitat (alcoves) has the greatest potential to increase coho salmon production in Oregon coastal streams
	Variety of structures used to create pools and their different installation positions.

25.

Publication title and principal investigator(s)	Nislow, K.H., C.L. Folt, and D.L. Parrish. 1999. Favorable foraging locations for young atlantic salmon: Application to habitat and population restoration. Ecological Applications 9: 1085–1099
Study dates and *study duration*	Spring 1992-summer 1993.
Study location, settings where the intervention was applied	White and West Rivers (Connecticut River Basin) in Vermont, USA.
Ecosystem type; plant association group	Not described (but assumed is a mixed forest cover watershed.)
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Determine if foraging models can be used to assess habitat quality and in mgt of Atlantic salmon. (1) Can a simple, foraging-based habitat selection model predict habitat use and preference by juvenile salmon in six tributaries with differences in fish retention? (2) Do reaches with more suitable habitat retain a higher proportion of salmon and show higher per capita growth rates? (3) Do restoration actions (introduction of large structures) increase availability of good age-0 salmon habitat?
Species studied (if applicable)	Atlantic salmon
Study design, experimental controls	Habitat quality was described in terms of: a) availability of preferred microhabitat current velocities, b) abundance of prey, c) availability of preferred microhabitat depths. Treatment structures (LWD, boulder dams and clusters) were added to 150 m long reaches in 4 different streams. At each treated stream, two 80-m-long study segments were chosen. One of these segments was within the treated reach, the other was located 20 m upstream and was a control segment. Sampling was done once in spring and once in summer. Physical habitat and invertebrate data were collected for each treatment-control pair.
Pretreatment data (yes/no)	No. However, authors try to present evidence from prior agency surveys that suggested no difference between treated and control sites prior to manipulation.
Intervention or management action,	Placement of large structures: LWD, boulder dams and boulder clusters.
Replications (if applicable)	Yes. 4 in-stream structure-treated stream segments and 4 control stream segments.
Sample sizes and results	Sample size = 8. Structure treated stream segments had higher total benthic densities than control segments. But this effect was not reflected in the densities of those invertebrate taxa deemed important to salmon. There were not treatment induced invertebrate drift density. Large structure addition significantly increased microhabitat depth and reduced water velocities compared to the control conditions. Stream width, substrate size and overhead cover did not differ between segments. Based on prior model-predicted optimal-velocity microhabiat for juvenile salmon, large

	structure addition increased availability of early-season optimal habitat by 40% and of late-season habitat by 20%. The high variance among sites in the late-season resulted in no significant difference between treated and control segments. Changes in depth did not seem to affect fish habitat quality. Their key conclusion was that streams with a greater proportion of preferred microhabitats (those with the right conditions to allow for maximum food intake and lower energy expenses) retained more salmon, and the addition of large in-stream structures increased the proportion of such preferred locations.
Nature of the outcome measures used, their relative importance and robustness	Combination of theoretical mechanistic models (foraging theory based), with field manipulations of structures in stream channels. Field results only for treatment induced changes in prey availability and microhabitat (foraging station) quality (based on water velocity and column depth). Assumption is that if proportion of suitable microhabitats increases in a stream so does the number of juvenile salmonids it may retain. The interesting aspect of this study is that after showing that in-stream structures increased proportion of good foraging spots, the authors focus on explaining why such commonly used restoration techniques should enhance juvenile salmon growth and survival. The models are sound (although as usual simplistic) and hold for simple habitat conditions. The contribution of this study to the primary review question is limited by the lack of field data on salmonid densities in response to treatment. According to the models developed by the authors, the documented changes in prey density and water velocity should translate into more young salmon occupying the treated sites. But it would have been best to test the model prediction in the field setting.
Effects Modifier (confounding factors)	LWD is not studied separate from boulder dams or boulder clusters. Authors seem to combine all sorts of structures as treatment and any differences among them (which exist according to other studies) are not dealt with.

*26a.

Publication title and principal investigator(s)	Roni, P. and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:282-292.
Study dates and *study duration*	August 1996 and April 1999. 2 ½ years.
Study location, settings where the intervention was applied	Thirty coastal streams in Oregon and Washington.
Ecosystem type; plant association group	Forested watersheds dominated by Douglas fir, Sitka spruce and western hemlock.
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	Determine whether artificially placed LWD produces a significant change in physical habitat and juvenile salmonid abundance. Hypotheses: paired treated and reference sites would not differ in (a) densities of LWD and pool area, (b) densities of juvenile salmonids in summer and winter, (c) that the magnitude of fish response to treatment would not depend on the magnitude of change in habitat, and (d) the sizes of the fish would not differ between treated and reference sites.
Species studied (if applicable)	Juvenile coho salmon, cutthroat and steelhead trout.
Study design, experimental controls	Extensive post-treatment design. Compared between treatment and reference reaches at a large number of sites (30) after restoration actions. Each stream had paired control and treated sites of similar discharge,

	width, gradient, channel type, confinement, riparian vegatation and fish species composition (sites length range: 75 to 120 m long). Reference sites located some 200 m or more upstream from treated reaches. Each stream sampled once in summers and winter, and reaches within a stream were sampled on the same day. Fish sampled in summer using multiple-removal (3-4 passes) electroshocking while sites closed with blocknets. Fish weighed, measured, and assigned into age classes. Winter sampling done through night snorkeling.
Pretreatment data (yes/no)	**No**.
Intervention or management action,	Artificial placement of LWD in stream channel. Only reaches with LWD that remained in the channel after several high-winter events (more than one winter) were used.
Replications (if applicable)	**Yes**. 30 treated sites and 30 controls
Sample sizes and results	Sample size relatively large (60). Although treatment and reference sites had similar lengths, slope and bankfull widths, they differed in physical habitat features expected to respond to LWD treatment. The total number of LWD/100 m was higher (1.83 times in summer and 1.89 times in winter) in treated than in control sites. The number of pool creating LWD pieces was also higher (2.83 and 2.96, summer and winter respectively) in treated than in control sites. Treated reaches also exceeded reference sites in total wetted area, total number of habitat units, total pool area, total number of pools. Summer densities of juvenile coho salmon were significantly higher in treatment than in reference sites (1.81 times higher), but none of the trout densities differ with treatment. However, steelhead summer densities may be slightly reduced in relation to treatment. No relationship detected between coho or trout response and any other individual or combination of physical variables. In winter, differences in densities between sites were significant for all three species. Coho densities were 3.23 times higher in treated than in control sites. Age-1+ cutthroat and steelhead trout densities were 1.70 and 1.73 times higher respectively in treated reaches. Fry trout density did not seem to respond to LWD treatments though. Coho response seemed to be strongly correlated with pool area (which indicates that they benefited the most from LWD placements that increased pool area). No differences were observed in mean lengths of salmonids between treated and control sites in summer. However, coho size was always negatively correlated with density (revealing that treatment led to more but smaller juvenile coho in summer).
Nature of the outcome measures used, their relative importance and robustness	Sound statistical procedures and data transformation methods were used. Attention was paid to compensating for differences in fish densities among streams and to assure that all streams had equal weight in multiple regression analyses. The differences in seasonal response both within and among species appeared to be due to differences in species-specific seasonal habitat preferences. Broad geographic range covered by 30 streams used suggest results are broadly applicable to the region. Physical changes in response to LWD placements were observed in all 30 streams sampled. Study results apply to forested streams, because in watersheds with other types of dominant land uses they may be different.
Effects Modifier (confounding factors)	Possible benefit of LWD effect in terms of adult abundance may be smaller than anticipated in the case of coho because where numbers increased growth decreased. Spatial scale at which response quantified relatively small (100-m-long reaches). If treatment simply concentrates fish that moved among reaches and reduces their growth, then the benefits for the population may be negligible.

*26.b

Publication title and principal investigator(s)	Roni, P. and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:282-292.
Study dates and *study duration*	Summer and winter survey between August 1996 and April 1999. Each stream appears to have been sampled once.
Study location, settings where the intervention was applied	Western Oregon and Washington streams with inchannel wood placements that withstood several high flow events.
Ecosystem type; plant association group	Forested ecosystems dominated by Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sichensis*), and western hemlock (*Tsuga heterophylla*).
Watershed type (if applicable, e.g. 6th field)	Study reaches of constant lengths, 4 to 12 m in bankfull width, 0.5 to 4.2% in slope, and 124 to 2388 ha in upstream drainage area.
Research question(s), hypotheses	Determine whether placement of wood significantly changed physical habitat and juvenile salmonid abundance. Tested null hypotheses that paired treatment and reference reaches did not differ in (i) wood densities and pool area or (ii) densities of juvenile coho salmon and cutthroat and steelhead trout in summer and winter and that (iii) magnitude of fish response to treatment was independent of magnitude of habitat change and (iv) sizes of the fish would not differ between treatment and reference reaches.
Species studied (if applicable)	Coho salmon, steelhead, cutthroat trout.
Study design, experimental controls	Extensive post-treatment design wherein treatment and reference reaches (similar slope and channel width) were compared using paired *t* tests for differences in habitat, wood, and fish abundance. Multiple regression was used to examine the relationship(s) between fish response (ratio of treatment density to reference density) and difference in habitat variables (pool area, percent pool area, riffle area, pieces of wood, pieces of wood creating pools, number of habitats, channel slope, region (Washington or Oregon), and structure type (engineered or naturally placed log).
Pretreatment data (yes/no)	No.
Intervention or management action,	Placement of large wood into treatment reaches.
Replications (if applicable)	30 streams (treatment and reference) but number of placed wood pieces differed among treated reaches.
Sample sizes and results	Treatment and reference reaches differed significantly for most habitat variables in summer and/or in winter. Summer: densities of juvenile coho salmon densities (fish per m) were higher in treatment than in reference reaches, but densities of age-1+ cutthroat, age-1+ steelhead trout, and trout fry did not differ. Response of coho juveniles was positively correlated with functional wood but not to other variables. Responses of trout fry and age 1+ cutthroat trout were not correlated with other variables but response of age-1+ steelhead was negatively correlated with pool area and percent pool area. Winter: treated reaches had higher densities of coho salmon, age-1+ cutthroat trout, and age-1+ steelhead than reference reaches, but trout fry densities did not differ. Coho response was positively correlated with pool area and restoration type (engineered or natural). No significant correlations were detected between treatment and either age-1+ cutthroat trout or age-1+ steelhead response. Trout fry response was negatively correlated with difference in percent pool area. No differences between treatment and reference reaches in mean lengths of coho salmon, cutthroat trout, steelhead trout, or trout fry during summer or winter.
Nature of the outcome measures used, their relative importance and robustness	Examined responses to wood placement at reach level. Streams sampled from about 3-7 years after large wood was added, so any biological response was likely to have been manifested. Reaches with low levels of wood prior to treatment generally had the largest physical and biological responses. Authors indicate that non-

	significant, but consistent inverse, relationships between coho numbers and size suggest density-dependent effects that may limit broader-scale responses of large wood placement on coho salmon.
Effects Modifier (confounding factors)	Authors indicated that differences among streams were most likely due to differences in habitat rather than in spawner densities because streams were at moderate seeding levels.

*27.

Publication title and principal investigator(s)	Roni, P. and T. Quinn. 2001. Effects of wood placement on movement of trout and juvenile coho salmon in natural and artificial stream channels. Transactions of the American Fisheries Society 130:675-685.
Study dates and *study duration*	September 1998 through April 1999. 7 months.
Study location, settings where the intervention was applied	Shuwah Creek, in Washington State. Also used artificial channel in National Marine Fisheries Service's Manchester Field Station, Washington.
Ecosystem type; plant association group	Forested watersheds dominated by Douglas fir, Sitka spruce and western hemlock.
Watershed type (if applicable, e.g. 6^{th} field)	Small, 6.5 m bankfull width channel, with low gradient (slope = 1.5%) and pool-riffle sequence.
Research question(s), hypotheses	Examined the movement of juvenile salmonids during fall and winter in a natural stream, testing the hypothesis that: no fish would move between unrestored (reference) and restored (treatment) reaches. Study also examined the movement patterns and growth of juvenile coho salmon in artificial channels with and without woody debris, testing the hypothesis that: the frequency of movement is independent of habitat quality, fish size, and growth.
Species studied (if applicable)	Juvenile coho salmon, cutthroat and steelhead trout (although both species of trout were combined in analyses).
Study design, experimental controls	**In natural stream both treatment** (artificial LWD placement) and **reference** (no LWD placement, only naturally occurring wood present) reaches were used. Restoration including LWD placement was conducted on 500 m of the stream in summer 1996. Two 90-m-long reaches of this creek were used in this study. One on the upper part of the restored reach (with 47 pieces of LWD and 80% pool area), the other 100 m farther upstream in an unrestored reach (with 35 pieces of LWD, most of it on the margins and only 56% pool area). In September 1998, Salmonids were captured using three pass removal electrofishing. Treatment reach fish were tagged with a red "photonic" pigment mark on the dorsal fin, while control reach fish received a blue mark. 114 fish were tagged in the treated reach and 71 in the reference one. Fish were tracked through monthly night snorkel surveys from October 1998 until April 1999 (which the authors reported as being equivalent to multiple-removal electrofishing during winter in terms of resulting abundance estimates). Simple statistics and linear models used in data analyses. **Parallel experiment conducted in artificial outdoor channel** (45 x 6 m and 3% grade). Channel divided longitudinally into two identical channels, and each of these channels were subdivided into 8 individual habitat units (plunge pool like) that were 30 cm deep at the head and decreased gradually to 2 cm in depth at the tail. LWD pieces were placed in habitat units 1, 2, 4, and 6 in one channel and none in the other (**control**). Thirty hatchery juvenile coho salmon were placed in each unit, except for the top units of each channel that received 43 fish instead. Fish were PIT tagged and measured two weeks later. Subsequent sampling was conducted 3 times (May 19, June 2 and June 16) to determine fish location and size.

Pretreatment data (yes/no)	**No**.
Intervention or management action,	Artificial placement of LWD in 500-m-long stream reach. Only upper 90 m section of this reach used and compared with reference site. Also LWD placement in one of two identical artificial wooden channels.
Replications (if applicable)	**No**.
Sample sizes and results	Little movement of tagged fish observed between reference and treated reaches in natural stream from September through April. Hence, null hypothesis of limited movement between treated and control reaches was not rejected. The percentage of marked fish declined over time in both reaches. The sharp drop between September and October could be due to emigration, subsequent decline may be explained by both emigration and winter mortality. Total numbers of fish were not significantly different between reaches, although they had tendency to be higher in treated site. Increased proportion of unmarked fish resulted both from immigration of marked fish and emigration of marked fish. In artificial channel there was no difference in fish growth between movers and holders, but fish in channel with LWD moved more frequently and shorter distances than those in the control channel. No difference in length, weight or growth was observed between the movers and holders in the treated channel, whereas in the control channel fish that moved tended to be larger, heavier and grew more rapidly than holders.
Nature of the outcome measures used, their relative importance and robustness	Study suggests that short-distance movement among individual habitats are common for juvenile coho and trout. However, little exchange seems to occur between nearby stream reaches of different "complexity". Lack of replication and pre-treatment data reduces this study contribution to primary review question.
Effects Modifier (confounding factors)	Possible loss of marks, mortality, emigration and the spatial scale examined.

*28.

Publication title and principal investigator(s)	Roper, B.B., D. Konoff, D. Heller, and K. Wieman. 1998. Durability of Pacific Northwest instream structures following floods. North American Journal of Fisheries Management. 18: 686-693 [Roni et al. 2002]
Study dates and *study duration*	Unclear but some time after winter flood of 1995-1996.
Study location, settings where the intervention was applied	94 streams within the Puget Sound, Yakima, Lower Columbia, Middle Columbia, Willamette, Lower Snake, and the coast range regions of Washington and Oregon were surveyed.
Ecosystem type; plant association group	Forested watersheds within US. Forest Service Lands
Watershed type (if applicable, e.g. 6th field)	
Research question(s), hypotheses	As part of an evaluation of the effects of the 1995-1996 floods on US Forest Service lands in the pacific Northwest, this study had three objectives: 1) determine the overall durability of in-stream structures following floods with 5-150-year return intervals, 2) relate durability to geomorphologic and stream conditions, and 3) provide recommendations to improve future performance of structural in-stream restoration treatments.
Species studied (if applicable)	None
Study design, experimental controls	No controls. The protocol classified structure durability into one of 3 movement types: 1) in place, 2) shifted on site, and 3) removed form site. The surveys also measured a variety of basin features and

	structural attributes thought to affect structure movement (e.g., flood magnitude, stream order, location of structure within channel, channel constrainment, structure material, and whether structure was anchored). For streams that were not gauged, flood magnitude was calculated by extrapolating flow data from the nearest USGS stream gauge. The simple protocol combined with surveyor training may have reduced inter-observer variability.
Pretreatment data (yes/no)	No.
Intervention or management action,	In-stream structures were impacted by 5-150-year frequency flood events and potentially displaced.
Replications (if applicable)	Although 94 streams were included in this survey they were not similar enough to the point of considering them all replicates. If there were some "replicates" among the many streams and the 3,946 structures surveyed was more a coincidence than a study design consideratin. It is hard to determine how many replicates of each stream order and structure type were included in the analyses, although with so many structures the power of the tests should have been high.
Sample sizes and results	Although it is hard to consider the many sites and structures replicates, the authors created clusters for various combinations of conditions (treatments), and sample size tended to be high, ranging from 35 to 3,054. Overall durability was high with less than 20% of the surveyed structures being removed from site during large floods. Flood magnitude had a significant effect of structure durability, with higher flood magnitudes resulting in higher percentages of structures being removed from their original sites. Stream order also affected structure durability. Movement of structures was less in low-order than in high-order streams. Structure durability were also affected by the interaction between flood magnitude and stream order (structures were twice as likely to be removed in a fifth-order than in a second order stream when flood magnitude was less than a 40-year return interval, and when return intervals exceeded 40 years, structures in a fifth-order stream were four times more likely to be removed from site than in a second-order system). Structure location within the channel affected structure movement. Structures not connected to the channel edge were less stable than those placed either on the edge or that spanned the entire channel. Location interacted with channel constrainment to affect durability in such a manner that if a structure was not attached to the edge its chances of being displaced were higher in an unconstrained than in a constrained channel. Structure material affected durability. Structures made of either logs or boulders were mode durable than those made of a combination of logs and boulders. Similarly, anchored structures were more stable than not anchored ones. High land-slide frequency also increase chances of structures being removed.
Nature of the outcome measures used, their relative importance and robustness	This study concluded that structure durability is affected by many stream characteristics and engineering factors. Structures became less durable as the energy of the reach increased, if they were not connected to the stream bank, and if they were in unconstrained channels. Although their findings seem to conflict with other studies on this topic like Frissell and Nawa (1992), the authors explain that this could be attributed to differences in geographic areas considered, and inconsistency in the use of terms describing structure durability. The results are not relevant to the question being examined by the S.E.R.
Effects Modifier (confounding factors)	Broad variety of conditions and structure types being considered. Grouping of similar "treatments" and "subjects" (structures) receiving those treatment remains unclear to the reader.

29a.

Publication title and principal investigator(s)	Rubin, J.F., C. Glismater, and T. Jarvi. 2004. Characteristics and rehabilitation of the spawning habitats of the sea trout, *Salmo trutta*, in Gotland (Sweden). Fisheries Management and Ecology 11:15–22
Study dates and *study duration*	1992-1999. Seven years
Study location, settings where the intervention was applied	Gotland, the largest island of the Baltic Sea. Apparently 5 streams were used: Sjalso, Gartarve, Svajde, Halsegrada, and Aran.
Ecosystem type; plant association group	Small coastal streams with riparian vegetation transitioning from forest, through bushes to reeds towards the coast.
Watershed type (if applicable, e.g. 6th field)	River basin area for Sjalsoa Creek = 35 km^2 –for other creeks is not clear.
Research question(s), hypotheses	Objective was to describe the natural spawning grounds used by the sea trout in Sjalsoan Creek and a method to rehabilitate spawning habitats
Species studied (if applicable)	Sea trout (*Salmo trutta*)
Study design, experimental controls	No experimental manipulations vs. control comparison. Only lowermost reach (550-m-long) used because upstream waterfall formed a fish barrier. This reach was surveyed in detailed with transects at 10 m intervals. Natural spawning grounds of reach were characterized (geometrical mean, Freedle index, sorting coefficient, median particle diameter), so was area were spawning did not take place. Width, length and depth were recorded for numerous redds (22 in winter 1992-93; 10 in 1997-98; 16 in 1998-99). During the first winter five spawning beds were measured to detect overcutting. Spawners were sampled in a fish trap at the mouth of the creek and fish size, sex, migration and spawning behavior were recorded.
Pretreatment data (yes/no)	**No.** There was no treatment.
Intervention or management action,	Creation of artificial spawning grounds.
Replications (if applicable)	**No.**
Sample sizes and results	Geometrical mean particle and mean diameter were greater in spawning than in non-spawning areas of Sjalsoa Cr. Mean spawning ground density was 156 redds/hectare of stream bed. Only 2.7% of the total area available at Sjalsoa was used for redd building. Overcutting (superimposition) in 60% of area suggested that number of spawners exceeded are of suitable spawning beds. Redds were 70-350 cm long and 50-130 cm wide, with a total surface of 1.7 ± 1.2 m^2. Their depth was 35 ± 15 cm at the "nest" and 11 ± 8 cm over the tail. Egg survival to fry emergence was high in the artificial spawning grounds (60% in artificial vs. 45% in natural grounds) probably due to lower concentration of fine particles in gravel. Number of spawners increased in island after construction of artificial spawning grounds.
Nature of the outcome measures used, their relative importance and robustness	Study presents general characterization of sea trout redds. Shows that natural spawning beds were limited and led to high superimposition among spawners. The study also documents that artificial spawning grounds were used, that egg survival in them was higher than in natural reaches and that numbers of spawners (actual figures not given) increased after artificial grounds were built. Study design makes it slightly more relevant to the primary question than having anecdotal evidence on the effectiveness of rehabilitating spawning grounds. It lacks replication, treated and control sites, no pre-construction data.
Effects Modifier (confounding factors)	Their "N" for reaches with natural spawning is = 1. Comparing this single reference with spawning

	success in several artificially placed gravel beds in other streams of the island is not statistically supportable.

29b.

Publication title and principal investigator(s)	Rubin, J.F., C. Glismater, and T. Jarvi. 2004. Characteristics and rehabilitation of the spawning habitats of the sea trout, *Salmo trutta*, in Gotland (Sweden). Fisheries Management and Ecology 11:15–22
Study dates and *study duration*	Winters of 1992/1993; 1997/1998; 1998/1999; 1999/2000
Study location, settings where the intervention was applied	Study reach was the first 550 m upstream from the mouth in Sjalsoan stream, located 7 km north of Visby on Gotland, the largest island in the Baltic Sea (58°N, 19° E) off the coast of Sweden. Artificial spawning grounds were created in four streams (Gartarvean, Halsegardaan, Svajdean, Aranon).
Ecosystem type; plant association group	Riparian and adjacent vegetation is forested for about the upper 2/3 and bushes for the lower 1/3 and reeds beyond the study reach in Sjalsoan stream to the sea.
Watershed type (if applicable, e.g. 6^{th} field)	35 km^2 - Sjalsoan stream
Research question(s), hypotheses	Describe natural spawning grounds used by the sea trout and a method to rehabilitate spawning habitat.
Species studied (if applicable)	Sea trout, *Salmo trutta*
Study design, experimental controls	A descriptive study of spawning ground characteristics in Sjalsoan stream. Study section mapped every 10 m to assess redd dimensions and substrate composition (geometrical mean diameter; Freedle index; sorting coefficient; and median diameter, D50) in areas not used for spawning and in natural redds (22 during the winter 1992/1993, 10 during the winter 1997/1998 and 16 during the winter 1998/1999). Between 1992/1993 and 1999/2000, the spawning population structure (size of the fish, number, sex-ratio, migration, spawning behaviour) was examined using a fish trap at the mouth of the Sjalsoan stream.
Pretreatment data (yes/no)	No.
Intervention or management action,	1978 -1992 Creation of artificial spawning grounds using boulders (20–40 cm in diameter) on both sides of the stream in a downstream V-shape to create optimal flows., Placed a log (≥ 30 cm in diameter) at the narrowest downstream point of the V to produce a dam and a waterfall, creating a channel in the middle of the dam to concentrate summer low flows, and upstream from the dam, depositing coarse gravel for good water percolation and overlaying this with spawning gravel (15 and 60 mm in diameter). A sediment trap was also constructed upstream of the artificial spawning grounds.
Replications (if applicable)	No, but four other artificial spawning grounds (Gartarvean, Halsegardaan, Svajdean, Aranon) were described.
Sample sizes and results	Differences between sites used for spawning and those that were not were found in all examined variables. Described characteristics of the adult spawning population and redd dimensions. Total surface of natural spawning grounds was neither significantly correlated with the number of times different spawners were observed on them nor with the size of observed females. Stated that more than 60% of the eggs produced emerging fry in the artificial spawning grounds compared with less than 45% in the natural habitats.
Nature of the outcome measures used, their relative importance and robustness	This was a descriptive study of natural spawning grounds and construction of artificial spawning grounds. Findings have little relevance for the primary review question.
Effects Modifier (confounding factors)	

*30.

Publication title and principal investigator(s)	Shirvell, C.S. 1990. Role of in-stream rootwads as juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) cover habitat under warying streamflows. Canadian Journal of Fisheries and Aquatic Sciences 47: 852-861. [Lassettre 1999]
Study dates and *study duration*	June 24 to July 25, 1985
Study location, settings where the intervention was applied	Kloiya Creek, British Columbia 12 km southeast of Prince Rupert.
Ecosystem type; plant association group	Coastal forested watershed.
Watershed type (if applicable, e.g. 6th field)	108 km^2 of watershed area and a dam at 3.2 km upstream from creek's mouth.
Research question(s), hypotheses	Determine effect of abundance and position of rootwads on their function as cover for young salmonids under varying stream flows. Hypotheses were: 1) juvenile salmonids use position downstream from rootwads for shelter from current at all flows, not for predation protection; 2) positions downstream from rootwads will be occupied if close to bank but not if structure is in midstream; and 3) juvenile salmonids are attracted to rootwads themselves and not just the conditions created by rootwads.
Species studied (if applicable)	Coho salmon and steelhead trout were the focus of the study, but some observations were also made on Dolly Varden, chinook salmon fry, and cutthroat trout.
Study design, experimental controls	Rootwads were the treatment used. Salmonid abundance was the response variable. To examine fish distribution in relation to rootwads, a single pool was used which had one rootwad at one site, and an adjacent area of similar depth, velocity and substrate but not rootwad. In addition, an artificial rootwad was placed 3 m laterally to the natural rootwad. To investigate whether fish would use rootwads in the center of the channel, and artificial rootwad was placed 3 m laterally to the natural one. This created a pattern of natural rootwad, no rootwad, and artificial rootwad. To investigate whether the role of rootwads as habitat depends upon their location relative to the shore, two additional artificial rootwads were placed laterally to the first to end up with rootwads at ¼, ½, and ¾ of the stream width. This positioning of the artificial rootwads created the following wood treatments for the fish to choose from: 1) natural rootwad (against right bank), 2) no rootwad, or 3) artificial rootwads at 3 distances from bank for a total of 5 in-stream positions. Artificial rootwads were made of standard 100 x 120 x 13 cm warehouse pallets with alternating slats on two sides of the pallet. The orientation of the pallets mimicked the natural rootwad, which was almost 3 m in diameter and lay on its side (although only ½ its mass was wetted at most flows). Depth velocity, and light intensities for five positions and at different flows were recorded downstream from the natural rootwad and from the artificial rootwads as well as at the no-rootwad site to determine whether the sites were comparable with regards to those conditions (this showed that artificial rootwad #1 was similar to the natural one for all the variables considered, while artificial rootwads #2 and 3 were similar to the natural except for their lower water depths). Flow conditions were manipulated artificially by storing or spilling water from the upstream reservoir. In-stream light conditions were inversely related to flow. Fish response was assessed by a diver who recorded their distribution among the five positions at 12 stream flows. Fish counts where limited to a 1 m^2 area downstream of each structure and at the selected

	no-rootwad site. Water depth, water velocity and light intensity were measured in the center of each observation area after fish counts were completed. When observations were carried out the fish community at study pool keep changing because of smolts and fry migrating downstream, and adult sockeye and resident trout migrating upstream. This caused the size of the study population in the pool to differ on each sampling date. In theory, replicates in time were not conducted with the same group of fish, but a combination of new fish and "experienced" fish. ANOVA was used to determine difference in conditions at each of the five stream positions with the different flow treatments, and multiple linear regressions were used to determine the role of the various physical conditions on the positions chosen by the fish.
Pretreatment data (yes/no)	No.
Intervention or management action,	Placement of three artificial structures imitating a natural rootwad in a single pool. Flow was manipulated to create "drought", "normal" and "flood" conditions.
Replications (if applicable)	Yes (but some difficult to estimate degree of pseudo-replication because some of the fish change between observations and some remain the same).
Sample sizes and results	N = 12 in total (N = 6 for drought, N = 3 for normal and N = 3 for flood flow). Coho salmon fry and steelhead trout parr corresponded to over 80% of the observed fish. 99% of all coho fry occupied positions downstream of either the natural or the artificial rootwads (independently of how far these structures were from the bank). This affinity for rootwads was observed regardless of streamflow treatment. Most coho fry preferred the natural rootwad which was associated with the deepest, slowest and darkest waters. When they used artificial structures they showed preference for rootwad #3, which was where the water was the shallowest and slowest; and they least frequently used rootwad #2 with intermediate water depth and velocity. Thus, it seems that coho fry did not select position based on water column depth, but were accepting the depths that were associated with some other variable they responded more readily to (possibly velocity). In contrast, steelhead parr used the natural rootwad position the least and they most frequently chose positions downstream the 3 artificial rootwads equally. 20% of the trout selected the position with no rootwad, which was faster and brighter then any of the other locations observed. There was not significant repositioning of coho fry when flows decreased from "normal" to "drought" conditions. However, whenever streamflows increased to "flood" levels, coho fry redistributed themselves and preferred the position by the natural rootwad (which was closer to shore and with deeper and slower waters). In the case of trout ,when flows decreased they showed a tendency to avoid the no-rootwad position (which they preferred to the natural rootwad under normal conditions) and increased their use of positions behind any of the rootwads. In general, as conditions got shallower, slower and brighter they chose positions that were deeper, slower and darker. As far the variable ranking in terms of importance, for both main study species water velocity ranked first, water depth, second, and light intensity third.
Nature of the outcome measures used, their relative importance and robustness	Study shows that vast majority of coho fry and steelhead trout parr choose postions downstream of rootwads (natural or aritificial). Fish associate themselves with structures regardless of their distance form shore. However, coho fry tend to favor rootwads near shore and trout rootwads away from shore. Their distributions suggest they were using structures as water velocity shelters and to a lesser degree as predation protection (assuming the deeper water and darker conditions concealed them better form view).

	The results are interesting but not new even at the time of publication of the study (see Bustard and Narver 1975. J. Fish. Res. B. Can. 32:667-680 among others). Lack of replicates using more than one pool, apparent partial pseudo-replication over time, ever changing nature of the fish community and population size in the study pool, the fact that no "control" positions upstream of structures or in other locations were considered, and the "similarity" between the "normal" and "flood" flow conditions reduce the relative importance of this study to the primary review question. The exception being the general conclusion that juvenile salmonids show a tendency to associate themselves with in-stream structures and that the strength of the association differs among species and in response to various habitat variables.
Effects Modifier (confounding factors)	Flood conditions did not seem to differ significantly from normal conditions in terms of flow and depth, only drought conditions created significantly slower and shallower conditions than normal flows behind the rootwads. This may have precluded flood conditions to make a difference in the use fish made of structures when compare to normal flows.

*31.

Publication title and principal investigator(s)	Solazzi, M.F., T.E. Nickelson, S.L. Johnson, and J.D. Rodgers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fish and Aquatic Sciences 75: 906-914
Study dates and *study duration*	1988-1994
Study location, settings where the intervention was applied	East Fork Lobster Creek and Upper Lobster Creek (Alsea Basin), and East Creek and Moon Creek (Nestucca Basin)
Ecosystem type; plant association group	Coastal forested streams
Watershed type (if applicable, e.g. 6th field)	Study streams ranged in length from 3.5 to 5.0 km, in drained area from 12.4 to 17.5 km^2, and in summer wetted width from 3.2 to 4.0 m.
Research question(s), hypotheses	Determine the effects of habitat restoration projects on coho salmon smolt abundance in two coastal streams of Oregon.
Species studied (if applicable)	Coho salmon was the focus, but also considered response of steelhead and cutthroat trout.
Study design, experimental controls	**Yes.** Paired streams in two separate coastal basins. Upper Lobster Creek, within the Alsea Basin, and east Creek, within the Nestucca Basin, were designated treatment streams. All four study reaches (one per creek) had a smolt trap at the downstream end. Hankin and Reeves methodology was used to estimate the amount of available habitat in each study reach. Habitat was surveyed both in late summer and in winter. A combination of snorkeling and electrofishing was used in the summer to estimate fish numbers. Divers counted the numbers of each species in every third pool, this value was adjusted by a calibration factor derived from electrofishing population estimates in a subset of the snorkeled pools. Numbers of fish in glides and riffles were estimated based on the average fish density for a subset of each habitat type (by electrofishing), then such density was multiplied by the area of each habitat type in the entire reach. Electrofishing-based population estimates used either mark-recapture or removal methods (mark-recapture was used were thick cover would impede effective depletion). Downstream traps were used to estimate number of downstream migrants from March to June (trap efficiency was estimated with mark and recapture method). For each habitat and fish population parameter the ratio of treatment to reference

	reach was calculated each year, then the mean ratios for the pretreatment and post-treatment periods were estimated, and they were compared using t-tests.
Pretreatment data (yes/no)	**Yes.** BACI design
Intervention or management action,	Placement of LWD (full-spanning logs to create dam pools, which also received additional pieces of wood) and excavation of off-channel ponds or alcoves. In Upper Lobster Creek: 23 dam pools and 8 alcoves over 3.2 km. In East Creek: 29 dam pools and 13 alcoves in 2.4 km.
Replications (if applicable)	**Yes**. 2 replicates of treatment and 2 controls
Sample sizes and results	Small, N = 4. Amount of winter rearing habitat increased in LWD treated reaches in both streams. The area of fast-water habitat decreased in both treatment reaches. In the Alsea treated stream numbers of juvenile coho salmon increased by 50% during summer after restoration compared to the reference stream where they decreased by 25%. In both streams of the Nestucca basin, summer numbers of juvenile coho declined after restoration; however, the population in the treated stream declined by 20% while the one in the reference stream dropped by 50%. In both systems, numbers of coho smolts increased significantly in the treated reaches relative to the control sites during the post-treatment period. Overwinter survival of coho salmon also increased in both treated streams relative to the control streams. Summer trout populations in the treated reaches did not change, but downstream migrant numbers the following spring did increase.
Nature of the outcome measures used, their relative importance and robustness	Habitat modification in two Oregon coastal streams resulted in increased winter habitat for anadromous salmonids, which translated into higher winter survival for coho and, in turn, greater numbers of smolts being produced. This study underlies the role of winter habitat as limiting to coho production in small coastal streams. The benefits of the manipulations examined by this study were not that clear during the summer for both species of trout that were considered. However, the result suggest no negative impacts of the restoration actions on their populations for summer, and a significant benefit over the winter period. The replication, the use of control reaches and the pre and post-treatment data made the results of this study highly relevant to the primary review question. However, it is important to note that results are specific to the types of habitat created and do not necessarily apply to all kinds of "restoration" projects.
Effects Modifier (confounding factors)	The interannual variability of trout population estimates made the power of the statistical tests used very low.

*32.

Publication title and principal investigator(s)	Spaulding, S., N.P. Peterson, and T.P. Quinn. 1995. Summer distribution, survival, and growth of juvenile coho salmon under varying experimental conditions of brushy stream cover. Transactions of the American Fisheries Society 124: 124-130
Study dates and *study duration*	Spring to late-summer 1991
Study location, settings where the intervention was applied	Seminatural research stream within the Big Beef Creek drainage in Washington State.
Ecosystem type; plant association group	Coastal forested streams
Watershed type (if applicable, e.g. 6^{th} field)	Not applicable (artificial experimental arena).
Research question(s), hypotheses	To determine the role of brushy woody debris in the summer time ecology of coho salmon. Hypothesis:

	fish distribution, growth, and survival are affected by the complexity of brushy material in otherwise similar, unstructured pools.
Species studied (if applicable)	Coho salmon.
Study design, experimental controls	No true controls. First, a fish distribution experiment was conducted allowing fry to move throughout two channels that differ in debris complexity. Second, a growth and survival experiment was conducted after the units were isolated and fry densities equalized among them. Experimental stream was 34 m long, 9 m wide, and divided longitudinally to create to parallel and identical channels. Each channel consisted of 7 riffle-pool units. The substrate was gravel from the creek. All food came from natural aquatic and terrestrial production. Invertebrates were sampled from the drift with nets and the insects coming from the canopy were caught with pit-type traps. Douglas fir Christmas tress were used as replicable debris to simulate tree tops or material left after logging operations. Newly emerged coho fry were collected from Big Beef Creek and released into experimental channels. Approximately 52-53 fry were released into each unit. The exception was the top unit in each channel because it received an additional 32 fry to ensure adequate colonization after the anticipated downstream migration from all units. Live boxes installed at the downstream end of the channels trapped early emigrants. For the growth and survival experiment, 56-57 fry were placed at each unit in may and removed the following September.
Pretreatment data (yes/no)	No. Unnecessary because it was a replicated manipulation in artificial channels.
Intervention or management action,	Tree treatments were applied in increasing numbers creating four different levels of complexity (simple, half complex, complex and double complex).
Replications (if applicable)	**Yes**. 4 replicates for two of the treatments and 3 for the other two. No control units however.
Sample sizes and results	Medium, N = 14. Most of the fry released during the distribution experiment were recovered. Their densities differed among treatments. Units with simple debris had higher than average fish densities, but densities under any of the other treatments were similar. Unit position may have had a greater influence on its fish numbers than the simple type of debris. Survival was not clearly affected by the various types of cover treatments used. Growth varied within treatments and among treatments. However, its variation among treatments was not related to the degree of cover complexity. Growth was inversely related to coho fry densities.
Nature of the outcome measures used, their relative importance and robustness	Study found no evidence that coho salmon were attracted to brushy debris, nor did the presence of the treatment influence survival or growth. Lack of true control is of concern. The artificial nature of the setting also limits the applicability of the results.
Effects Modifier (confounding factors)	The woody debris used in this study was smaller than that used in restoration projects and a direct comparison of results is therefore not recommended. The large wood shapes the flow, depth and productivity of stream habitats and this may be more beneficial to the fish than the sole presence of woody material. Scale and other attributes of artificial experimental channels do not make the comparison of the study results with those in natural channels very easy. Season may have also influenced results as coho’s affinity for woody debris increases towards winter, and as the fish become larger.

*33.

Publication title and principal investigator(s)	Young, K.A., S.G. Hinch, and T.G. Northcote. 1999. Status of resident coastal cutthroat trout and their habitat twenty-five years after riparian logging. North American Journal of Fisheries Management 19: 901-911.
Study dates and *study duration*	1973 to 1997 (25 years)
Study location, settings where the intervention was applied	East Creek, second order stream within the University of British Columbia's Malcolm Knapp Research Forest (60 km east from Fraser River's estuary), British Columbia, Canada.
Ecosystem type; plant association group	Headwater forested mountain creek within the coastal western hemlock biogeoclimatic zone. Riparian dominated by western hemlock, Douglas-fir, western redcedar, and red alder.
Watershed type (if applicable, e.g. 6th field)	100 ha. Watershed
Research question(s), hypotheses	To assess the effects of two different riparian timber harvest treatments on allopatric, resident populations of cutthroat trout in small headwater streams.
Species studied (if applicable)	**Cutthroat trout (resident coastal type)**
Study design, experimental controls	**Yes.** Pre-treatment vegetation was a second-growth mixed-age forest that regenerated naturally after fire and logging earlier in the century. In spring of 1973 two sections of East Creek were subjected to two different types of logging. Section A was clear-cut to the stream bank with all debris removed and burnt (scarified treatment); whereas Section B was clear-cut to the stream bank with all debris left in the stream and on hill slopes (including LWD present in channel before logging). Section B was located some 800 m upstream from Section A. The third, upstream, section (C) was designated as a **reference reach**. Hill slopes adjacent to both sections A and B were replanted after logging with Douglas-fir, and the riparian zones were covered by a mix of alder, Douglas-fir, hemlock and redcedar. In 1985, nineteen structures consisting of combinations of logs and rootwads were placed in section A. Stream habitat assessments, fish population estimates, and temperature monitoring were conducted intermittently during the subsequent 25 years at selected reaches located towards the downstream end of all three sections. Trout movement between sections was limited by culverts and the steep terrain. Hence, trout in each section are considered a separate (allopatric) population for discussion purposes. Fish population estimates were carried out during summer periods but using different methods during the various surveys (mark-recapture or three pass removal). To ensure that at least the two capture methods (electrofishing and baited minnow traps) used during different surveys were somehow equivalent the authors estimated population densities through mark-recapture using both capture methods.
Pretreatment data (yes/no)	**No**.
Intervention or management action,	Clear-cut logging, all the way to the bank. One treatment included removal and burning of all debris while the other left all woody debris in channel and on hill slopes. The logged and burnt section received LWD structures 12 years after logging.
Replications (if applicable)	**No**. The two reaches that were treated received different treatments.
Sample sizes and results	Habitat features differed between both treated sections. Two-years after logging Section B had over 10 times as many pieces of wood and over 100 times the wood volume per meter as Section A, yet it was similar to the reference section C on both measures. Pool percentages were 62% and 69%, for sections B and C respectively; whereas section A only had 14% of its area in pools. By 1985 (before LWD was

	added) pool area in Section A had more than doubled. By 1997, the wood pieces in Section A had increased three-fold; the wood volume/m had increased by seven times but was still less than one-tenth of that in section B or C. Approximately 50% of the LWD pieces and the wood volume that built up in Section A were associated with the structures placed in 1985. Discounting the added wood structures, the number of LWD pieces in Section A doubled and the wood volume increased by a factor of three from 1975 to 1997. By 1997 pool percentage in Section A had increased to 49% (50% higher than in 1985 and four times more than in 1975). During the two summers after logging the stream warmed substantially (up to 15 C for Section A in September 1973) as it passed through the treatment sections. In section A, summer maximum stream temperatures surpassed 30 C immediately after logging in 1973 but moderated a bit by 1975 and were similar to the reference section by 1983. Trout in Section B had similar population densities to those in Section C (reference) in all years and similar age-class distributions in all years but one. Trout population in Section A had lower densities and different age-class distributions (less age-1 fish) than Section C for the years immediately after logging. However, by 1983 (10 year later) both trout densities and age-class distributions were similar for all three sections.
Nature of the outcome measures used, their relative importance and robustness	Good case study of how resident trout populations and their habitats respond to two different types of riparian logging treatments over time scales longer than those considered by most other studies. Despite the lack of replication and pre-treatment data, the study benefits by having all sections within the same watershed which controls for climatic variation between sites. Additionally, observed trout population response matched those reported for other clear-cut systems in Oregon (Alsea -Hall and Lantz 1969) and Washington (West Fork Creek, Olympic Peninsula –Osborn et al. 1980).
Effects Modifier (confounding factors)	Different habitat survey methods were used during the different years, but authors were aware of this problem and applied some calibration techniques to make up for this. Differences between mark-recapture and three pass removal fish population estimates were successfully downplayed by the authors referring to previous work by Rodgers et al. (1992). Lack of pre-treatment data and replication diminished the "impact" of this study somehow. Different gradients between Sections C and A make them less perfect a match than Sections C and B.

Appendix D. Publications deemed to be high relevance to the primary review question as determined by the science reviewers from the decision tree in Figure 1 and the summary tables in Appendix B.

Study	**Research Question**	**Season**	**Spatial Extent**	**Spatial Grain**	**Temporal Extent**	**Temporal Grain**	**Type and Location**	**Habitat response**	**Fish response**
1. Bjornn, T., S. Kirking, and W. Meehan. 1991. Relation of Cover Alterations to the Summer Standing Crop of Young Salmonids in Small Southeast Alaska Streams. Transactions of the American fisheries society 120(5): 562-570.	The null hypotheses tested were that changes in riparian vegetation and four types of cover (woody debris, large-boulder substrate, undercut banks, and simulated overhead vegetation) would not change the standing crop of young fish.	Summer	6 streams	Habitat unit	9-11 days	9-11 days	Controlled, replicated experiment in forested streams, Prince of Wales Island, AK	None examined	Abundance of fish (age 0 coho salmon or of all juvenile salmonids, including Dolly Varden and steelhead) did not change significantly in response to large wood placement
2. Boss, S. M. and J. S. Richardson (2002). Effects of Food and Cover on the Growth, Survival, and Movement of Cutthroat Trout (*Oncorhynchus Clarki*) in Coastal Streams. Canadian Journal of Fisheries and Aquatic Sciences 59(6): 1044-1053	Predicted for age-1 resident cutthroat trout that during summer: (i) food addition would affect cutthroat trout primarily through increased growth, (ii) cover addition would primarily increase	Summer and Winter	2 streams	Habitat unit to Reach	Summer: 20-40 days Over winter	Summer: 20-40 days Over winter	Controlled, replicated experiment in forested streams, BC	None examined	*Summer:* Added cover did not affect individual growth rates of cutthroat trout; Added cover decreased mortality by approximately 50% in one stream, but survival was high both with and without cover in the other; Mean number of times that fish emigrated per enclosure was low and not

	survival, and (iii) both would decrease emigration. Assessed body size differences relative to over-winter growth and survival.								affected by added cover. *Over winter:* Added cover had no affect on over-winter growth or survival
3. Cederholm, C. J., R. E. Bilby, et al. (1997). Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17(4): 947-963.	Do large wood inputs increase the size and frequency of pools and amount of wood cover during winter, and positively influence the number of overwintering juvenile salmonids?	Wood: summer Habitat: spring, summer, fall Fish: spring summer, fall	1 stream	Reach	6 years	Wood: year Habitat: 3 years pre- and 3 years post treatment Fish: 3 years pre- and 3 years post treatment	Pre-treatment, controlled experiment in forested streams, WA	Total number of pieces, median piece length and total volume of large wood increased after addition of large wood, but the median diameter and median volume did not. The %area in pools increased and %area in fast water habitat decreased after addition of large wood in all three seasons.	Results for salmonids were equivocal and, therefore, were not considered.
4. Giannico, G.R. 2000. Habitat selection by juvenile coho salmon in response to food and woody debris manipulations in suburban and rural	Investigate the spatial distribution of coho salmon during two experiments that manipulated wood and	Summer	2 streams	Habitat unit	Days - months	Days - months	Controlled, replicated experiment in agricultural/ rural streams, BC	None examined	Pools that combined abundant food with sparse added wood were the most highly used by juvenile coho salmon in summer. Juvenile coho salmon

stream sections. Can. J. Fish. Aquat. Sci. 57: 1804–1813.	food abundance in pools. Another experiment examined whether the spatial distribution of fish was affected by wood density or type (large wood versus small wood).								responded primarily to food but wood altered the response. Added wood density affected fish distribution more strongly in late than early summer. Juvenile coho salmon tended to use pools more when added wood was sparse than when wood was dense or absent.
5. Gowan, C and K.D. Fausch. 1996. Long-Term Demographic Responses of Trout Populations to Habitat Manipulation in Six Colorado Streams. Ecological Applications, 6(3): 931-946.	Test for cause and effect relationships among wood placement and trout (brook trout, Colorado River cutthroat trout, brown trout, rainbow trout) abundance, biomass, growth, survival, and movement. Also examined whether variation in population abundance	Summer	6 streams	Reach	8 years	Year	Pre-treatment, replicated, controlled field experiment in high-elevation, forested Rocky Mountain streams	Pool volume, mean depth, and total cover were significantly greater after treatment than before but not wetted area. Mean depth and %fine substrate were greater in treatment than controls.	Log placements increased the number and biomass of adult trout in treated sections, mainly due to immigration, not increased survival, recruitment, or growth. Few (<5%) immigrants to treatment sections came from adjacent controls.

	was concordant among streams and among reaches within streams to evaluate potential regional-scale effects.								
6. Hartzler. J.R 1983. The Effects of Half-Log Covers on Angler Harvest and Standing Crop of Brown Trout in McMichaels Creek, Pennsylvania. North American Journal of Fisheries Management 3:228-238.	Tested the hypothesis that increasing the amount of only one physical feature, cover habitat, would result in both greater numbers and biomass of "catchable-size" (>200 mm) wild brown trout, in a stream generally considered to have adequate cover prior to treatment.	Summer	1 stream	Reach	5 years	Trout harvested and trout biomass: 2 years pre and 3 years post-treatment Fish Density: year	Controlled, replicated, field experiment in McMichaels Creek, Pocono plateau eastern Pennsylvania	None examined	Half-log devices did not produce a substantial change in the total number of brown trout creeled by anglers but the number harvested increased in five out of six treated reaches. Pre- and post treatment numbers and biomass of brown trout ($\geq$200 mm) were not significantly different. Number and biomass of trout in the yearling (100-199 mm) group was significantly higher in the post-treatment period in both treated and control sections. The biomass of trout ($\geq$100 mm) increased in treated reaches.

									Supplemental cover had little effect on the relative proportion of yearling or older trout in the population.
7. Johnson, S. L., J. D. Rodgers, M. F. Solazzi, and T.E. Nickelson. 2005. Effects of an Increase in Large Wood on Abundance and Survival of Juvenile Salmonids (*Oncorhynchus Spp*.) in an Oregon Coastal Stream. Canadian Journal of Fisheries and Aquatic Sciences 62: 412-424.	Examine prior to and after treatment with large wood: number of key wood pieces (12 m length and 60 cm diameter); total volume (m^3) of all wood pieces (≥ 3 m length and ≥ 15 cm diameter); mean % total wetted surface area in pools during summer and winter; winter wetted surface area (m^2) of mainstem and of side-channel habitats; overwinter survival of juvenile salmonids; abundances of summer	Habitat: Summer and winter Fish: Summer and overwinter	Habitat: 2 streams Fish: 2 streams	Habitat: Reach Juveniles: Stream Smolts: Stream	Summer wood and winter habitat: 2 years Summer pools: 10 years Juveniles: 10 years Smolts: 12 years	Summer wood and winter habitat: year Summer pools: 3 years pre- and 4 years post-treatment Fish: Year	Modified BACI design Tenmile Creek (treatment) and Cummins Creek, OR Coast Range	More large wood (pieces and volume) after than before treatment in treated and untreated streams; %summer pool area increased in two of four treated reaches but not in untreated reaches in either stream. In the reach with the greatest number of placed wood, the % pool habitat associated with deep pools (>1m) increased significantly. Results from this reach suggested increases in winter %pool area, total mainstem habitat area, and total side channel habitat area.	Results for fish were equivocal due to several factors beyond the control of the researchers.

	juveniles and smolts;								
8. Lehane, B.M., P.S. Giller, J. O'Halloran, C. Smith, and J. Murphy. 2002. Experimental provision of large woody debris in streams as a trout management technique Aquatic Conservation Marine and Freshwater. Ecosystems. 12: 289–311	Quantify changes in stream physical habitat and evaluate potential for enhancement of brown trout through large wood placement in plantation forested streams.	Spring	1 stream	25-m segment	2 year	Year	Controlled, replicated, field experiment in Cork County, Ireland	After wood treatment, pool area, amount of eddies, and slack water areas increased and riffle area decreased.	Trout density and biomass in debris treated segments increased significantly 1 and 2 years after treatment. But, trout condition did not change.
9. Roni, P. and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58(2):282-292.	Tested null hypotheses that paired treatment and reference reaches did not differ in (i) wood densities and pool area or (ii) densities of juvenile coho salmon and cutthroat and steelhead trout in summer and winter and that (iii) magnitude of fish response	Habitat and juvenile densities: Summer and winter	30 streams	Reach	Year	Year	Extensive post-treatment design in western WA and OR	Total wetted area, total number of habitat units, total pool area, total number of pools, total number of wood forming pools, total and average number of large wood pieces (per 100 m) and of functional large wood pieces was greater in treatment than reference reaches during both summer and winter. But,	*Summer:* Coho densities (fish/m) were higher in treatment than reference reaches, but densities of age-1+ cutthroat, age-1+ steelhead, and trout fry did not differ. Coho densities were directly related to the number of functioning large wood pieces but not to other habitat variables. Densities of cutthroat or trout fry were not related to habitat variables associated with

	to treatment was independent of magnitude of habitat change and (iv) sizes of the fish would not differ between treatment and reference reaches.							total riffle area was not significantly different between treatment and reference reaches during either summer or winter.	wood placement. Age-1+ steelhead densities were negatively correlated with a difference in total and % pool area and positively correlated with a difference in riffle area. *Winter:* Coho, age-1+ cutthroat and age-1+ steelhead densities were higher in treatment than reference reaches but trout fry densities did not differ. Coho response was significantly correlated with only pool area and restoration type (engineered or natural) Age-1+ cutthroat and age-1+ steelhead trout responses were uncorrelated with any habitat variable. Trout fry response to treatment was negatively correlated with

									difference in %pool area
10. Solazzi, M.F., T.E. Nickelson, S.L. Johnson, and J.D. Rodgers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fish and Aquatic Sciences 75: 906-914	Determine the effects of habitat restoration projects on coho salmon smolt abundance in two coastal streams of Oregon.	Habitat: Winter Fish: Summer juveniles and smolts and overwinter survival (coho only)	4 streams	Stream	Winter habitat: 3-4 years Fish: 8 years	Winter habitat: year Fish: year	BACI design, Alsea and Nestucca Rivers western OR	Amount of winter rearing habitat increased in the treatment stream for both the Alsea and Nestucca basisn. The amount of winter fastwater habitat decreased in the treatment stream for the Alsea (not significantly) and the Nestucca (significantly) basisn. Total surface area of the treatment stream increased in the Nestucca but not in the Alsea.	*Coho:* the ratio of treatment to reference stream increased after treatment for overwinter survival and for abundances of summer juveniles and smolts in both the Alsea and Nestucca. *Trout:* the ratio of treatment to reference did not differ for summer juveniles in either basin or for cutthroat trout migrants in the Alsea but did increase for cutthroat trout migrants in the Nestucca and for steelhead migrants in both basins.