Beaver Restoration Toolbox

A collection of insights, resources, and expert contacts to guide riparian restoration projects that capitalize on the engineering capacity of the North American beaver

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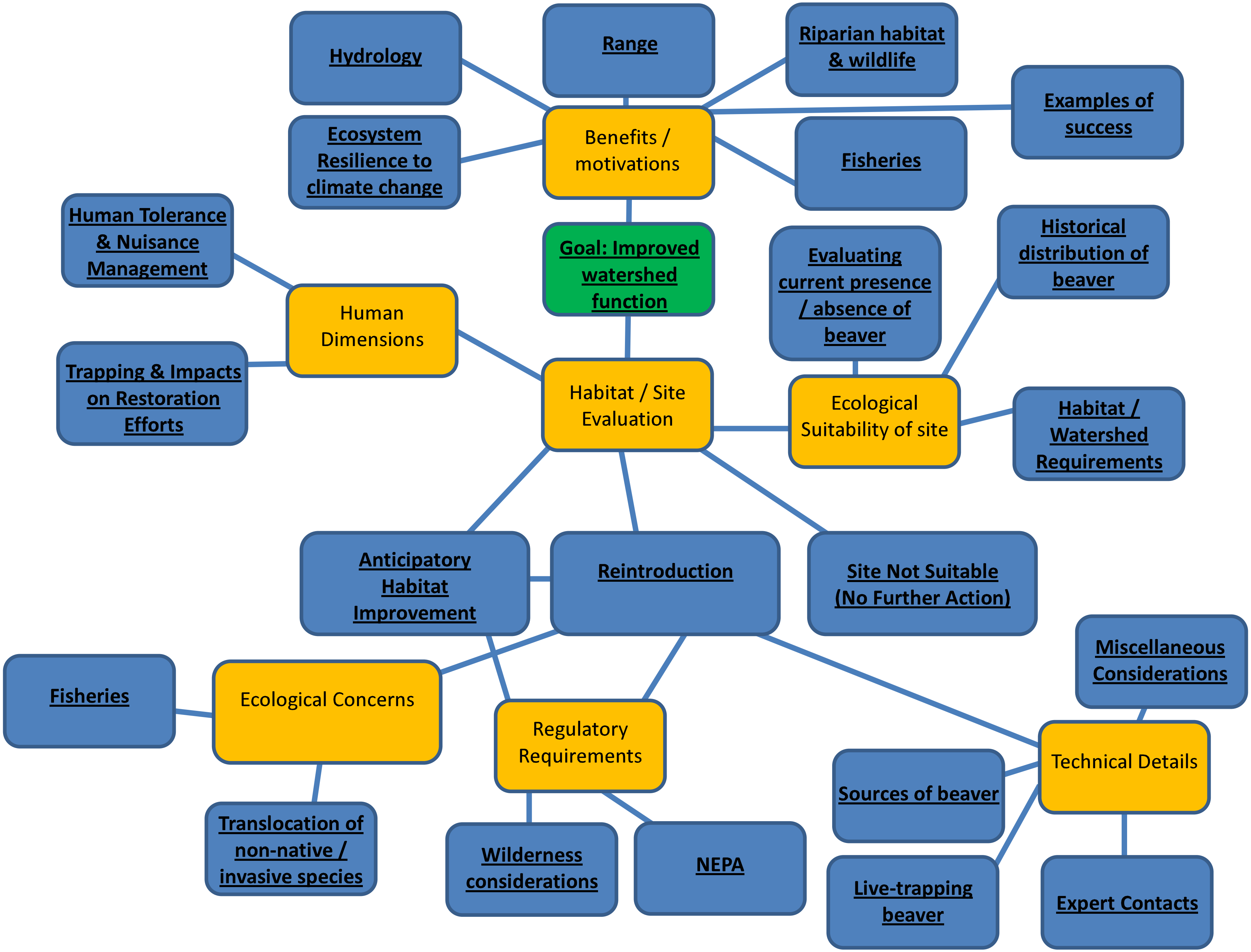


The topic map above illustrates relationships among all included content pages. Each topic area is linked through the Table of Contents to respective content within this document version of the guide. Orange boxes correspond to categories of related topics (no content) while blue boxes represent actual content pages.

Introducing "The Beaver Toolbox"

Welcome to the Beaver Toolbox – a web-based guide to assist in the development and implementation of aquatic, water storage / hydrologic function, and riparian habitat restoration projects by promoting robust populations of dam-building beaver.

This guide was developed in response to the growing body of science that increasingly underscores the extensive benefits that beavers yield to the ecosystems they occupy and alter. Technical expertise related to beaver restoration is scattered throughout the United States Forest Service, its partner organizations, universities, and members of the general public. This guide aims to provide an easy-to-use clearinghouse of relevant information that captures and disseminates the collective knowledge of those with firsthand experience in restoring beaver populations and associated wetlands. The ultimate goal of this guide is to help Forest Service staff and our partners implement successful projects that get more beavers *and water* on the landscapes we manage. This work is of particular value in regions where water is limited and the climate is warming and drying.

While the potential benefits of restoring beaver populations are numerous, so too are the pitfalls and logistical hurdles that must be considered and overcome. Field biologists with years of experience working with and studying beavers are quick to acknowledge that the success of any given restoration effort is not guaranteed and many important lessons remain to be learned. By reviewing the topic areas covered in this guide, resource managers can approach beaver restoration projects from a more informed perspective, and thoughtfully evaluate and augment their chances of success by setting realistic expectations in terms of time required, identifying factors that could prevent successes, and identifying potential conflicts such that adaptive management is employed from the outset.

Another service available through this site is the ability to connect directly with subject matter experts who can provide additional consultation beyond the scope of the guide. See the Expert Contacts section for details.

Note that many of the images and documents included and referenced in this guide are hyperlinked to related sites and full documents. Click on those images while holding down the ctrl button to reach linked resources.

We seek to continue improving the utility of this guide and value your input in doing so. Please contact Karl Malcolm with any feedback, recommended additions, or other suggestions.

Goal: Enhanced Aquatic / Riparian Habitat Condition and Resilience

The relationship between humans and beaver has and continues to vary greatly in time and space. Depending on the date and location of interest, the predominate attitudes of people towards beaver range from viewing them as a prized source of fur (and, in some cases, food) to seeing the species as a relentless nuisance, to understanding and appreciating the contributions to water-rich landscapes. Regardless of prevailing opinion, the capacity of beaver to modify habitat has remained inarguable; putting them on a short list of species (along with humans) recognized as "ecosystem engineers".

In recent decades, the capacity of beaver to change their environments for the better has led many to view the species in a new light. A growing body of research indicates that the habitat modifications induced by beaver create a boon for a broad spectrum of fish and wildlife beyond the beavers themselves. Furthermore, the list of beneficiaries clearly includes people and our domestic stock in some settings. The crucial role of the beaver as an ecosystem engineer is particularly apparent in landscapes where water is a limiting factor and climates are becoming more arid and warm. Previously occupied patches of suitable beaver habitat in these settings are optimal places to consider beaver restoration projects.

Anticipatory Habitat Improvement

The habitat requirements to support beaver are fairly intuitive and basic, including adequate water flows, vegetation for food and building, a modest gradient (or lack thereof), less porous soils, and protection from various threats (trapping, overgrazing, major flooding, depredation, etc.).

There are management actions that can be taken to improve habitat quality, thereby promoting occupation by beaver. These measures can encourage incoming dispersal and can help support current or future reintroductions.

Grazing

Proper management of grazing is particularly important in riparian areas, where the availability of vegetation, for building, cover, and food, is essential to beaver survival. Riparian rehabilitation and protection can be accomplished by resting some or all of the cattle allotment(s) that include streamside habitats or altering the season of use and the length of time spent in the pasture and/or adding riders to keep cattle moving through pastures. Cessation of grazing should be considered leading up to and during the acclimation of new beaver to an otherwise grazed area. Livestock and wild grazers can be physically excluded from riparian areas with recovering beaver populations by constructing simple exclosures.

Minimizing Human Disturbance

Managers should consider implementing road closures, trapping closures, and selecting release and restoration sites that are relatively inaccessible, when possible. By minimizing disturbance following the release of relocated beaver, managers can reduce the likelihood of beaver deserting release sites.

Fencing and Planting New Vegetation

Protecting and expanding the availability of vegetation in anticipation of new beaver colonization or release can improve chances for long-term success. Aspen and willow are excellent sources of food and building materials for beaver. The photos shown in this section were taken during a habitat improvement project implemented by WildEarth Guardians in northern New Mexico (Valles Caldera National Preserve). Note the general lack of riparian vegetation other than that being provided. More details on that particular project are available here:

http://www.flickr.com/photos/wildearth_guardians/sets/72157628078011530/

Considerations for Beaver Restoration in Designated Wilderness

Management activities that have the potential to compromise any aspect of the wilderness character of lands congressionally designated as part of the Wilderness Preservation System are subject to the Minimum Requirements Analysis (MRA) process. Minimum Requirements Analysis is typically addressed through the completion and approval (by various levels of line officers, depending on the proposed actions) of a Minimum Requirements Decision Guide (MRDG). By completing the steps in a MRDG, managers and decision-makers document that they have carefully considered potential impacts to specific characteristics that the federal land management agencies are mandated to maintain in these specially designated lands. Goals of wilderness designation include maintaining lands that are untrammeled, undeveloped, and natural, provide outstanding opportunities for solitude or a primitive and unconfined type of recreation, and / or contain significant cultural resources.

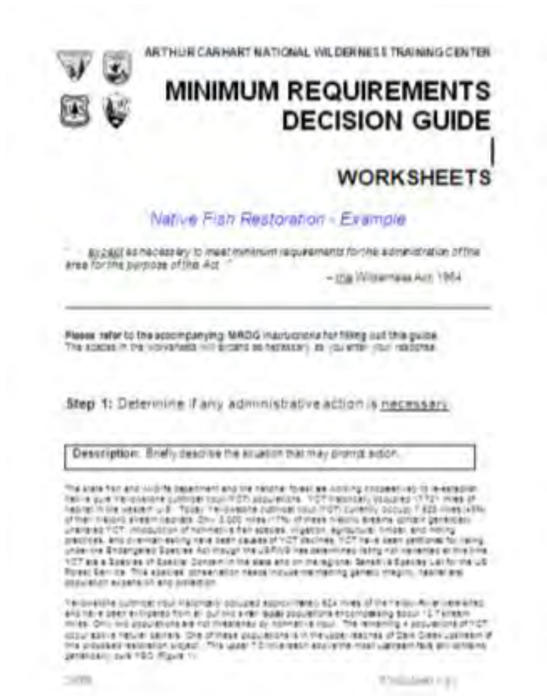
Wilderness management resources - Wilderness.net

A useful website was developed to serve public and government needs related to the preservation, management, understanding, and appreciation of wilderness. Some basic training can be obtained, at no cost, through the web-based resources on this site:

www.wilderness.net

In addition to training opportunities, Wilderness.net provides resources that can provide guidance for managers working on a beaver restoration project that may include reintroduction in wilderness areas. Some of the most valuable tools are completed

MRDGs that have addressed similar projects. For example, there is a completed MRDG dealing with restoration of a native fish species in wilderness. That document can be found here, while other example MRDGs can be found here.



ARTHUR CARHART NATIONAL WILDERNESS TRAINING CENTER

MINIMUM REQUIREMENTS DECISION GUIDE

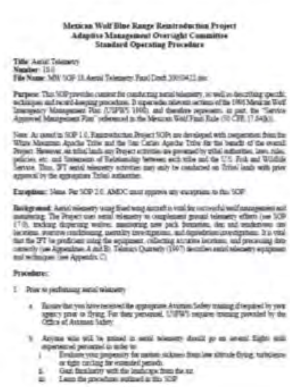
WORKSHEETS

Native Fish Restoration - Example

Step 1: Determine if any administrative action is necessary

Description: Briefly describe the situation that may prompt action.

Another useful example of documentation supporting native wildlife restoration in wilderness stems from efforts to restore **Mexican wolves in the Gila Wilderness** of New Mexico. The Mexican wolf Blue Range reintroduction project documentation (including a discussion of MRDG procedures) is linked here:



Mexican Wolf Blue Range Reintroduction Project
Adaptive Management Oversight Committee
Standard Operating Procedure

Title: Aerial Telemetry

Procedures:

Arizona Game and Fish Department. 2005. Mexican wolf Blue Range reintroduction project adaptive management oversight committee, standard operating procedure. 44 pp.

Minimum Requirements Analysis Webinars

The following webinar recordings are from the 2013 offering of MRA Live, an instructor-led online training course consisting of four webinars, weekly online discussions and an evaluation exercise.

These relevant trainings available on Wilderness.net:

Minimum Requirements Analysis and the Wilderness Act
The Minimum Requirements Analysis Process
Common Minimum Requirements Analysis Problems

One or more of these courses should be completed before managers attempt to complete the MRDG analysis for beaver restoration in wilderness.

Basic Considerations for Wildlife Management in Wilderness

Generally speaking, efforts to actively manage fish and wildlife are discouraged within designated wilderness. However, because beaver were historically an important part of many healthy, functioning wilderness ecosystems (prior to their extirpation), restoration of beaver can be highly desirable and justifiable in some wilderness settings.

Working in wilderness presents a unique set of challenges however, stemming from a prohibition of motorized transport, discouragement from any habitat modifications (including, for example, construction of livestock exclosures), etc. Through the MRDG process the specific management action(s) being considered are thoughtfully scrutinized. Managers are required to consider less disruptive actions (e.g., transporting beaver for reintroduction via pack stock rather than using any motorized transport) when developing their reintroduction plans. An understanding of these issues is imperative to a thorough, sound, and defensible minimum decisions analysis.

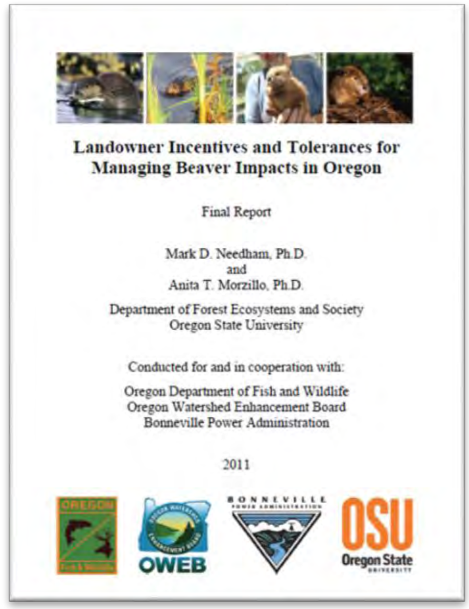
Considerations for Beaver Restoration in Urban Landscapes

When conflicts with people can be averted beavers stand to make considerable ecological contributions in urban settings. A case study is the urban beaver population in Martinez, California, which has been highlighted for its role in improving habitat for native species of fish, birds, and mammals. The beavers have served as a valuable tool for community environmental education. More about the Martinez beaver project can be found by clicking the logo to the right:

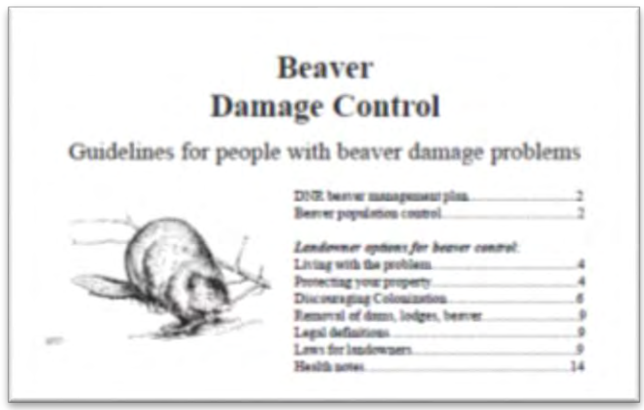
WORTH A DAM
MARTINEZBEAVERS.ORG

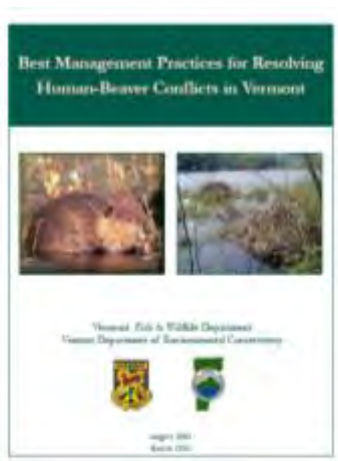
Evaluating Tolerance and Coping with Human-Beaver Conflict

Encouraging work from researchers at Oregon State University (linked right) suggests that many members of the general public are highly supportive of expanding populations of beaver and that tools are available to managers to expand that tolerance further. Despite these encouraging findings and the benefits beaver can provide to the systems they occupy, they are still regarded as pests by many. In some cases negative attitudes towards beaver are rooted in specific, negative personal experience(s). Their potential to cause nuisance problems to people should be considered when sites are being evaluated for beaver restoration or reintroduction.



Some states require that landowners within a radius of multiple miles of a proposed relocation site be consulted prior to a sanctioned release of beaver. Consult with the state wildlife management authority to determine these requirements. Regardless of state mandate, discussing the benefits and nuisance management options while engaging landowners is strongly advised.





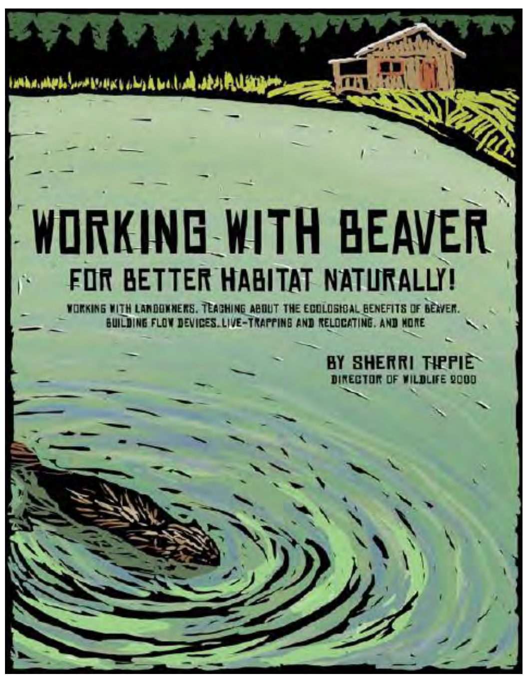
Many states, conservation organizations, and interested citizens have invested tremendous time developing a wide array of tools and written guidance to address nuisance beaver problems (examples from Wisconsin and Vermont are linked through the adjacent images). Some nuisance management programs depend heavily on non-lethal management techniques, which allow newly expanding or established beaver populations to remain in place. Familiarity with available and practical management tools could be crucial for obtaining buy-in from people who may be impacted by recovering beaver populations. Knowing that there are non-lethal methods that facilitate coexistence with beaver encourages landowners to view beaver restoration more favorably and discourages reactionary beaver removal.

Note: The installation of any beaver / flow management device on National Forest System lands will require NEPA analysis.

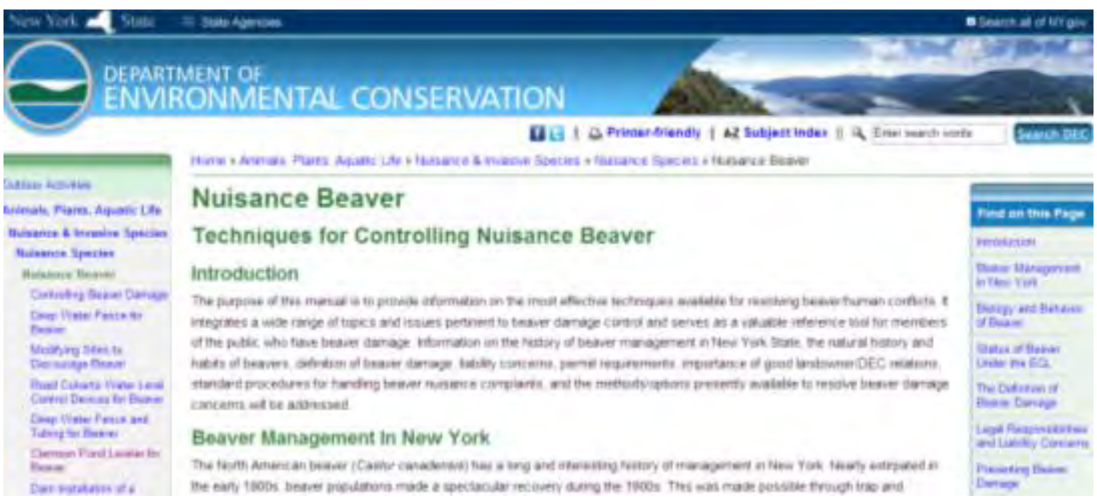
Guidance on the applicability of some non-lethal beaver damage mitigation techniques was contributed to this guide by Joe Cannon, a Plant Ecologist working on beaver restoration projects with the Lands Council. Joe's suggestions follow:

"The Lands Council is continuing to experiment with ways to restrict beavers from causing tree damage. Fencing around each tree is very reliable, and effective in most instances. The younger trees are more of a challenge, when beavers can easily bend the tree over and remove the caging. So we've been experimenting with herbivory deterrents such as neem oil, cayenne, and sand paint- all advised by other sources. Each substance works to some degree, and sometimes with good success. Effectiveness of these applications seems to depend on the season and specific beaver activity. All substances need to be reapplied seasonally as trees expand and as are exposed to weathering."

The additional resources linked below provide information about tools and management practices that can promote successful coexistence of beaver and humans.

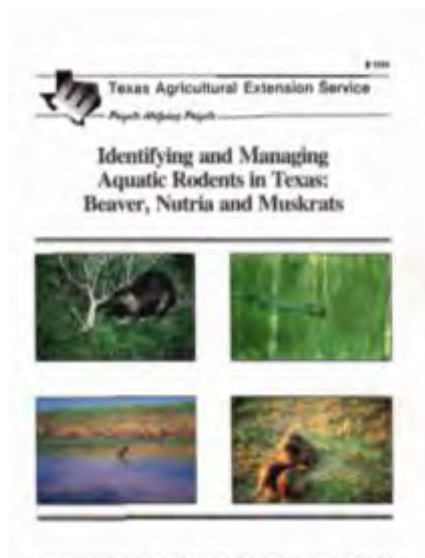



How to Build &
Install A Flexpipe
Working together for people, streams & fish.
Jake Jacobson
Watershed Steward
Surface Water Management Division
of
Public Works Department
Snohomish County


DEPARTMENT OF
ENVIRONMENTAL CONSERVATION
Nuisance Beaver
Techniques for Controlling Nuisance Beaver
Introduction
Beaver Management in New York

Evaluating Current Presence / Absence of Beaver

Accurately determining the presence or absence of beaver in a site being considered for a management action (e.g., beaver reintroduction, habitat manipulation, etc.) is of obvious importance. Familiarity with beaver sign, behavior, and life history will also make efforts to capture beaver more productive. In some areas beaver overlap with other aquatic rodents (e.g., muskrat and nutria), and evidence of these cohabitants has the potential to be confused with that of beaver. Many resources are available that can provide guidance on identifying the signs of beaver and other aquatic rodent activity. A selection is linked here:



Identification

Fig. 2 Beaver tracks

Evaluating Habitat Suitability for Beaver

The fact that beaver were historically found over much of the North American continent is a testament to their adaptability and capacity to alter aquatic systems to meet their needs. Despite these traits, a basic understanding of the habitat characteristics that support beaver occupancy is needed to make appropriate management decisions for a given site.

For beaver to induce many of the key habitat changes and benefits discussed in this guide they must not only survive in a given location. They must also succeed in the construction of functional dams. Therefore it is important, from the standpoint of promoting riparian restoration, to evaluate habitat in terms of supporting functional (i.e. dam-building) beaver.

Prior to initiating a riparian restoration project involving beaver translocation, candidate sites should be evaluated thoughtfully based on habitat characteristics discussed in the citations provided below. The same process can allow managers to identify restoration needs that could promote natural colonization by beaver from surrounding populations.

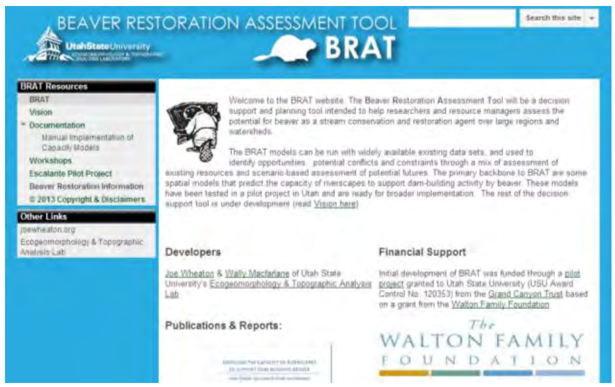
Through these evaluations sites can be categorized as:

- **Suitable for reintroduction of beaver (proceed with project implementation)**

- **Potentially suitable but in need of improvement prior to beaver release**
    - **Anticipatory Habitat Restoration**

- **Not suitable habitat for beaver (no further action taken)**

Several habitat suitability models have been developed and tested for beaver in different regions of North America. While reviewing all available literature on the subject is informative, managers should pay particular attention to the findings reported from habitats similar to their management sites and focus specifically on the habitat characteristics that support beaver ***and their dams***. Some of the models listed below were developed for potential application species range-wide (e.g., Allen 1983), however the variation in vegetation, climate, topography, soils, etc. across beaver range underscores the value of region-specific information (e.g., Suzuki and McComb 1998 in the Pacific Northwest). Also, most of the models focus simply on beaver survival and occupancy rather than their needs for dam building. One important exception is the Beaver Restoration Assessment Tool (BRAT), which was created specifically to evaluate habitats based on their capacity to support dam building by beaver. More information is available here:



Although there is some variation in the key parameters identified among beaver habitat and occupancy models, some general and intuitive patterns emerge consistently. The following variables are of the utmost importance in evaluating suitability of aquatic habitat for beaver and have been shown to affect beaver positively or negatively as indicated by the adjacent symbols.

- Availability of hardwood vegetation **+**
- Availability of aspen (food and building) **+**
- Consistent and adequate water availability **+**
- Increasing stream gradient **-**
- Progressively well-drained soils **-**
- Trapping pressure **-**
- Grazing by ungulates **-**
- Proximity to human conflicts **-**
- Conservation / management objectives (fish, dam removal) **-**

A similar list of variables was considered in the Beaver Management Strategy drafted by the Malheur National Forest and the Keystone Project, dated September 2007 (shown below).

Identification of Watersheds and Subwatersheds with Potential for Beaver Recovery

Key habitat components:

- A channel gradient of less than six percent
- Channels with suitable soils/sediment for dam construction
- Water flows stable and sufficient to make a pond
- Deciduous trees, shrubs, sedges for adequate food supply
- Winter conditions which will not freeze ponds
- Sufficient valley floor area to allow for flooding
- Shelter (riparian shrubs) for safety and building materials
- Protection from trapping and recreational killing until colonies are well established

The full Strategy is available here:

BEAVER MANAGEMENT STRATEGY

Malheur National Forest and the Keystone Project
September 2007

This strategy renews the commitment to beaver management agreed to in the 1998 John Day Basin Beaver Restoration Memorandum of Agreement, (attached, Appendix A) as attested by the following:

USDA Forest Service, Malheur National Forest	Date
Grant County Commissioners	Date
Confederated Tribes of the Warm Springs, John Day Basin Office	Date
Oregon Department of Fish and Wildlife, John Day District Office	Date
Bureau of Land Management, Prineville District	Date
USDA Natural Resource Conservation Service, John Day Office	Date
Grant County Soil and Water Conservation District	Date
Oregon State University, Grant County Extension Office	Date
Confederated Tribes of the Umatilla, Pendleton Oregon	9/27/07 Date
Burns Paiute Tribe, Burns Oregon	Date

The following citations provide an introduction to habitat suitability / occupancy research efforts in North America:

Allen, A.W. 1983. Habitat suitability index models: beaver. U.S. Department of Interior Fish and Wildlife Service. FWS/OBS-82/10.30 Revised. 20p.

Beier, P. and R.H. Barrett. 1987. Beaver habitat use and impact in the Truckee River Basin, California. Journal of Wildlife Management 51(4) 794-799.

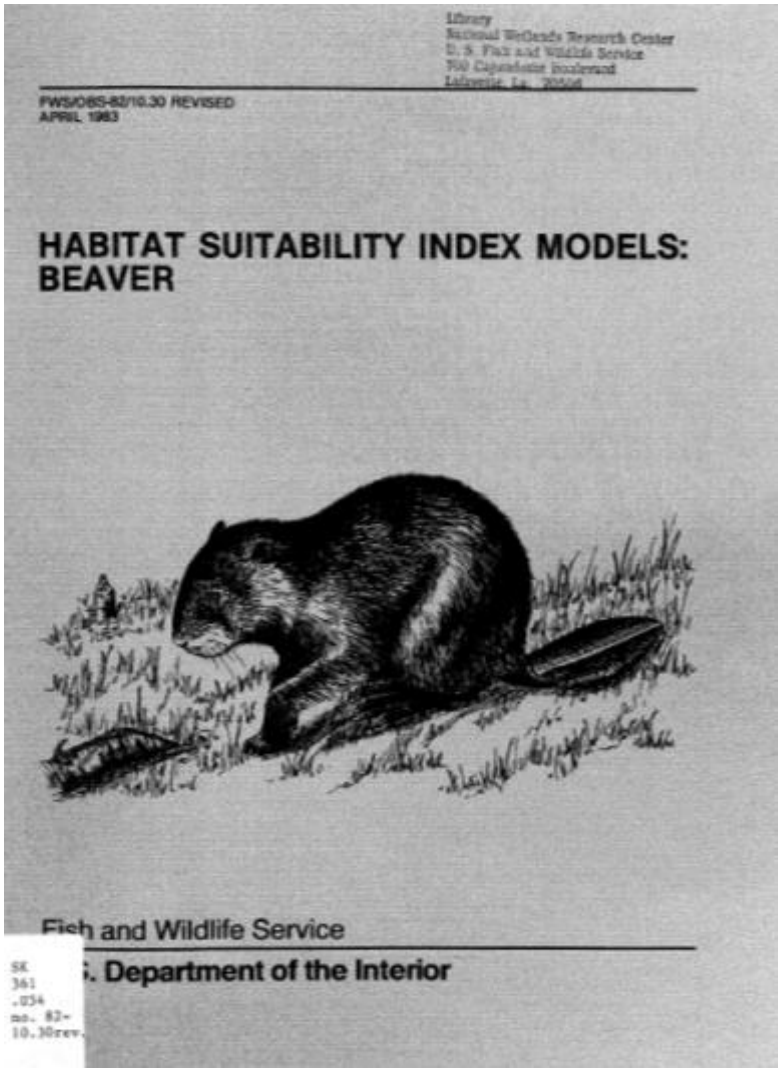
Curtis, P.D. and P.G. Jensen. 2004. Habitat features affecting beaver occupancy along roadsides in New York State. Journal of Wildlife Management 68(2) 278-287.

Howard, R.J. and J.S. Larson. 1985. A stream habitat classification system for beaver. Journal of Wildlife Management 41(1) 19-25.

Macfarlane W.W. and J.M. Wheaton. 2013. Modeling the capacity of riverscapes to support dam-building beaver-case study: Escalante River watershed. Ecogeomorphology and Topographic Analysis Lab, Utah State University, Prepared for Walton Family Foundation, Logan, Utah, 78 pp.

Slough, B.G. and R.M.F.S. Sadleir. 1976. A land capability classification system for beaver (Castor Canadensis Kuhl). Canadian Journal of Zoology 55(8) 1324-1335.

Suzuki, N. and W.W. McComb. 1998. Habitat classification models for beaver (Castor Canadensis) in the streams of the Central Oregon Coast Range. Northwest Science 72(2) 102- 110.



Allen, A.W. 1983. Habitat suitability index models: beaver. U.S. Department of Interior Fish and Wildlife Service. FWS/OBS-82/10.30 Revised. 20p.

BEAVER HABITAT USE AND IMPACT IN TRUCKEE RIVER BASIN, CALIFORNIA

PAUL BEIER, Department of Forestry and Resource Management, University of California, Berkeley, CA 94720
REGINALD H. BARRETT, Department of Forestry and Resource Management, University of California, Berkeley, CA 94720

Abstract: Stepwise logistic regression was used to identify factors important for habitat use by beavers (*Castor canadensis*) on streams. Increasing stream width and depth and decreasing gradient had the strongest positive effects on habitat use; food availability variables added little explanatory power. Some abandoned colony sites appeared to have been located on physically unsuitable habitat, whereas others appeared to be physically suitable sites abandoned due to resource depletion. The fact that few unused or uncolonized reaches were misclassified as suitable habitat suggests that suitable habitat has been saturated. Impact of beaver on woody plants was assessed for 8 forage species. Local extinction of quaking aspen (*Populus tremuloides*) and black cottonwood (*P. trichocarpa*) occurred on 4–5% of stream reaches. Willow (*Salix* spp.) showed good vigor despite heavy use in most reaches.

J. WILDL. MANAGE. 51(4):794–799

Beier, P. and R.H. Barrett. 1987. Beaver habitat use and impact in the Truckee River Basin, California. Journal of Wildlife Management 51(4) 794-799.

HABITAT FEATURES AFFECTING BEAVER OCCUPANCY ALONG ROADSIDES IN NEW YORK STATE

PAUL D. CURTIS,[1] Department of Natural Resources, Fernow Hall, Cornell University, Ithaca, NY 14853, USA
PAUL G. JENSEN,[2] New York Cooperative Fish and Wildlife Research Unit, Fernow Hall, Cornell University, Ithaca, NY 14853, USA

Abstract: Characterizing habitat features that influence beaver (*Castor canadensis*) occupancy along roadsides may have important implications for managing damage to roads caused by beaver activity. We initiated this study to develop proactive and long-term approaches to deal with nuisance beaver along roadsides. From June to October 1997 and 1998, we sampled 316 roadside sites in New York state, USA—216 sites where beaver occupied the roadside area and 100 unoccupied sites. We used stepwise logistic regression to identify habitat variables associated with beaver occupancy along roadsides. We evaluated regression models through measures of sensitivity and specificity. The logistic function retained the percentage of roadside area devoid of woody vegetation, stream gradient, the interaction between these 2 variables, and stream width in the final model. Precluding beaver occupancy along highways would necessarily involve large-scale removal of woody vegetation that would be impractical in all but the most intensive management scenarios. However, beaver habitat assessment adjacent to roads may be a useful tool for designing new highways, prioritizing culvert replacements, and developing proactive plans for beaver damage management.

JOURNAL OF WILDLIFE MANAGEMENT 68(2):278–287

Key words: beaver, *Castor canadensis*, habitat, highways, logistic regression, New York, vegetation, wildlife damage.

When beaver occupy roadside areas, they can seriously damage the highway by plugging culverts or constructing dams nearby that flood the road or cause water to impound against the road base. This can result in the formation of potholes and general destabilization of the road. Beaver damage to roads is a widespread problem for highway departments throughout much of North America. Historically, many highways and smaller roads have allocate between 5 and 25 man-days of effort and $543–4,900 in total repair costs at each beaver-obstructed culvert annually (Purdy and Decker 1985; Enck et al. 1988, 1992). In a recent survey of New York highway departments, half of the respondents reporting beaver damage to their roads indicated that they spent over $1,000 at each problem site in 1999, and nearly 20% of respondents spent over $2,500 at each problem

Curtis, P.D. and P.G. Jensen. 2004. Habitat features affecting beaver occupancy along roadsides in New York State. Journal of Wildlife Management 68(2) 278-287.

A STREAM HABITAT CLASSIFICATION SYSTEM FOR BEAVER

REBECCA J. HOWARD,[1] Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003
JOSEPH S. LARSON, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003

Abstract: Documentation over a 28-year period of beaver (*Castor canadensis*) habitat use permitted development and testing of two models to predict maximum density of active beaver colonies on streams. Principal components regression, a technique that reduced the confounding effects of closely correlated ecological variables found in earlier studies of this type, and discriminant analysis were used for model development. In mixed coniferous-deciduous forest habitat, the percentage of hardwood vegetation, watershed size, and stream width had significant positive effects on active colony density. Increasing stream gradient and progressively well-drained soils had negative effects. In field-tests, the models were 80% and 75% reliable in predicting active colony density.

J. WILDL. MANAGE. 49(1):19–25

Evaluation and classification of North American beaver habitat have progressed from early qualitative descriptions (Atwater 1940, Packard 1947, Northcott 1964) and systems based solely on woody food requirements (Buckley 1950, MacDonald 1956) to more recent quantitative studies. Retzer et al. (1956) quantified the relationship of habitat variables to habitat suitability in the Rocky Mountain region. Boyce (1974) used linear regression analysis to relate stream distances between colonies to major plant associations and physical properties of streams in Alaska. In British Columbia, Slough and Sadleir (1977) described the relation of colony site

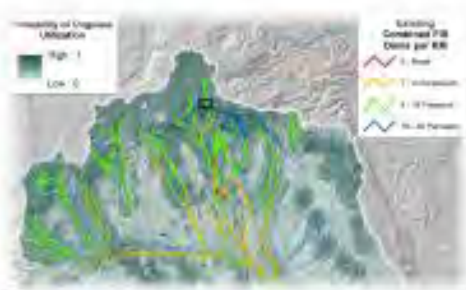
[1] Present address: National Coastal Ecosystems Team, U.S. Fish and Wildlife Service, 1010 Gause Blvd., Slidell, LA 70458.

Howard, R.J. and J.S. Larson. 1985. A stream habitat classification system for beaver. Journal of Wildlife Management 41(1) 19-25.

MODELING THE CAPACITY OF RIVERSCAPES TO SUPPORT DAM-BUILDING BEAVER

CASE STUDY: ESCALANTE RIVER WATERSHED

FINAL REPORT TO THE GRAND CANYON TRUST & WALTON FAMILY FOUNDATION



Prepared by:

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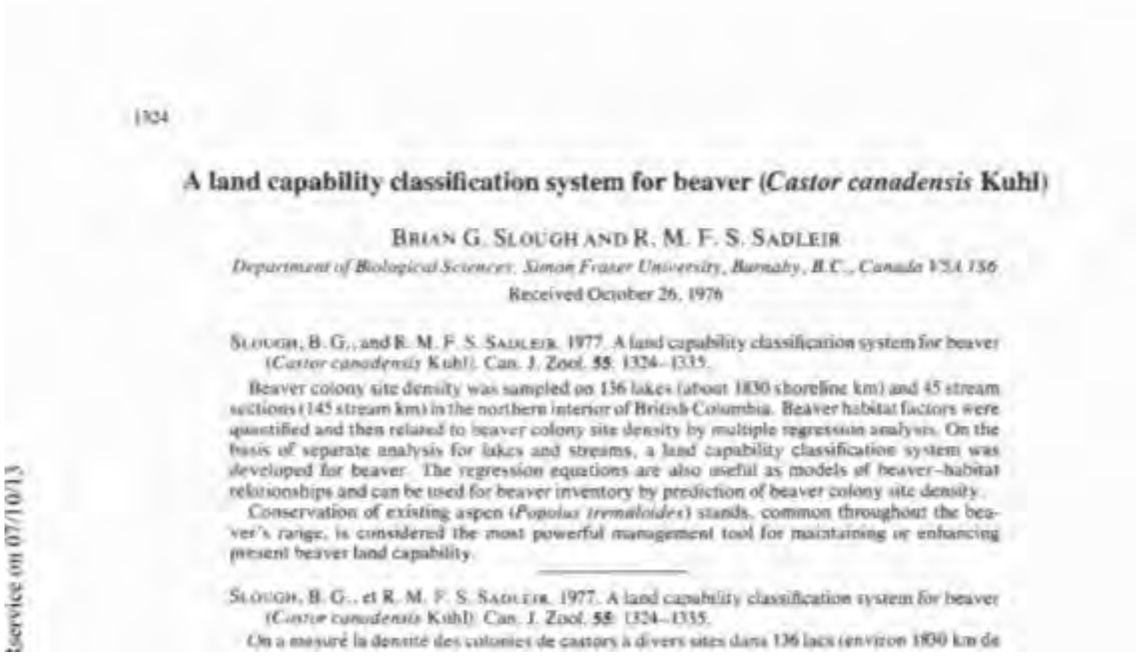
ECOGEOMORPHOLOGY & TOPOGRAPHIC ANALYSIS LABORATORY

JANUARY, 2013

Macfarlane W.W. and J.M. Wheaton. 2013. Modeling the capacity of riverscapes to support dam-building beaver-case study: Escalante River watershed. Ecogeomorphology and Topographic Analysis Lab, Utah State University, Prepared for Walton Family Foundation, Logan, Utah, 78 pp.


1324

A land capability classification system for beaver (*Castor canadensis* Kuhl)

BRIAN G. SLOUGH AND R. M. F. S. SADLEIR

Department of Biological Sciences, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6

Received October 26, 1976

SLOUGH, B. G., and R. M. F. S. SADLEIR. 1977. A land capability classification system for beaver (*Castor canadensis* Kuhl). Can. J. Zool. **55**: 1324–1335.

Beaver colony site density was sampled on 136 lakes (about 1830 shoreline km) and 45 stream sections (145 stream km) in the northern interior of British Columbia. Beaver habitat factors were quantified and then related to beaver colony site density by multiple regression analysis. On the basis of separate analysis for lakes and streams, a land capability classification system was developed for beaver. The regression equations are also useful as models of beaver–habitat relationships and can be used for beaver inventory by prediction of beaver colony site density.

Conservation of existing aspen (*Populus tremuloides*) stands, common throughout the beaver's range, is considered the most powerful management tool for maintaining or enhancing present beaver land capability.

SLOUGH, B. G., et R. M. F. S. SADLEIR. 1977. A land capability classification system for beaver (*Castor canadensis* Kuhl). Can. J. Zool. **55**: 1324–1335.

On a mesuré la densité des colonies de castors à divers sites dans 136 lacs (environ 1830 km de

service on 07/10/13

Slough, B.G. and R.M.F.S. Sadleir. 1976. A land capability classification system for beaver (Castor Canadensis Kuhl). Canadian Journal of Zoology 55(8) 1324-1335.

Nobuya Suzuki, Department of Forest Science, Oregon State University, 020 Forestry Sciences Laboratory, Corvallis, Oregon 97331

William C. McComb, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, Massachusetts 01003

Habitat Classification Models for Beaver (*Castor canadensis*) in the Streams of the Central Oregon Coast Range

Abstract

During 1988-1989, 22 stream habitat attributes were measured and compared between 40 beaver-dam sites and 72 unoccupied-stream sites to identify attributes associated with dam-site selection by beaver (*Castor canadensis*) in streams of the Drift Creek Basin, Lincoln County, Oregon. Beaver built dams in areas with wide valley-floors; narrow, low gradient streams; high grass/sedge cover; and low red alder (*Alnus rubra*) and shrub cover. Unoccupied sites lacked these characteristics. A discriminant function model correctly classified 83% of beaver-dam sites and 88% of unoccupied-stream sites with a chance-corrected classification rate of 69% (Cohen's *Kappa* statistic). We used 3 geomorphic attributes (stream width, gradient, and valley floor width) and developed a new Habitat Suitability Index (HSI) model for the basin. Land managers can use the discriminant function model or the HSI model to inventory potential beaver-dam sites along streams of the Oregon Coast Range. Information obtained from our habitat classification models can be incorporated into plans to preserve unique riparian habitats maintained by beaver.

Introduction

Over 60 million beaver (*Castor canadensis*) are

distribution of suitable beaver habitats in the modern drainage systems, have become quite dif-

Suzuki, N. and W.W. McComb. 1998. Habitat classification models for beaver (Castor Canadensis) in the streams of the Central Oregon Coast Range. Northwest Science 72(2) 102- 110.

Fisheries

Extensive research has focused on the effects (both positive and negative) on stream fisheries of the aquatic and riparian habitat changes induced by beaver. The purpose of this section is to provide an overview of the benefits and costs associated with beaver restoration, with supporting documentation to be referenced for more detailed reading. Kemp et al. (2012) completed a thorough review of primary literature (which predominately focuses on North America) and a subsequent meta-analysis of this topic, the results of which significantly informed this portion of the guide.

Fish species dealt with specifically (in descending order) in the literature reviewed by Kemp et al. (2012) included:

- Brook trout (*Salvelinus fontinalis*), 22 records
- Coho salmon (*Oncorhynchus kisutch*), 15 records (also see recent coho recovery language included in the recovery plan that pertains to the crucial role of beaver for this species)

- Rainbow trout (*O. mykiss*, including the anadromous steelhead trout, and the golden trout sub-species), 14 records
- Cutthroat trout (*O. clarki*, composed of several sub-species) 14 records
- Atlantic salmon (*Salmo salar*), 13 records
- Brown trout (*Salmo trutta*), 12 records

Species-specific findings and methodologies are presented in Table 4 below.

Table 4 The impacts of beaver dams on fish and the methods used to assess the impact.

Species	Effect of beaver dams	Method of assessment	Reference
Atlantic salmon	Limit spawning distribution	Electrofishing and seine netting	Mitchell and Cunjak 2007
Atlantic salmon	Some beaver dams pose serious obstacles to migrating salmon, especially when discharge is low	Redd counts	Taylor *et al.* 2010
Atlantic salmon, brook trout	Partial to complete blockage	Anecdotal evidence	Scruton *et al.* 1998
Atlantic salmon, brook trout, alewife	Prevent both upstream migrants from reaching spawning grounds also impacts seaward movements for some species	Observed/speculative	Guignion 2009
Atlantic salmon, sea trout	Obstruct upstream and downstream migration	Quantified amount of habitat behind dams/speculative	Parker and Ronning 2007
Bull trout	Blocked or delayed downstream movements	Radio telemetry	Dupont *et al.* 2007
Brook trout	Dam removal leads to range expansion but not abundance increase	Dam removal and electrofishing	Avery 1991
Brook trout	Fall spawners blocked from reaching spawning grounds	Discursive/observation	Grasse 1951; Doucett *et al.* 1999;
Brook trout	Dam impede upstream and downstream migration, but not totally impassable	Fish trapping	Rupp 1954
Brown trout	Block downstream movement	No data	Tambets *et al.* 2005
Brown trout, minnow, bullhead, burbot, pike	Barriers to colonization and migration, especially for slow dispersing species	Discursive	Hägglund and Sjöberg 1999
Coho salmon	Dams (one = 2 m height) did not block migration. Movement facilitated by fall freshets	Fish trapping	Bryant 1984
Coho salmon, steelhead trout	Impact ability to colonize new areas	Seine netting	Murphy *et al.* 1989
Cutthroat trout, rainbow trout	Fish usually pass because of high spring flows	Discursive	Grasse 1951
Lahontan cutthroat trout	Seasonal blockage of at least upstream movement	Anecdotal and observational	Talabere 2002
Lake whitefish (*Coregonus clupeaformis*, Salmonidae), walleye	Reduce access to spawning grounds	Discursive	Bertolo and Magnan 2006
Northern pike, walleye	Block spawning runs	Speculative	Knudsen 1962
Oregon chub	Population isolation	Speculative	Scheerer *et al.* 2004
Roach, sticklebacks, brook lamprey	Total barrier to movement	Methods not stated	Elmeros *et al.* 2003
Salish suckers (*Catostomus* spp., Catostomidae)	Species rarely crossed beaver dams	Radio telemetry	Pearson and Healey 2003
Sea trout	Partially block spawning run	Methods not stated	Elmeros *et al.* 2003
Sockeye salmon	Block access to spawning sites	Observational/speculative	McPhee *et al.* 2009
Steelhead trout	Fish appeared able to cross barriers	Observational	Lowry 1993
Steelhead trout, rainbow trout	Upper extent of distribution fluctuates with occurrence of dams		Andonaegui 2000
Trout spp.	Adults unable to return downstream after spawning	Methods not stated	Rasmussen 1941
Trout spp.	Block spawning runs or upstream migration	Discursive/speculative	Bradt 1935; Cook 1940; Knudsen 1962; Grasse 1979
Trout spp.	Tagged fish did not pass upstream over dams but were able to move downstream to spawning grounds	Tagging	Salyer 1935

Table 4 *from* Kemp P.S., Worthington T.A., Langford T.E.L., Tree A.R.J. & Gaywood M.J. (2012) Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries, 13, 158–181.

Note: A full bibliography including each of these records is provided at the end of this guide.

Overall, the references cited indicate that beaver have a net positive effect on stream fish in most settings (see Table 5 below and refer to bibliography for more information).

Table 5 Studies showing positive (+) and/ or negative (–) impacts of beaver on species abundance or productivity.

Species	Impact	References
Atlantic salmon	+/–	Scruton *et al.* 1998; Cunjak *et al.* 1998; Cunjak and Therrien 1998; Mitchell and Cunjak 2007; Guignion 2009
Bonneville cutthroat trout	+	White and Rahel 2008
Brook stickleback (*Culaea inconstans*, Gasterosteidae)	+	France 1997
Brook trout	+/–	Hale 1966; Scruton *et al.* 1998; Rabe 1970; Rutherford 1955; Gard 1961; Collins 1993; Balon and Chadwick 1979; Mitchell and Cunjak 2007
Brown trout	+	Hale 1966; Müller-Schwarze and Sun 2003; Gard and Seegrist 1972; Gard 1961; Kukula and Bylak 2010
Bull trout	+	Andonaegui 2000
Chinook salmon	+	Andonaegui 2000
Coho salmon	+	Bustard and Narver 1975; Pollock *et al.* 2004; Lang *et al.* 2006; Leidholt-Bruner *et al.* 1992; Nickelson *et al.* 1992; Bryant 1984; Murphy *et al.* 1989; Riley and Lemieux 1998 in Gottesfeld *et al.* 2002
Colorado River cutthroat trout	+	Horan *et al.* 2000
Creek chub (*Semotilus* spp., Cyprinidae)	+	Schlosser 1998; Rupp 1954
Cutthroat trout	+	Grasse 1951; Harig and Fausch 2002
Dolly Varden	+	Gregory 1988
Eastern brook trout	+	Rupp 1954; Grasse 1951
Fallfish (*S. corporalis*, Cyprinidae)	+	Rupp 1954
Fathead minnow (*Pimephales promelas*, Cyprinidae)	+	France 1997
Finescale dace (*P. neogaeus*, Cyprinidae)	+	France 1997
Golden trout	–	Müller-Schwarze and Sun 2003
Lahontan cutthroat trout	+	Talabere 2002
Lake whitefish	–	Bertolo and Magnan 2006
Minnow (Cyprinidae spp.)	+	Knudsen 1962
Mudminnow (Umbridae spp.)	+	Knudsen 1962
Muskellunge (*E. masquinongy*, Esocidae)	+	Frohnauer *et al.* 2007
Ninespine stickleback	+	Rupp 1954
Northern pike	+	Bertolo and Magnan 2006; Knudsen 1962
Northern redbelly dace (*P. eos*, Cyprinidae)	+	Rupp 1954; France 1997
Pinewoods darter	–	Rohde and Arndt 1991
Puye (*Galaxias maculatus*, Galaxiidae)	+	Moorman *et al.* 2009
Rainbow trout	+	Müller-Schwarze and Sun 2003; Grasse 1951; Andonaegui 2000; Gard 1961
Sandhills chub	–	Rohde and Arndt 1991
Slimy sculpin (*C. cognatus*, Cottidae)	+	Mitchell and Cunjak 2007; France 1997
Sockeye salmon	+	Murphy *et al.* 1989
Steelhead salmon	+	Andonaegui 2000
Walleye	–	Bertolo and Magnan 2006
White sucker (*C. commersonii*, Catostomidae)	+	Rupp 1954; France 1997
Yellow Perch (*Perca flavescens*, Percidae)	+	Balon and Chadwick 1979

Table 5 *from* Kemp P.S., Worthington T.A., Langford T.E.L., Tree A.R.J. & Gaywood M.J. (2012) Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries, 13, 158–181.

The impacts (positive and negative) most commonly cited were:

Benefits of beaver activity to fisheries

- Increased fish productivity / abundance
- Increased habitat and habitat heterogeneity (which promotes biodiversity [Smith and Mather, 2013])
- Increased rearing and overwintering habitat
- Enhanced growth rates
- Providing flow refuge
- Improved production of invertebrate

Case Study: Bridge Creek, Oregon

Some of the most compelling data regarding the relationship between beaver restoration and improved fish production are beginning to emerge from on ongoing project on Bridge Creek, a tributary to the John Day River in eastern Oregon. Preliminary data from monitoring efforts indicate that human-facilitated beaver restoration is increasing production of a population of Endangered Species Act-listed steelhead (*Oncorhynchus mykiss*). The project and findings were presented in a recorded webinar presented by Dr. Joe Wheaton which, along with related PowerPoint slides can be found here:

http://beaver.joewheaton.org/beaver-links/beaver-news-annoucements/webinarcheapcheerfulstreamrestoration-withbeaver?pli=1

(See slides 85-91 for information from Bridge Creek.)

A detailed description of the Bridge Creek Project can also be obtained from the following documents:

Pollock M, Wheaton JM, Bouwes N and Jordan CE. 2011. Working with Beaver to Restore Salmon Habitat in the Bridge Creek Intensively Monitored Watershed: Design Rationale and Hypotheses, Interim Report, NOAA Northwest Fisheries Science Center, Seattle, WA, 108 pp.

Pollock M, Wheaton JM, Bouwes N and Jordan CE. 2012. Working with Beaver to Restore Salmon Habitat in the Bridge Creek Intensively Monitored Watershed: Design Rationale and Hypotheses. NOAA Technical Memorandum, NOAA Northwest Fisheries Science Center, Seattle, WA, 63 pp.

Costs of beaver activity to fisheries

- Barriers to fish movement
- Siltation of spawning habitat
- Low oxygen levels in beaver ponds
- Altered temperature regime

Note: Over half (51.5%) of the *positive* impacts cited were based on data, whereas for *negative* impacts (71.4%) were speculative. The commonly cited negative impact of beaver dams impeding fish movement was supported by data on 21.6% of occasions (Kemp et al., 2012).

More on Impedance of Fish Movement by Beaver Dams

Recent research focused on the passage of beaver dams by stream fishes further illustrates that these concerns may be largely unfounded and that beaver dams might even provide a competitive advantage to native fish species relative to non-natives.

In a 2013 paper accepted by the Transactions of the American Fisheries Society, titled *"Do beaver dams impede the movement of trout?"* scientists Ryan L. Lokteff [1, 2], Brett B. Roper[1, 2], and Joseph M. Wheaton[2] report that Bonneville cutthroat trout (a native trout species in their study area) pass dams more frequently than both non-native brown trout and brook trout. They determined that timing of spawning affected seasonal changes in dam passage for each species. Physical characteristics of dams such as height and upstream location affected the passage of each species. Movement behaviors of each trout species were also evaluated to help explain dam passage. These data suggest beaver dams are not acting as barriers to movement for cutthroat and brook trout but may be impeding the movements of invasive brown trout.

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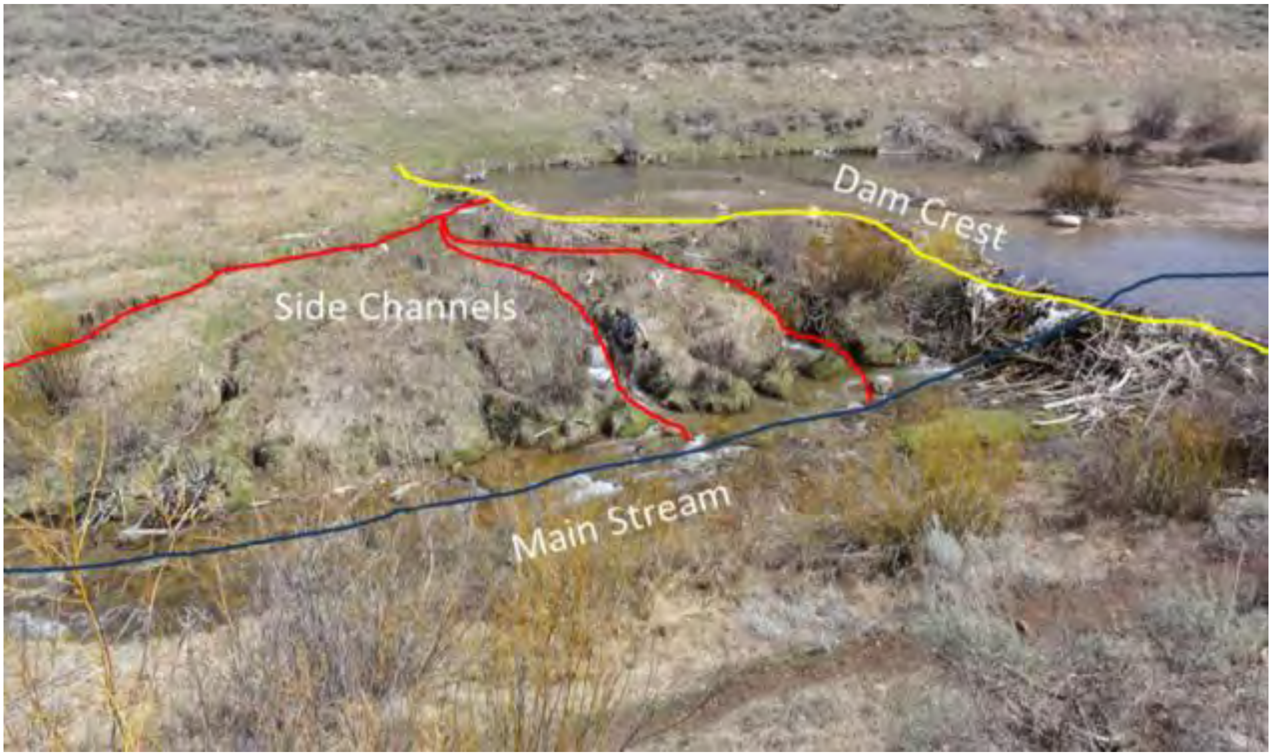
In their paper Lokteff et al. (2013) provide an illustration (below) that depicts the various channels that commonly exist in beaver dams, which facilitate travel of stream fishes around or through these natural obstacles. Side channels (shown in red) often act as particularly effective fish ladders.



Side channels often act as fish ladders that allow movement of stream fishes around otherwise impassable obstacles created by beavers. Recent research has shown that some native species are better able to navigate past beaver dams than their invasive competitors. **Illustration provided by:**

Lokteff, R.L., Roper, B.B., and Wheaton, J.M. (2013) Do beaver dams impede the movement of trout? Transactions of the American Fisheries Society 142:1114-1125

Historical Distribution of Beaver

One of the most logical criteria for evaluating potential beaver restoration sites is whether or not a given location was historically occupied by beaver.

North American Distribution of Castor Canadensis

Note: The range map shown above has recently been shown to be inaccurate. Nearly the entire contiguous 48 United States were historically occupied by this species.

Prior to the fur rush of the mid-19th century, beaver could be found throughout the North American continent, from Alaska to Mexico. Even in areas from where beaver have long been extirpated, evidence of their historic activity may still exist.

A combination of field reconnaissance and scouring historical trapping records can help identify the locations where beaver could be found centuries ago. In many cases streams have become incised in the absence of beaver during the subsequent decades or centuries.

An especially compelling case can be made for riparian restoration, including beaver reintroduction, in settings where managers can provide clear evidence of historic occupation by beaver, and demonstrate degradation of stream health following their removal.

Novel physical evidence that beaver historically were native to the Sierra Nevada

Charles D. James and Richard B. Lanman*

In a recent case study, researchers studying a site in California showed, through carbon dating of recently exhumed dam remnants, that beaver were active in the Sierra Nevada, disproving long-held claims that beaver were not extant to that region. The results of their analysis suggest that beaver activity in the area lasted for over a millennium, and ceased in the mid-1800′s coinciding with a concerted trapping effort in the region (James and Lanman, 2012). In the decades since beaver extirpation, stream channels have become incised, possibly as a direct result. Information like this can be a strong foundation upon which managers can build a case for beaver and riparian restoration.

FIGURE 1.—Photograph of a remnant ancient beaver dam with multiple sticks, and a 12 ounce juice bottle for scale. The acute angle cuts on the stick ends are characteristic of beaver. The beaver dam is 1.5 m below the surface of a montane meadow on the wall of an incised channel on Clarks Creek, approximately 8 km southeast of Antelope Lake, Plumas County, California. The elevation of the meadow is 1,707 m (5,600 feet) and located at approximately 40° 08' N, 120° 30" W. Reprinted with permission of J. Wilcox, Plumas Corporation, 2011.

From: James, C.D. and R.B. Lanman. 2012. Novel physical evidence that beaver historically were native to the Sierra Nevada. California Fish and Game 98(2) 129-132

For additional evidence also see: Lanman, R.B., Perryman, H., Dolman, B., and C.D. James. 2012. The historical range of beaver in the Sierra Nevada: a review of the evidence. California Fish and Game 98(2):65-80.

Hydrology

Early accounts from trappers and mountain men traveling the land that today is the western United States often referred to the seemingly endless supplies of beaver in many of the watersheds they encountered. Undoubtedly, the landscapes rich with beaver looked and functioned differently before beaver populations plummeted in the face of unsustainable trapping. One of the most basic and important changes induced by beavers is that vast quantities of water are stored by beaver dams, which remain available to vegetation, fish, and wildlife.

Beavers directly impact the hydrology of the watersheds they occupy by:

- Storing water for more consistent and later season delivery (Gurnell 1998)*
- Raising ground water levels (Westbrook et al., 2006)
- Altering water temperature regimes (Collen and Gibson, 2001)
- Introducing complexity and dynamism to streams (Naiman et al., 1988)
- Increasing nutrient availability in streams (Naiman et al., 1986)
- Improving stream function by reconnecting floodplains (Rosell et al., 2005)
- Decreasing sediment delivery to the stream system (McDowell and Naiman, 1986)

*Each bullet point above is accompanied by a peer-reviewed source that can be referenced for more detailed information. Single references are far from representing an exhaustive literature review, but are included to serve as a starting point for those seeking further reading.

Selected References

Collen, P., and Gibson, R.J. (2001) The general ecology and beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. Reviews in Fish Biology and Fisheries 10, 439-461.

Gurnell, A.M. (1998) The hydrogeomorphological effects of beaver dam-building activity. Progress in Physical Geography 22, 167-189.

McDowell, D.M., and Naiman, R.J. (1986) Structure and Function of a Benthic Invertebrate Stream Community as Influenced by Beaver (*Castor Canadensis*). Oecologia 68, 481-489.

Naiman, R.T., Johnston, C.A., and Kelley, J.C. (1988) Alterations of North American Streams by Beaver. BioScience 38, 753-762.

Naiman, R.J., Melillo, J.M., and Hobbie, J.E. (1986) Ecosystem Alteration of Boreal Forest Streams by Beaver (*Castor Canadensis*). Ecology 67, 1254-1269.

Rossell, F., Bozser, O., Collen, P., and Parker, H. (2005) Ecological impact of beavers *Castor fiber* and *Castor Canadensis* and their ability to modify ecosystems. Mammal Rev. 35, 248-276.

Westbrook, C.J., Cooper, D.J., and Baker, B.W. (2006) Beaver dams and overbank floods influence groundwater – surface water interactions of a Rocky Mountain Riparian area. Water Resources Research 42.

For further reading, links to a selection of relevant webpages are provided below:

Article:

Impact of Beaver Dams Wider Than Thought

Bjorn Carey

Date: 05 June 2006 Time: 08:37 AM ET

Recommend 0 Tweet 0 in Share

Two beavers.
CREDIT: Tom Smylie, U.S. Fish and Wildlife Service

A busy beaver's dam work is felt downstream in a major way, a new study suggests.

Beavers are well known for creating large pond-like areas upstream from their dams, but scientists have found that the construction projects also spread water downstream with the efficiency of a massive once-every-200-years flood.

Researchers spent three years

http://www.livescience.com/10512-impact-beaver-dams-wider-thought.html

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Beaver Dams Create Healthy Downstream Ecosystems

June 6, 2006 — Beavers, long known for their beneficial effects on the environment near their dams, are also critical to maintaining healthy ecosystems downstream. Researchers have found that ponds created by beaver dams raised downstream groundwater levels in the Colorado River valley, keeping soil water levels high and providing moisture to plants in the otherwise dry valley bottom. The results will be published 8 June in Water Resources Research, a journal of the American Geophysical Union.

Cherie Westbrook of Colorado State University and colleagues there and at the U.S. Geological Survey in Fort Collins, Colorado, conducted a three-year study in Rocky Mountain National Park, examining valley ecosystems downstream in the Colorado River. They noted that water diverted by beaver

Beaver dam. (Photo courtesy of Yellowstone National Park / U.S. National Parks Service)

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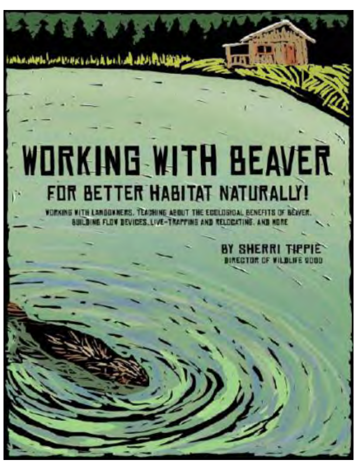
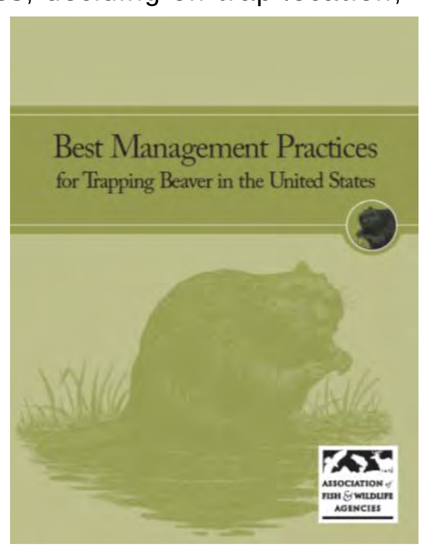
Live Trapping Beaver for Translocation



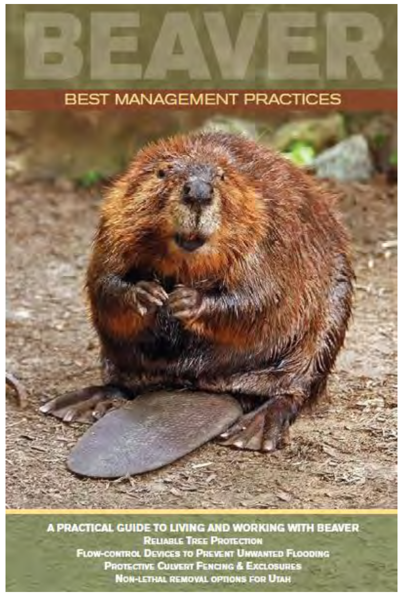
When an appropriate source of beaver has been identified for removal and translocation, the task of capturing live beaver becomes a potentially challenging reality. Because there are many "tricks of the trade" when it comes to trapping beaver, the assistance of an experienced trapper can accelerate the learning process (see expert advice provided by Sherri Tippie, left). Selecting trap types, deciding on trap location, selecting bait / lure, and understanding safe handling practices (for trapper and beaver alike) are examples of some steps in the process that can benefit from the guidance of an experienced mentor.



A number of live traps are available for the job as are various sources of written technical advice. The Association of Fish and Wildlife Agencies issued a set of Best Management Practices (BMPs) for capturing beaver using both fatal and live trapping techniques. The full guide is available here:

[Association of Fish and Wildlife Agencies. Best management practices for trapping beaver in the United States, 24 pp.]

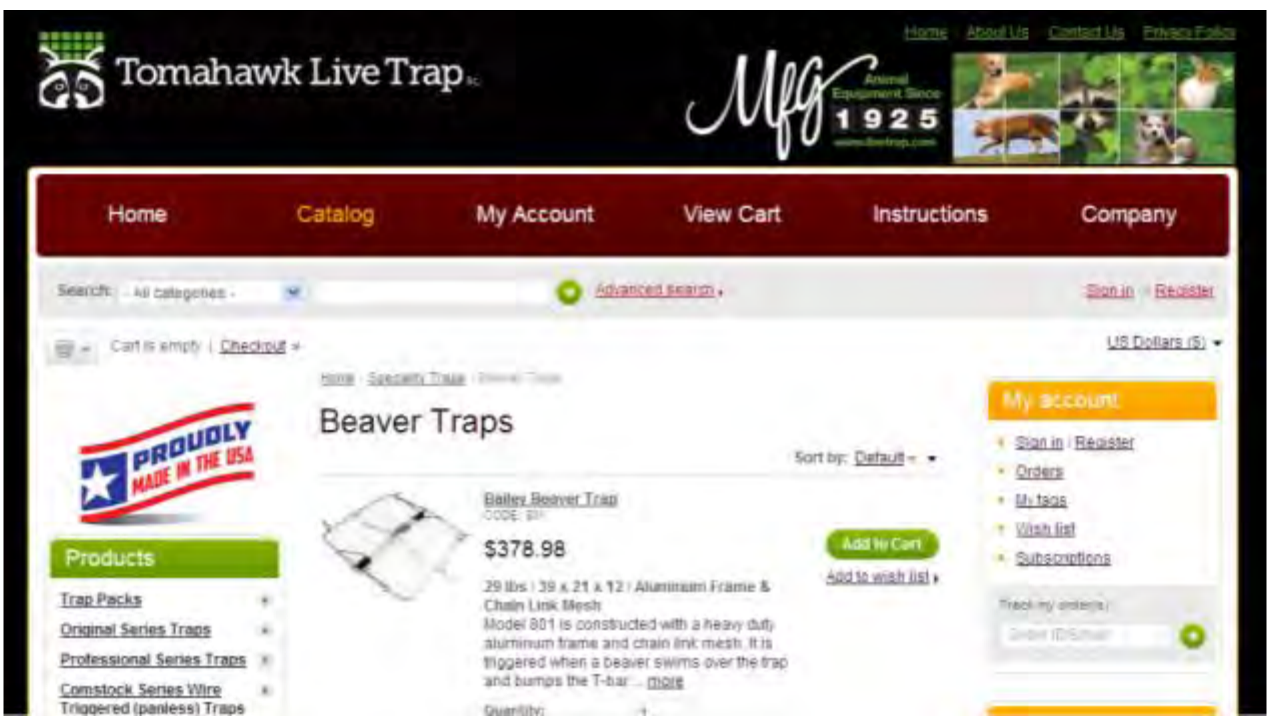
Another oustanding resource for related information is the Beaver Best Management Practices Guide produced by the Grand Canyon Trust, provided below:



One of the most commonly used live traps for capturing beaver is the suitcase style trap (also called the "Hancock" or "Bailey" trap". Many how-to videos are available online that explain the use of this type of trap. A selection is provided here:

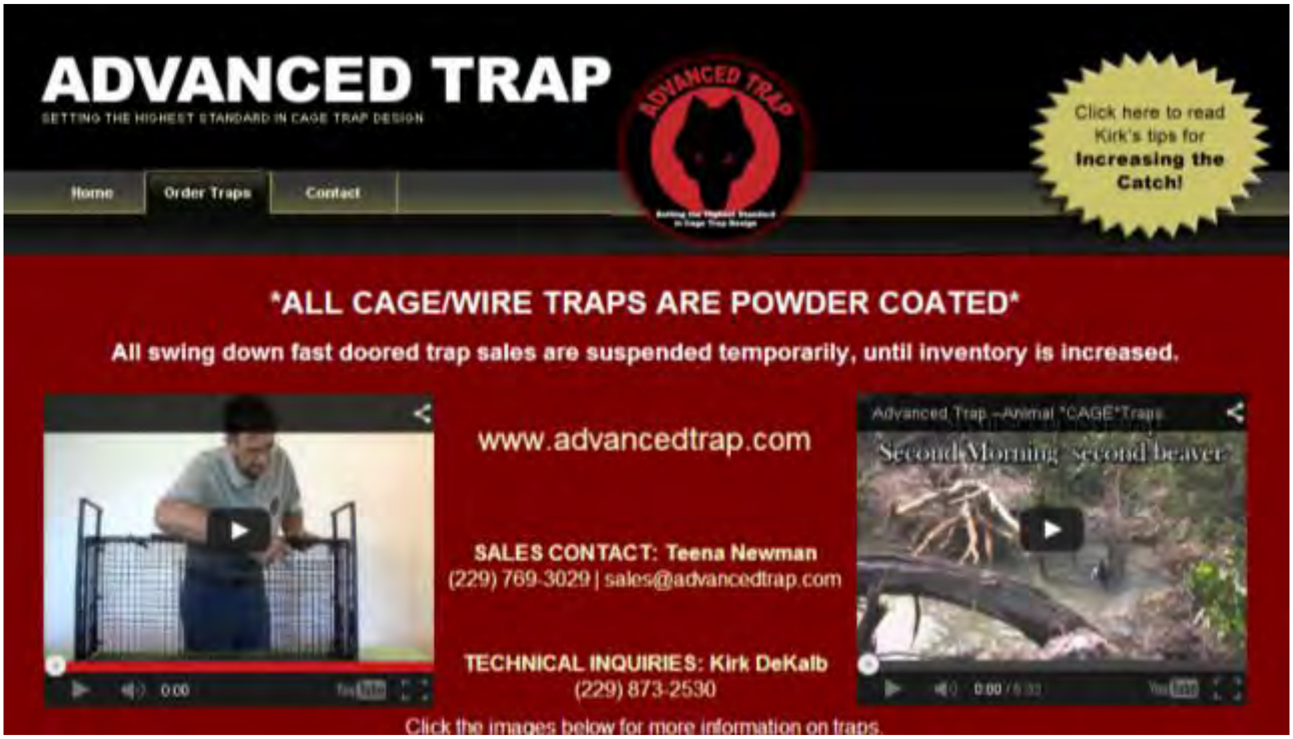
Another commonly used live trap for capturing beaver is a wire cage type trap. A selection of videos is linked here for more information on their use:

Multiple companies manufacture the various models of live traps appropriate for beaver. Several options for online orders are linked here:



Tomahawk Live Trap

http://www.livetrap.com/index.php?dispatch=categories.view&category_id=605



Advanced Trap

http://advancedtrap.com/

Comstock Custom Cage LLC

http://www.comstockcustomcage.com/

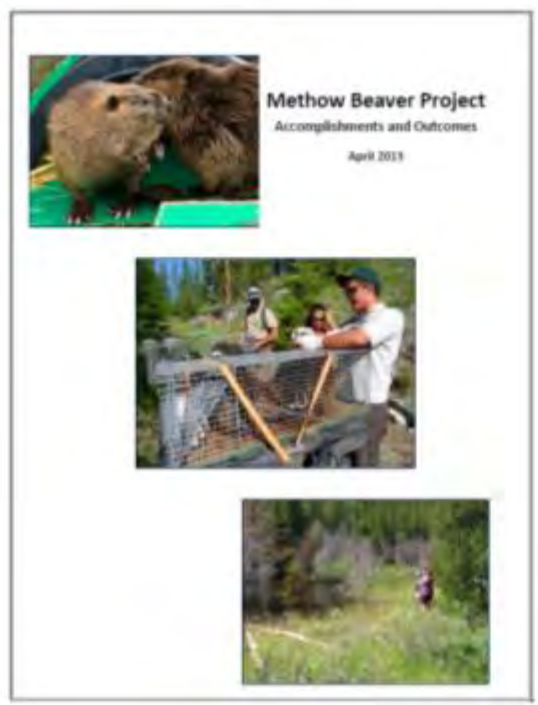
Miscellaneous Considerations for Beaver Reintroduction Projects

Seek to Relocate Matched Pairs or Family Groups When Possible

To establish a reproducing population of beaver in an unoccupied site requires, of course, a minimum of one male and one female. Ideally, a live trapping program will lead to the capture of an entire family group. Paired adult beaver that have successfully reared offspring may be more prone to breed successfully again following translocation than two beaver from disparate sources. When family groups cannot be captured and moved together managers should consider acclimating unfamiliar beaver to each other prior to release, and matching them based on opposite sex.

Sex identification of live beaver can be challenging because males and females lack external sex organs. During the Methow Beaver Project, advancements were made in non-invasive and rapid beaver sex identification. The same project report describes outcomes of captive pairing and wild release attempts.

Sex Determination (Reported by Methow Beaver Project)



One of the significant innovations of this project, beyond developing a strong GIS analysis of the beaver habitat, was the ability to rapidly and reliably tell male and female beavers apart. The need to determine gender is obvious, but is confounded by the confusing physical structure of beavers, with two sets of glands, internal reproductive organs, and genital openings that are difficult to discern – especially on live beavers that could inflict serious injury with their teeth.

Our initial effort was to work with the University of Idaho Genetics Laboratory lead by Lisette Waits. We helped the team there develop DNA markers for beaver males and females. We then collected hair from all beavers we captured and sent it to the lab for gender ID. This proved 100% reliable for sexing beavers and resulted in a 2011 publication (Goldberg et al. 2011). Issues were the 10 – 15 day turnaround time and the expense for the lab analysis.

In May 2011, with the generous help of beaver expert Dr. Lixing Sun at Central Washington University, we learned how to determine gender with secretions from the oil glands of beavers captured. His approach involved expressing oil from oil glands while beavers were anesthetized and examining color, odor, and viscosity. We learned that oil from male and female beavers is distinctly different. Issues were the 1-2 hour processing time for each beaver and the expense for anesthesia.

The next improvement involved connecting with the local North Cascades Smokejumper base where we asked for help designing a restraint bag that could eliminate the need for anesthesia. After a few trials, our jumper friend, J.T. Sawyer created a sturdy nylon funnel that fit over the Hancock traps and very effectively allowed us to hold a beaver immobile for our entire intake process, including sex determination, with no injury or trauma to crew members or beavers. Now, three to five minutes was the time required to remove beavers from the trap, sex, tag, and release the beavers into the holding facility. For the rest of the season we compared the crew's ability for oil gland sex determination with DNA hair analysis. At the end of the season we learned the process was 100% accurate and reliable.

The ability to quickly and reliably determine the sex of captured beavers greatly improved our competence in making grouping choices in the holding facility. This innovation, along with providing a period of group acclimation at the facility, was perhaps the most substantial benefit to increasing the establishment rate for groups released, because we had strong assurance that compatible males and females were included in release groups.

Be Cognizant of Overheating Captive Beaver

Beaver are prized for their lush, insulating fur which effectively protects them in nearly frozen water. As a result of their fur they are prone to overheating in warm temperatures, particularly when they lack access to water. These conditions may be encountered during relocation and every effort should be made to ensure that captive beaver do not overheat. One creative technique employed by Dan Tyers during his work in the Greater Yellowstone Area was to pack captive beaver with block ice while traveling via pack stock into backcountry release sites. By keeping beaver on ice during hot weather he avoided any losses to hyperthermia.

Late Summer and Early Fall are Preferable Release Times

Movement rates and behavior of beaver change dramatically with season. Beaver released in the early spring are prone to travel great distances from release sites, possibly seeking out their original territories. Conversely, those that are released during the late summer or early fall are more likely to begin making preparations for winter in their new location. By releasing beaver too late in the autumn months (or early winter) they may have inadequate time to prepare for cold weather (lodge building, caching food, etc.) and may suffer or perish as a result.

Road Closures

Temporary road closures might be considered if release sites are at risk of being compromised by traffic or disturbance from people with easy access.

For a case study example of proposed actions related to beaver reintroduction see the Beaver Management Strategy drafted by the Malheur National Forest and the Keystone Project, dated September 2007:

The full Malheur / Keystone Strategy is linked here:

BEAVER MANAGEMENT STRATEGY

Malheur National Forest and the Keystone Project
September 2007

This strategy renews the commitment to beaver management agreed to in the 1996 John Day Basin Beaver Restoration Memorandum of Agreement, (attached, Appendix A) as attested by the following:

USDA Forest Service, Malheur National Forest	4/10/08 Date
Grant County Conservationists	2/29/2008 Date
Confederated Tribes of the Warm Springs, John Day Basin Office	4-18-08 Date
Oregon Department of Fish and Wildlife, John Day District Office	2/4/08 Date
Bureau of Land Management, Prineville District	10/18/2007 Date
USDA Natural Resource Conservation Service, John Day Office	4/11/08 Date
Grant County Soil and Water Conservation District	4/1/08 Date
Oregon State University, Grant County Extension Office	3-3-08 Date
Confederated Tribes of the Umatilla, Pendleton Oregon	9/27/07 Date
Burns Paiute Tribe, Burns Oregon	1/22/2008 Date

National Environmental Policy Act (NEPA) and Beaver Restoration

The United States Forest Service has developed extensive guidance to facilitate appropriate and defensible NEPA analysis and support the decisions made by line officers. Like any other management actions agency personnel might consider, the following example beaver management activities are subject to various levels of NEPA analysis in most circumstances, depending on the location and other considerations (e.g., presence of species of conservation concern):

- Habitat modification
- Construction of exclosures in riparian habitats
- Removal / Translocation / Reintroduction of beaver

When NEPA analysis has already been completed for directly related activities in a given jurisdiction, management actions like live trapping, moving, and managing beaver populations may be exempted from further NEPA review. The U.S. Department of Agriculture Animal and Plant Health Inpsection Service (USDA-APHIS) in particular has completed statewide analyses for aquatic mammal management programs in some select states. In those cases, the previous work may be adequate to cover (some or all) current beaver restoration actions. USDA-APHIS posts all NEPA decision documents to the internet, where they are searchable by state. Managers are advised to familiarize themselves with any past NEPA work related to beaver management done by the Forest Service and other federal agencies. A collection of pertinent USDA-APHIS NEPA decisions is provided here:

Maine

Minnesota

Nebraska

South Carolina

Washington

Up-to-date information on state-specific NEPA analyses and decisions completed by USDA-APHIS can be searched here.

Structures built by beaver not subject to NEPA

One of the great advantages of riparian restoration through ecosystem engineering by beaver is that the structures created by beaver are not subject to NEPA analysis. When contrasted to the lengthy and demanding process to which any manmade flow-control devices must undergo, natural riparian restoration via beaver construction becomes even more appealing.

Forest Service staff are encouraged to collaborate with their unit-level NEPA specialists on crafting the appropriate level of NEPA documentation to support beaver restoration projects. A good starting point for other Forest Service NEPA guidance is provided here:

http://www.fs.fed.us/emc/nepa/nepa_procedures/

Range / Grazing / Beaver-Livestock / Wild Ungulate Interactions

Inadequate water is one of the primary factors limiting the quality of forage for domestic and wild grazers in western rangelands. As droughts become more frequent and intense throughout much of western North America, the ability to increase and retain soil moisture will be a key determinant of the condition of range vegetation. Many farmers and ranchers have historically viewed beavers negatively for their role in flooding agricultural lands. An improved understanding of and appreciation for the capacity of the beaver to increase range health through water retention has prompted some to take an active role in fostering beaver activity on the lands they manage.

This turnabout in opinion has garnered attention in the popular press. For example, the *Wall Street Journal* ran a story on August 30th, 2011 titled "With Trouble on the Range, Ranchers Wish They Could Leave It to Beavers". The article describes efforts in several western states to promote better range conditions through the reintroduction of live-trapped beaver. In some cases beaver are in such high demand that ranchers are put on a waiting list for their ranches to be considered as release sites.

In grazed rangelands, lacking riparian vegetation and competition with livestock can be key limiting factors for beaver (Ott and Johnson, 2005). Minimizing competition by excluding cattle from sensitive riparian habitats can help promote beaver activity, thereby improving range health on adjacent lands (Baker, 1995; Hosten and Whitridge, 2007).

Managers considering beaver restoration should be familiar with the potential benefits beaver can yield for domestic and wild grazers as well as the sensitivity of beaver to riparian habitat degradation stemming from foraging and tramping by domestic and wild ungulates. Highlighting increased water availability for water-limited grasses can be an effective approach for engaging ranchers who might otherwise oppose beaver restoration programs. Gaining support for excluding livestock from riparian areas might be facilitated by clarifying the subsequent benefits anticipated for grazing elsewhere in the watershed.

Citations:

Baker, B.W. 1995. Restoring healthy riparian ecosystems on western rangelands: beaver as a keystone species. Supplement to the Bulletin of the Ecological Society of America 76(2):10

Hosten, P. E. and H. Whitridge. 2007. Vegetation changes associated with livestock exclusion from riparian areas on the Dead Indian Plateau of southwest Oregon. U.S. Department of the Interior, Bureau of Land Management, Medford District.

Ott, G.D., and D.W. Johnson. 2005. Beaver Influence on Fisheries Habitat: Livestock Interactions. A research review.

For further reading, links to a selection of relevant webpages and popular press articles are provided below:

http://www.americanrivers.org/newsroom/blog/dnylen-2012124-can-beavers-help-us.html

http://www.grandcanyontrust.org/news/2012/08/the-good-beaver-do/

http://globalrangelands.org/dlio/55374

Ecosystem Resilience to Climate Change

Beaver promote dynamic and resilient systems that can better tolerate variation induced by climate change. The current absence of beaver from significant portions of their historical range significantly compromises the resilience of riparian and aquatic ecosystems.

The western and southwestern United States are already experiencing climate change impacts that underscore the increasing value of water retention on arid lands. In the Northwest, the regionally averaged temperature has risen about 1.5 degrees F over the past century (with some areas experiencing increases up to 4 degrees F) and is projected to increase another 3 to 10 degrees F during this century.

The U.S. Global Change Research Program has identified the effects of these increasing temperatures in the Northwest (USFS Region 6) to include:

- Declining springtime snowpack leading to reduced summer stream flows, straining agricultural and municipal water supplies;
- Increased insect outbreaks and wildfires, and species composition changes in forests, posing challenges for ecosystems and the forest products industry;
- Salmon and other coldwater species experiencing additional stresses as a result of rising water temperatures and declining summer stream flows; and
- Sea-level rise along vulnerable coastlines, resulting in increased erosion and the loss of land.

Warming trends in the Southwest are considered to be swifter than other regions of the country and may be significantly greater than the global average. The rapid increase in temperatures in this region, particularly during summer, will have drastic effects on hydrology which in turn may result in severe water supply challenges in the near future.

The U.S. Global Change Research Program has identified the effects of increasing temperatures in the Southwest (USFS Regions 3, 4, 5) to include:

- Water supplies becoming increasingly scarce, calling for trade-offs among competing uses, and potentially leading to conflct;
- Increasing temperature, drought wildfire, and invasive species, accelerating transformation of the landscape;
- Increased frequency and altered timing of flooding, increasing risks to people, ecosystems, and infrastructure;
- Unique tourism and recreation opportunities likely suffering; and
- Cities and agriculture facing associated risks.

Changes in snowpack and timing of runoff are certain in much of the western U.S. but are especially grave for the southwestern and interior western U.S. river basins. The National Research Council has concluded that runoff in the Rio Grande Basin will decrease by 12% for every one degree of temperature rise, the greatest reduction projected for any stream basin in the U.S. Both the upper and lower Colorado River basin will experience decreases in runoff of more than 6% for every degree in temperature rise. The Great Basin will experience a decrease in runoff of 5%, California a decrease of 3%, and the Pacific Northwest could see an increase of 1%.

Adapting to these changes will require a herculean effort on the part of modern society, especially in the western U.S., and coordination across large landscapes will be critical. An advantage in the West is the presence of vast, relatively well-connected holdings of federal lands that can buffer and mitigate the impacts of climate change. The Secretaries of Interior and Agriculture have acknowledged these unique opportunities and directed their respective departments to address climate change.

Adaptation to the effects of climate change is an objective that fits with the missions of the U.S. Forest Service. The federal forest lands were originally reserved at the end of the 19th centure to protect watersheds and secure favorable flows of water. Approximately one out of five Americans depends on a national forest for drinking water. In an area of climate change, forests and grasslands will play an increasingly vital role in protecting the Nation's watersheds. Successful response to climate change will entail sound stewardship of America's watersheds.

Through the hydrological and ecological effects of ecosystem engineering (i.e., dam-building), functional beaver populations rapidly and significantly contribute to climate change adaptation.

Beavers significantly contribute to climate change adaptation by:

- Storing Carbon (Wohl, 2013)
- Slowing snowmelt runoff, which
  - Extends summertime stream flow
  - Restores perennial flow to some streams
- Creating beaver ponds, which
  - Create and maintain wetlands
  - Provide critically needed habitat for amphibians
  - Increase habitat for small mammals and birds
  - Foster the establishment of deep-rooted sedges, rushes, hydric grasses, and woody riparian vegetation
  - Create mesic meadows
- Increasing groundwater upstream and downstream of dams, which
  - Sub-irrigates adjacent habitats
  - Allows water to re-enter flows as cooler seeps
  - Expands riparian vegetation which
    - Buffers banks against erosion during high flows
    - Shades creeks / streams, which
      - Reduces water temperature
      - Provides hiding cover for fish and wildlif e

Our gratitude to WildEarth Guardians, Grand Canyon Trust, and The Lands Council for contributions to this section.

Peer-Reviewed Citations:

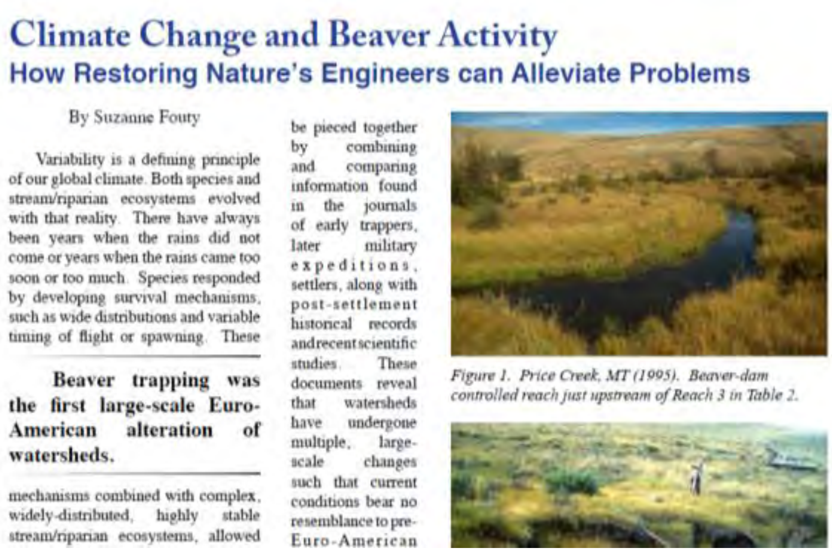
Hood, G.A., and S.E. Bayley. 2008. Beaver (Castor Canadensis) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. Biological Conservation 141: 556-567.

Lawler, J.J. 2009. Climate change adaptation strategies for resource management and conservation planning. The Year in Ecology and Conservation Biology, 2009: Ann. N.Y. Acad. Sci. 1162: 79–98.

Rosemond, A.D., and C.B. Anderson. 2003. Engineering role models: do non-human species have the answers? Ecological Engineering 20, 379-387.

Wohl, E. 2013. Landscape-scale carbon storage associated with beaver dams. Geophysical Research Letters (40) 3631-3636.

For further reading, links to a selection of relevant webpages are provided below:



Climate Change and Beaver Activity
How Restoring Nature's Engineers can Alleviate Problems

By Suzanne Fouty

Variability is a defining principle of our global climate. Both species and stream/riparian ecosystems evolved with that reality. There have always been years when the rains did not come or years when the rains came too soon or too much. Species responded by developing survival mechanisms, such as wide distributions and variable timing of flight or spawning. These

Beaver trapping was the first large-scale Euro-American alteration of watersheds.

mechanisms combined with complex, widely-distributed, highly stable stream/riparian ecosystems, allowed be pieced together by combining and comparing information found in the journals of early trappers, later military expeditions, settlers, along with post-settlement historical records and recent scientific studies. These documents reveal that watersheds have undergone multiple, large-scale changes such that current conditions bear no resemblance to pre-Euro-American

Figure 1. Price Creek, MT (1995). Beaver-dam controlled reach just upstream of Reach 3 in Table 2.

http://www.beaversww.org/assets/PDFs/ClimateChangeBeaverActivity.pdf

http://www.seventh-generation.org/Climate_riparian_beaver.html

http://www.wcs.org/news-and-features-main/grand-canyon-trust-beaver-video.aspx

http://www.wildearthguardians.org/site/PageServer?pagename=priorities_wild_places_jemez_mountains_beavers

http://troutunlimitedblog.com/beavers-play-role-in-protecting-trout-from-worst-of-changing-climate/

The Atlantic

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RODENTS JUNE 2012

Leave It to Beavers

Can they help us adapt to climate change?

DAVID FERRY | MAY 21 2012 2:17 PM ET |

IN THE 1820S, one of the largest corporations on Earth tried to kill every beaver in the Pacific Northwest. Britain's Hudson's Bay Company, threatened by the United States' westward expansion, sent trappers sweeping down the Columbia River watershed to exterminate all the beavers they found and harvest their valuable pelts. Without beavers to hunt, the company's governor reasoned, the United States would have "no inducement to proceed hither." Within 20 years, the beaver was nearly eradicated from an area the size of France.

Now, nearly two centuries later, beavers are valued not just for their pelts, but for the environmental benefits of their gnawing and nesting. A growing community of "beaver believers" is reintroducing the animal to regional water

VIDEO

What Does It Take to Make Real Craft Gin?

Tour the Green Hat Gin distillery

http://www.theatlantic.com/magazine/archive/2012/06/leave-it-to-beavers/308980/

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FROM THE APRIL 2010 ISSUE

Beavers Sign up to Fight Effects of Climate Change

Washington officials think the industrious critters could save more of 650 trillion gallons of water each year, blunting the effects of hot and dry summers.

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Body Horrors Talks Disease & Society on Skeptically Speaking

Is the UK's Mail in Bed with the CMO Devil?

Over the Edge: A Pictorial of One of Earth's Natural

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http://discovermagazine.com/2010/apr/19-beavers-sign-up-fight-effects-climate-change npr news arts & life music listen

SPECIAL SERIES

science out of the box

Beavers Offer Solution to Climate Change

by DAVID MALAKOFF

May 03, 2008 · 4:00 PM

Listen to the Story

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In the Southwest U.S., biologists are talking about returning beavers to rivers they once inhabited in order to fight droughts — which are expected to get worse as the globe warms. Beaver dams create great sponges that store lots of water.

http://www.npr.org/templates/story/story.php?storyId=90160624

THE YEAR IN ECOLOGY AND CONSERVATION BIOLOGY, 2009

Climate Change Adaptation Strategies for Resource Management and Conservation Planning

Joshua J. Lawler

College of Forest Resources, University of Washington, Seattle, Washington

Recent rapid changes in the Earth's climate have altered ecological systems around the globe. Global warming has been linked to changes in physiology, phenology, species distributions, interspecific interactions, and disturbance regimes. Projected future climate change will undoubtedly result in even more dramatic shifts in the states of many ecosystems. These shifts will provide one of the largest challenges to natural resource managers and conservation planners. Managing natural resources and ecosystems in the face of uncertain climate requires new approaches. Here, the many adaptation strategies that have been proposed for managing natural systems in a changing climate

http://training.fws.gov/csp/resources/climate_change/lcc/june_09/cc-adaptreview.pdf

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Ecological Engineering 20 (2003) 379–387

ECOLOGICAL ENGINEERING

www.elsevier.com/locate/ecoleng

Engineering role models: do non-human species have the answers?

A.D. Rosemond*, C.B. Anderson

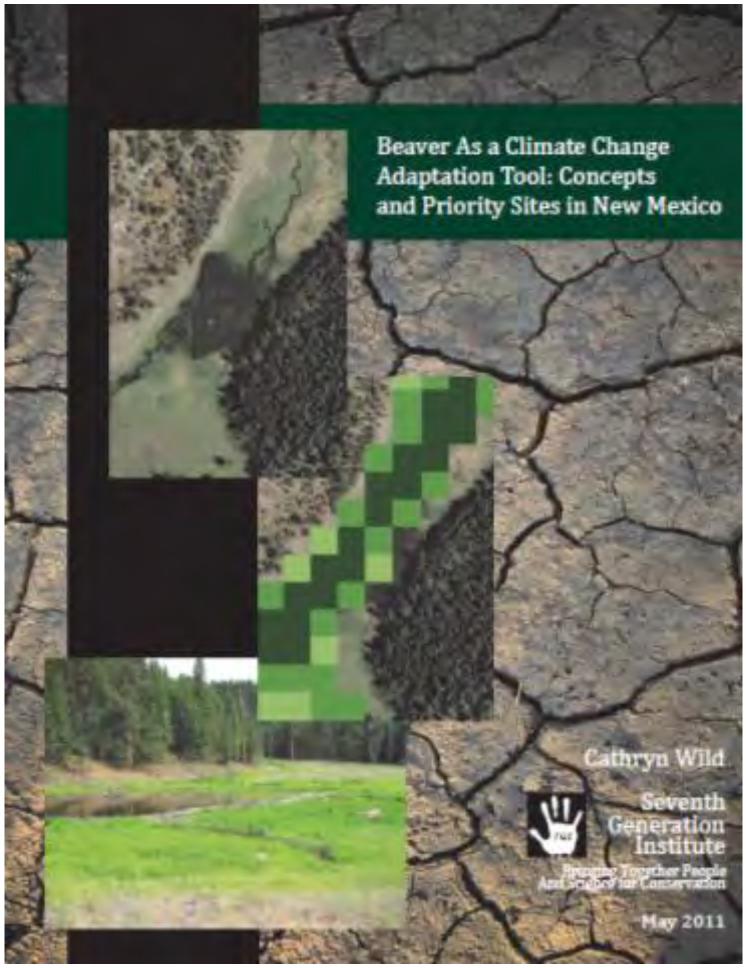
Institute of Ecology, University of Georgia, 18 Ecology Building, Athens, GA 30602-1681, USA

Received in revised form 3 December 2002; accepted 4 August 2003

Abstract

A shift from traditional engineering approaches to ecologically-based techniques will require changing societal values regarding 'how and what' is defined as engineering and design. Non-human species offer many ecological engineering examples that are often beneficial to ecosystem function and other biota. For example, organisms known as 'ecosystem engineers' build, modify,

http://ac.els-cdn.com/S0925857403000612/1-s2.0-S0925857403000612-main.pdf?_tid=4a503cfa-e8a7-11e2-9362-00000aab0f6c&acdnat=1373381778_833804e38052f49929d055dca0e05e95



http://www.seventh-generation.org/files/Beaver_As_a_Climate_Change_Adaptation_Tool_-_Concepts_and_Priority_Sites_in_New_Mexico2.pdf

Riparian Habitat Condition

Riparian habitat condition depends on the consistent availability of water to support hydrophytic vegetation. Water retention associated with dam construction by functional (i.e., dam-building) beaver populations provides increased supplies of groundwater thereby spurring vigorous vegetative growth in riparian corridors.

Benefits to Riparian Wildlife

The changes in riparian health induced by beaver can also be a boon for diverse species that rely on the unique vegetation communities supported by readily available water (particularly in arid landscapes). By increasing water availability, raising groundwater tables, and promoting consistent flows, beaver dams can play a critical role in increasing the availability of these habitats. In some settings (e.g., Greater Yellowstone Ecosystem, Olechnowski and Debinski 2008) the relative abundance and condition of willow (*Salix* spp.) was a key determinant in songbird richness. Differences in willow availability in the Greater Yellowstone Ecosystem have been attributed to decreased browsing by ungulates following wolf reintroduction (which altered ungulate behavior, Ripple and Beschta 2006), and the fires of 1988 (which, at least in part, prompted a decline in Moose, Dan Tyers, personal communication). Similar relationships among herbivores, beaver, and aspen were reported from that region as well (Runyon 2013). The notion that beaver could play a role in generating habitat for species of conservation interest is a commonly cited motivator for managers considering project initiation.

The benefits to riparian habitats are directly related to many of the hydrologic changes described in the Hydrology section of this guide, however a rich body of literature also exists related specifically to the impacts beaver have on riparian habitat condition. Wright et al. (2002) provide a good introduction to understanding the capacity of the beaver to increase species richness at the landscape scale. These changes are, in large part, attributable to the dramatic improvement and expansion of riparian and wetland habitat caused by damming. For example, a recent Master's thesis (Runyon, 2013, embedded below) documented the impacts of beaver activity in promoting aspen recovery in the Northern Yellowstone Winter Range.

Citation:

Runyon, M.J. 2013. Effects of beaver reintroduction and ungulate browsing on aspen recovery in the Eagle Creek Drainage of the Northern Yellowstone Winter Range. Master of Science Thesis in Animal and Range Sciences, Montana State University, Bozeman, Montana.

Olechnowski, B.F. and D.M. Bebinski. 2008. Response of songbirds to riparian willow habitat structure in the Greater Yellowstone Ecosystem. The Wilson Journal of Ornithology 120(4): 830-839.

Ripple, W.J. and R.L. Beschta. 2006. Linking wolves to willows via risk-sensitive foraging by ungulates in the northern Yellowstone ecosystem. Forest Ecology and Management 230 (1-3): 96-106.

Wright, J.P., Jones, C.G., and Flecker, A.S. (2002) An ecosystem engineer, the beaver, increases species richness at the landscape scale. Ecosystems Ecology 132, 96-101.

For further reading, links to a selection of relevant webpages are provided below:

The bibliography shown above is available at this link:

http://www.landscouncil.org/beaversolution/beavers_in_wetland_restoration.asp

The Role of Beaver in Riparian Habitat Management

Habitat Extension Bulletin No. 38

In recent years, resource managers have placed increased emphasis on protecting and managing riparian habitats (those areas next to or influenced by water). Land managers recognize that healthy riparian habitats provide numerous benefits. Proper management of these habitats can improve water quantity and quality, increase livestock forage production and quality, allow wildlife

http://wgfd.wyo.gov/web2011/Departments/Wildlife/pdfs/BULLETIN_NO380001785.pdf

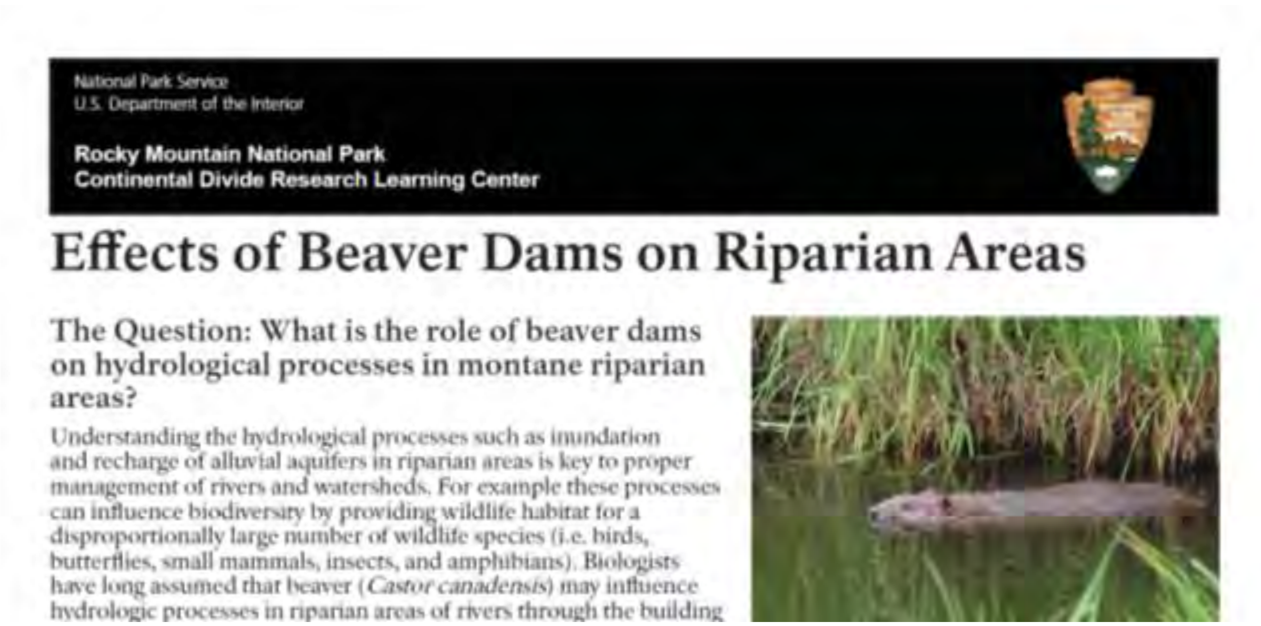
Forest FEATURES

WALLOWA-WHITMAN NATIONAL FOREST NOVEMBER 2011

Beaver Dams Restore Riparian Areas

Many streams and rivers in eastern Oregon have been heavily impacted by activities such as mining, grazing, logging, road building, farming, and urbanization. However, in the southern portion of the Wallowa-Whitman National Forest near Whitney Valley the Whitman Ranger District, in partnership with the Powder Basin Watershed Council, Oregon Department of Fish and Wildlife, Oregon Watershed Enhancement Board (OWEB), and Whitman College in Walla Walla, Washington are working to reverse

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5339528.pdf



National Park Service
U.S. Department of the Interior

Rocky Mountain National Park
Continental Divide Research Learning Center

Effects of Beaver Dams on Riparian Areas

The Question: What is the role of beaver dams on hydrological processes in montane riparian areas?

Understanding the hydrological processes such as inundation and recharge of alluvial aquifers in riparian areas is key to proper management of rivers and watersheds. For example these processes can influence biodiversity by providing wildlife habitat for a disproportionally large number of wildlife species (i.e. birds, butterflies, small mammals, insects, and amphibians). Biologists have long assumed that beaver (*Castor canadensis*) may influence hydrologic processes in riparian areas of rivers through the building

http://www.nps.gov/romo/parkmgmt/upload/beaver_dams.pdf

Sources of Beaver for Reintroduction Projects

Throughout much of their range beaver are targeted for removal in response to conflicts with humans. Many states allow affected landowners to shoot or trap nuisance beaver to alleviate problems including flooding, damage to trees, and plugged culverts. If nuisance beaver are identified they can be ideal candidates for relocation and reintroduction projects, with live trapping and removal providing an alternative to lethal control. Coordination with the state agency responsible for game and fish management is a must, and state furbearer specialists are key points of contact who stand to be valuable collaborators in the process.

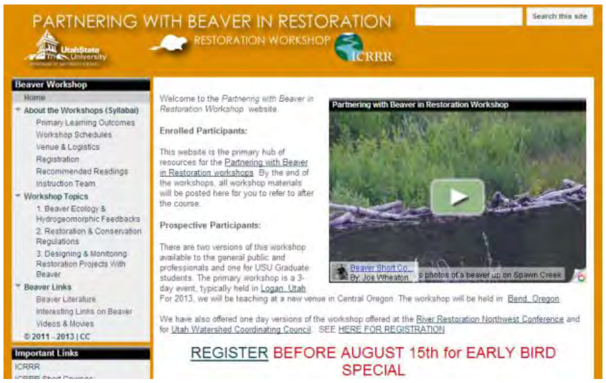
Utah Division of Wildlife Resources. 2000. Final protocol for the transplant and reestablishment of beavers into selected locations in Utah Division of Wildlife Resources' Southern Region. 27 pp.

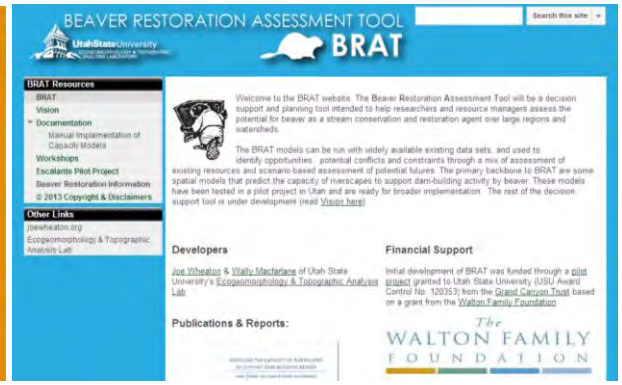
When nuisance beaver are not available for relocation, managers should consider trapping from other proximate wetlands with robust beaver populations. Again, coordination and support from the state is critical for live trapping and relocation.

Many states have developed strategic guidance for managing beaver. Many of these plans address nuisance beaver management. Some plans even deal directly with translocation (e.g., Utah, upper right). The Colorado State Parks Beaver Management Plan is also provided as another example (lower right).

Success Stories and Points of Contact

The list of successful watershed restoration projects based in part or whole on reintroducing and / or reinvigorating beaver populations is growing steadily. During the course of these efforts, many valuable lessons have been learned and a tremendous amount of experience gained. This section was created to provide motivating and informative examples as well as contact information for experts on the projects. For more information, readers are encouraged to direct follow-up questions to those responsible for these outstanding examples of watershed and beaver restoration.





Points of Contact:

Dr. Joe Wheaton is an Assistant Professor at Utah State University and a fluvial geomorphologist with over a decade of experience in river restoration. Joe runs the Ecogeomorphology & Topographic Analysis Lab in Utah State University's Department of Watershed Science and is a leader in the monitoring and modeling of riverine habitats and watersheds. Joe and his students are among the leading scientists and practitioners in the realm of river restoration through beaver. Together they have assembled excellent resources, including a website with many examples of success. Information about his group's Beaver Restoration Assessment Tool (BRAT) is also available online.

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USA
Direct: (435)-554-1247
Main Office: (435)-797-2459
Fax: (435)-797-1871

As an Ecosystems Analyst, **Dr. Michael Pollock** has been studying forest, stream and wetland ecosystems for the past 12 years. During this time he has engaged in a diverse suite of scientific studies including: the influence of disturbance and productivity on biodiversity patterns in riparian corridors, the influence of beaver habitat on coho smolt production and ecosystem function, the historical patterns of riparian forest conditions in the Pacific Northwest, and the importance of riparian forests to maintaining stream habitat. Dr. Pollock also provides policy analyses to parties interested in understanding the potential effects of proposed or existing laws, policies, and regulations on our environment. Past analyses include the environmental impact of habitat conservation plans (HCPs), the likely effect of proposed state legislation concerning the protection of salmonid habitat, and the probable environmental impacts of various specific land use proposals. Dr. Pollock holds a B.S. in Biochemistry (California State University, Humboldt, Cum Laude) and a Ph.D. in Ecosystems Analysis (University of Washington, College of Forest Resources). Prior to joining the Watershed Program in 1999, Dr. Pollock was a partner in a local consulting firm and director of a small, non-profit scientific research institute.

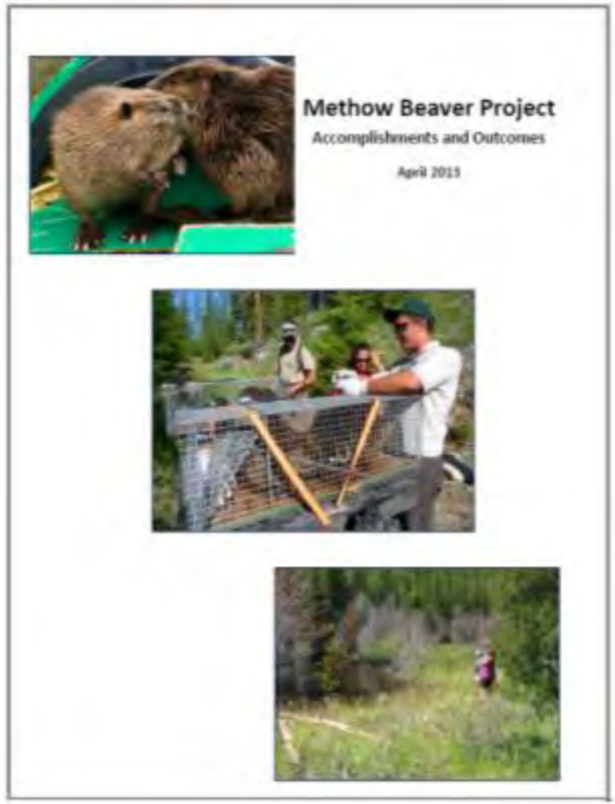
Dr. Michael Pollock
Email
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, WA 98112
Phone: 206-860-3451

Dr. Nick Bouwes received his BS at University of Wisconsin, Madison, and his MS and PhD at Utah State University. After that he was employed as a fish population analyst and a biometrician/modeler for Oregon Department of Fish and Wildlife. Nick started Eco Logical Research in 2000, and has since been working collaboratively with state, federal, tribal fisheries agencies and NGOs to review and develop status and effectiveness monitoring programs addressing NOAA and USFWS Biological Opinions and Recovery Plans and the Northwest Power Planning Councils Fish and Wildlife Program throughout the Columbia River Basin. Nick is a fisheries expert who has been critically involved with experimental design and monitoring for the Bridge Creek Beaver Project.

Dr. Nick Bouwes
Ecologist / Owner
Eco Logical Research, Inc.
nbouwes@gmail.com

Justin Dolling is an outstanding point contact at the Utah Division of Wildlife Resources. He is largely responsible for drafting the current Utah Beaver Management Plan.

Justin Dolling
Utah Division of Wildlife Resources
justindolling@utah.gov
801-476-2740


Methow Beaver Project

Accomplishments and Outcomes

April 2015

The Methow Beaver Project: History and Establishment

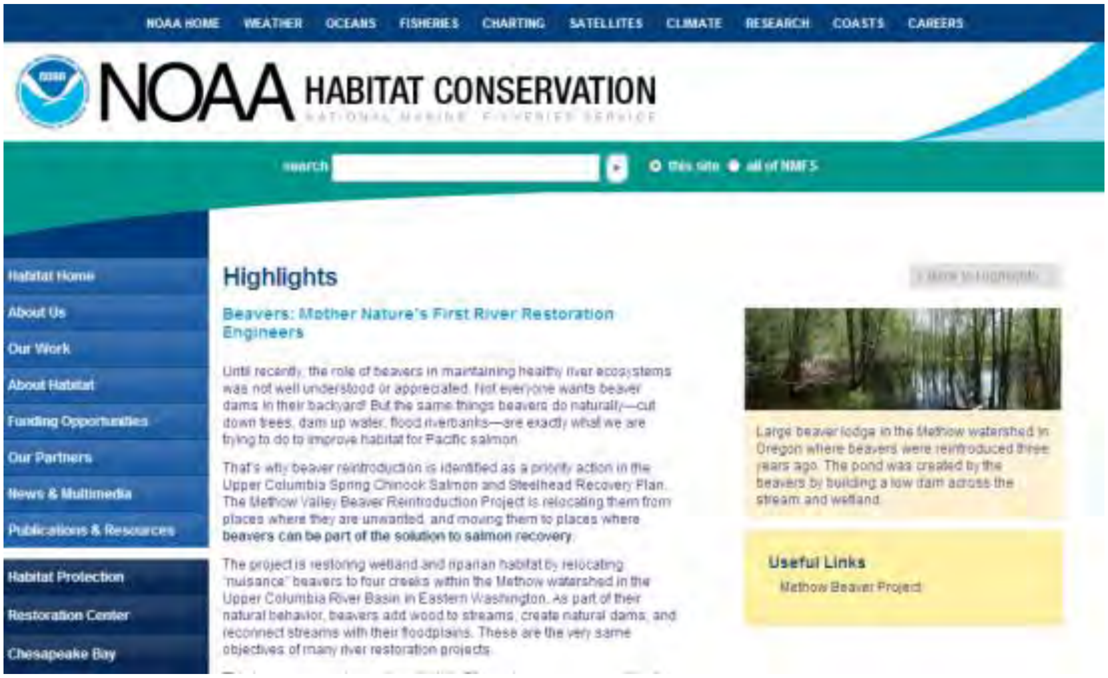
In 2000, John Rohrer had an idea. As a Forest Service District Wildlife Biologist working in the Methow Valley, he thought that 'nuisance' beaver removed by Washington Department of Fish and Wildlife enforcement agents might be valuable to restore an old wetland on Forest Service land where he had seen water tables lowered and riparian vegetation lost. After a series of releases there, the beaver set up shop and began restoring the site, returning the wetland to a 23 acre complex of dams and wet meadows. For the next few years, more attempts followed, some successful, some less than successful. All of this was a backyard, spare-time effort to try to improve places that had once held beavers. An inspiration for John was a 1932 map from the Forest Service archive that showed the original beaver relocation work at 61 sites in the Methow Valley. If it was possible to re-establish beaver then, maybe now would be even more feasible.

Points of Contact:

John Rohrer
jrohrer@fs.fed.us
509-996-4001

Kent Woodruff
kwoodruff@fs.fed.us
509-996-4043

More information about the Methow Beaver Project can be found here:



Climate Change and Beaver Activity

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Variability is a defining principle of our global climate. Both species and stream/riparian ecosystems evolved with that reality. There have always been years when the rains did not come or years when the rains came too soon or too much. Species responded by developing survival mechanisms, such as wide distributions and variable timing of flight or spawning. These be pieced together by combining and comparing information found in the journals of early trappers, later military expeditions, settlers, along with post-settlement historical records and recent scientific studies. These

Beaver trapping was

Figure 1. Price Creek, MT (1995). Beaver-dam

Point of Contact:

U.S. Forest Service Hydrologist Dr. Suzanne Fouty has been an outspoken proponent for beaver-based restoration projects since focusing on the topic for her PhD dissertation at the University of Oregon over a decade ago. Her writing and aquatic restoration projects in the Pacific Northwest have drawn considerable public attention to the value of beaver in their native habitats and the potential for expanding beaver / riparian restoration practices more broadly. Find related blog here.

Fouty, S.C., 2003. Current and historic stream channel response to changes in cattle and elk grazing pressure and beaver activity: southwest Montana and east-central Arizona. Ph.D. dissertation. Department of Geography, University of Oregon.

Dr. Suzanne Fouty
sfouty@fs.fed.us
541-523-1344

The Beavers of Yellowstone

Douglas W. Smith and Daniel B. Tyers

Beaver Biology

Dr. Dan Tyers has spent much of his career studying and managing wildlife in the Greater Yellowstone Area in various positions with the Forest Service. His personal experiences with beaver restoration work include establishing partnerships with key stakeholders, developing programs for live trapping and relocation, completing projects within designated wilderness areas (including pack transport of live beaver), and long-term monitoring and follow up after project completion. See the story linked above for more information.

Dr. Dan Tyers
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WildEarth Guardians, Grand Canyon Trust, and The Lands Council are among the most active and involved conservation organizations working to enhance beaver populations throughout their historic range. The groups collaborated to create the report linked above, and the three report authors (listed below) have considerable expertise in the science and policy related to beaver restoration.

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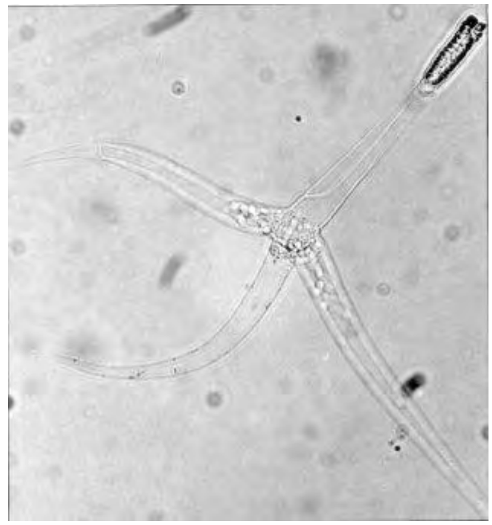
Transmission of Whirling Disease / Non-Native / Invasive Species



Whirling disease is a parasite that can have severe negative impacts on coldwater fishes (particularly trout) by causing skeletal and neurological damage. Several life history traits of the parasite (durable spores, extended period of infectivity, etc.) render the disease exceedingly easy to spread. It is a reasonable precaution to avoid spreading whirling disease during beaver relocation. Beaver from infected waters should only be relocated to other infected waters and these actions should be done *only* with the direct collaboration of fisheries specialists from the relevant state-level fish and wildlife resource management agency. If you are unsure of the whirling disease status of a given watershed err on the side of caution until you can obtain more information.

Other non-native / invasive species

Similar precautions should be followed in any setting where other non-native invasive aquatic species are present. The potential for transporting vegetation, vertebrate, and invertebrate species during beaver translocation necessitates that relevant partner agencies be consulted. Aside from these organisms being transported on relocated beaver, they could also be moved on gear, including live traps, waders, wading boots, trapping tools, etc.

Trapping and Potential Impacts on Stream and Riparian Ecosystems

The majority of states with occupied beaver habitat allow recreational and commercial beaver trapping. In wetlands that are readily accessible trapping remains one of the leading causes of mortality for beaver in North America. Because newly established beaver populations can be quickly eliminated by minimal trapping pressure, trapping can be a key limiting factor that must be considered and addressed.

One of the most effective approaches to protecting recently restored and recovering beaver populations is to work with the state agency responsible for managing fish and wildlife resources to institute a closure encompassing a specific recovery area.

Such closures should be widely advertised (e.g., included in the annual state trapping regulations / proclamation). Installation of signage might also be a worthwhile endeavor.

In order for states to agree to any limitation on trapping it may be prudent to engage active trapping organizations in the local, state, and (possibly) national levels. Trappers should be recognized and included as important stakeholders in states where they trap beaver legally. Where possible, trappers should be engaged as partners and allies in working to expand beaver populations – a goal that is mutually beneficial.

In one example case study Dr. Dan Tyers (USFS) was able to work with the State of Montana and local beaver trappers to institute a permanent beaver trapping closure in a watershed where he led a beaver restoration project. In addition to supporting and obeying a closure to protect newly introduced beaver, the local Montanan trappers contributed their expertise and services to capturing beaver live for reintroduction. In the years since the project beaver have dramatically altered the watershed where they were reintroduced, and trappers have had expanded trapping opportunity in the surrounding wetlands outside the closure zone.

The National Trappers Association website is a good starting point to learn more about active trapping groups in your area:

Bibliography Sorted by Topic Area

Considerations for Beaver Restoration in Designated Wilderness

Arizona Game and Fish Department. 2005. Mexican wolf Blue Range reintroduction project adaptive management oversight committee, standard operating procedure. 44 pp.

Evaluating and Coping with Human-Beaver Conflict

Vermont Fish and Wildlife Department. 2004. Best management practices for resolving human-beaver conflicts in Vermont. 30 pp.

Wisconsin Department of Natural Resources. 2005. Beaver damage control: guidelines for people with beaver damage problems. 15 pp.

Evaluating Current Presence / Absence of Beaver

Texas Agricultural Extension Service. 2010. Identifying and managing aquatic rodents in Texas: beaver, nutria and muskrats. 50 pp.

Evaluating habitat suitability for beaver

Allen, A.W. 1983. Habitat suitability index models: beaver. U.S. Department of Interior Fish and Wildlife Service. FWS/OBS-82/10.30 Revised. 20p.

Beier, P. and R.H. Barrett. 1987. Beaver habitat use and impact in the Truckee River Basin, California. Journal of Wildlife Management 51(4) 794-799.

Curtis, P.D. and P.G. Jensen. 2004. Habitat features affecting beaver occupancy along roadsides in New York State. Journal of Wildlife Management 68(2) 278-287.

Howard, R.J. and J.S. Larson. 1985. A stream habitat classification system for beaver. Journal of Wildlife Management 41(1) 19-25.

Macfarlane W.W. and J.M. Wheaton. 2013. Modeling the capacity of riverscapes to support dam-building beaver-case study: Escalante River watershed. Ecogeomorphology and Topographic Analysis Lab, Utah State University, Prepared for Walton Family Foundation, Logan, Utah, 78 pp.

Slough, B.G. and R.M.F.S. Sadleir. 1976. A land capability classification system for beaver (Castor Canadensis Kuhl). Canadian Journal of Zoology 55(8) 1324-1335.

Suzuki, N. and W.W. McComb. 1998. Habitat classification models for beaver (Castor Canadensis) in the streams of the Central Oregon Coast Range. Northwest Science 72(2) 102- 110.

Fisheries

Anderson, C.B., Pastur, G.M., Lencinas, M.V., Wallem, P.K., Moorman, M.C. and Rosemond, A.D. (2009) Do introduced North American beavers Castor canadensis engineer differently in southern South America? An overview with implications for restoration. Mammal Review 39, 33–52.

Andonaegui, C. (2000) Salmon, Steelhead and Bull Trout Habitat Limiting Factors Water Resource Inventory Area 48. Washington State Conservation Commission, Olympia, Washington.

Armstrong, J.D., Kemp, P.S., Kennedy, G.J.A., Ladle, M. and Milner, N.J. (2003) Habitat requirements of Atlantic salmon and brown trout in rivers and streams. Fisheries Research 62, 143–170.

Arquilliere, A. (1998) Experimental reintroduction of brown bears in the French Pyrenees. Oryx 32, 8–10.

Avery, E.L. (1991) Impact of Beaver Dam Removal on Brook Trout Populations and the Sport Fishery in a Northeastern Wisconsin Stream. Research Management Findings 31, 1–4. Bureau of Research. Wisconsin Department of Natural Resources. Madison, Wisconsin.

Baker, B.W. and Hill, E.P. (2003) Beaver (Castor canadensis). In: Wild Mammals of North America: Biology, Management, and Conservation, 2nd edn (eds G.A. Feldhamer, B.C. Thompson and J.A. Chapman). The Johns Hopkins University Press, Baltimore, Maryland, USA, pp. 288–310.

Balon, E.K. and Chadwick, E.M.P. (1979) Reclamation of a perch lake: a case study using density estimates and the guild concept. Archiv für Hydrobiologie 85, 543–547.

Bau, L.M. (2001) Behavioural Ecology of Reintroduced Beavers (Castor fiber) In Klosterheden State Forest, Denmark. Department Of Animal Behaviour, University Of Copenhagen, Copenhagen.

Beechie, T.J., Collins, B.D. and Pess, G.R. (2001) Holocene and recent geomorphic processes, land use and salmonid habitat in two north Puget Sound river basins. In: Geomorphic processes and riverine habitat, Water Science and Application, Vol. 4 (eds J.B. Dorava, D.R. Montgomery, F. Fitzpatrick and B. Palcsak). American Geophysical Union, Washington, DC, pp. 37–54.

Beechie, T.J., Sear, D.A., Olden, J.D. et al. (2010) Process-based principles for restoring river ecosystems. BioScience 60, 209–222.

Beedle, D. (1991) Physical dimensions and hydrologic effects of beaver ponds on Kuiu Island in southeast Alaska. Unpublished Master's thesis. Oregon State University, Corvallis.

Bertolo, A. and Magnan, P. (2006) Spatial and environmental correlates of fish community structure in Canadian shield lakes. Canadian Journal of Fisheries and Aquatic Sciences 63, 2780–2792.

Bertolo, A., Magnan, P. and Plante, M. (2008) Linking the occurrence of brook trout with isolation and extinction in small boreal shield Lakes. Freshwater Biology 53, 304–321.

Bradt, G.W. (1935) Michigan's beaver-trout management program. Transactions of the American Fisheries Society 65, 253–257.

Breitenmoser, U. (1998) Large predators in the Alps: the fall and rise of man's competitors. Biological Conservation 83, 279–289.

Bruner, K.L. (1990) Effects of beaver on streams, streamside habitat, and coho salmon fry populations in two coastal Oregon streams. Unpublished Master's thesis. Oregon State University, Corvallis.

Bryant, M.D. (1984) The role of beaver dams as coho salmon habitat in southeast Alaska streams. In: Proceedings of the Olympic Wild Fish Conference. Fisheries Technology Programme (eds J.M. Walton and D.B. Houston). Peninsula College, Port Angeles, Washington, pp. 183–192.

Burchsted, D., Daniels, M., Thorson, R. and Vokoun, J. (2010) The river discontinuum: applying beaver modifications to baseline conditions for restoration of forested headwaters. BioScience 60, 908–922.

Bustard, D.R. and Narver, D.W. (1975) Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Resource Board of Canada 32, 667–680.

Call, M.W. (1966) Beaver Pond Ecology and Beaver-Trout Relationships in Southeastern Wyoming. University of Wyoming, Wyoming Game and Fish Commission, Laramie, Wyoming, 296 pp.

Chisholm, I.M., Hubert, W.A. and Wesche, T.A. (1987) Winter stream conditions and use of habitat by brook trout in high elevation Wyoming streams. Transactions of the American Fisheries Society 116, 176–184.

Christenson, L.M., Ehly, A.E., Hale, J.B. et al. (1961) Beaver-Trout-Forest Relationships. Wisconsin Conservation Department, Madison, Wisconsin, 34 pp.

Cirmo, C.P. and Driscoll, C.T. (1993) Beaver pond biogeochemistry: acid neutralizing capacity generation in a headwater wetland. Wetlands 13, 277–292.

Collen, P. (1997) Review of the potential impacts of re-introducing Eurasian beaver Castor fiber L. on the ecology and movement of native fishes, and the likely implications for current angling practices in Scotland. Scottish Natural Heritage Review No. 86 .

Collen, P. and Gibson, R.J. (2001) The General Ecology of Beavers (Castor Spp.) as related to their Influence on Stream Ecosystems and Riparian Habitats, and the Subsequent Effects on Fish – A Review. Reviews in Fish Biology and Fisheries 10, 439–461.

Collins, T.C. (1993) The role of beaver in riparian habitat management. Department Habitat Extension Bulletin No 38. Wyoming Game and Fish, Cheyenne.

Cook, D.B. (1940) Beaver-trout relations. Journal of Mammalogy 21, 397–401.

Correll, D.L., Jordan, T.E. and Weller, D.E. (2000) Beaver pond biogeochemical effects in the Maryland coastal plain. Biogeochemistry 49, 217–239.

Cramb, A. (1998) Fragile Land: Scotland's Environment. Edinburgh, Polygon.

Cunjak, R.A. (1996) Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl 1), 267–282.

Cunjak, R.A. and Therrien, J. (1998) Inter-stage survival of wild juvenile Atlantic salmon, Salmo salar L. Fisheries Management and Ecology 5, 209–223.

Cunjak, R.A., Prowse, T.D. and Parrish, D.L. (1998) Atlantic salmon (Salmo salar) in winter: "The Season of Parr Discontent"? Canadian Journal of Fisheries and Aquatic Sciences 55, 161–180.

Curtis, P.D. and Jensen, P.G. (2004) Habitat features affecting beaver occupancy along roadsides in New York State. Journal of Wildlife Management 68, 278–287.

Danilov, P.I. (1995). Canadian and Eurasian beavers in Russian North-west (distribution, number, comparative ecology). The Third Nordic Beaver Symposium. Helsinki, Finland, pp. 10–16.

Danilov, P.I. and Kan'shiev, V.Y. (1983) The state of populations and ecological characteristics of European (Castor fiber L.) and Canadian (Castor canadensis Kuhl.) beavers in the northwestern USSR. Acta Zoologica Fennica 174, 95–97.

Dolloff, C.A. (1987) Seasonal population characteristics and habitat use by juvenile coho salmon in a small southeast Alaska stream. Transactions of the American Fisheries Society 116, 829–838.

Doucett, R.R., Hooper, W. and Power, G. (1999) Identification of anadromous and nonanadromous adult brook trout and their progeny in the Tabusintac River, New Brunswick, by means of multiple-stable-isotope analysis. Transactions of the American Fisheries Society 128, 278–288.

Dumke, J.D., Hrabik, T.R., Brady, V.J., Gran, K.B., Regal, R.R. and Seider, M.J. (2010) Channel morphology response to selective wood removals in a sand-laden Wisconsin trout stream. North American Journal of Fisheries Management 30, 776–790.

Duncan, S.L. (1984) Leaving it to beaver. Environment 26, 41–45.

Dupont, J., Brown, R.S. and Geist, D.R. (2007) Unique allacustrine migration patterns of a bull trout population in the Pend Oreille River drainage, Idaho. North American Journal of Fisheries Management 27, 1268–1275.

Elmeros, M., Madsen, A.B. and Berthelsen, J.P. (2003) Monitoring of reintroduced beavers (Castor Fiber) in Denmark. Lutra 46, 153–162.

EU (1992) European Union: Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.

Finnigan, R.J. and Marshall, D.E. (1997) Managing beaver habitat for salmonids: working with beavers. In: Fish Habitat Rehabilitation Procedures. (eds P.A. Slaney and D. Zaldokas) (WRP technical circular no. 9). Edited by. B.C. Ministry of Environment, Lands, and Parks, pp. 15.1–15.11.

Fox, M.G. and Keast, A. (1990) Effects of winterkill on population structure, body size, and prey consumption patterns of pumpkinseed in isolated beaver ponds. Canadian Journal of Zoology-Revue Canadienne De Zoologie 68, 2489–2498.

France, R.L. (1997) The importance of beaver lodges in structuring littoral communities in boreal headwater lakes. Canadian Journal of Zoology 75, 1009–1013.

Fritts, S.H., Bangs, E.E., Fontaine, J.A. et al. (1997) Planning and implementing a reintroduction of wolves to Yellowstone National Park and central Idaho. Restoration Ecology 5, 7–27.

Frohnauer, N.K., Pierce, C.L. and Kallemeyn, L.W. (2007) Population dynamics and angler exploitation of the unique muskellunge population in Shoepack Lake, Voyageurs National Park, Minnesota. North American Journal of Fisheries Management 27, 63–76.

Gard, R. (1961) Effects of beaver on trout in Sagehen Creek, California. Journal of Wildlife Management 25, 221–242.

Gard, R. and Seegrist, D.W. (1972) Abundance and harvest of trout in Sagehen Creek, California. Transactions of the American Fisheries Society 3, 463–477.

Gates, S. (2002) Review of methodology of quantitative reviews using meta-analysis in ecology. Journal of Animal Ecology 71, 547–557.

Glass, G.V. (1976) Primary, secondary, and meta-analysis of research. Educational Researcher 5, 3–8.

Gorshkov, D. (2003) Is it possible to use beaver building activity to reduce lake sedimentation? Lutra 46, 189–196.

Gottesfeld, A.S., Rabnett, K.A. and Hall, P.E. (2002) Conserving Skeena Fish Populations and their Habitat. Skeena Fisheries Commission, Box 229, Hazelton, B.C. 281 pages .

Grasse, J.E. (1951) Beaver ecology and management in the Rockies. Journal of Forestry 49, 3–6.

Grasse, J.E. (1979) Some trout-raising alternatives ...irrigation ditches and beaver ponds. Salmonid 3, 12–15.

Grasse, J.E. and Putnam, E.F. (1955) Beaver Management and ecology in Wyoming. Wyoming Game and Fish Commission Bulletin 6, Cheyenne, 75.

Gregory, S.L. (1988) Population characteristics of Dolly Varden in the Tiekel River, Alaska. Master's thesis. University of Alaska, Fairbanks, Alaska, USA.

Guignion, D. (2009) A Conservation Strategy for Atlantic Salmon in Prince Edward Island. The Atlantic Salmon Conservation Foundation, Fredericton, New Brunswick.

Gurevitch, J. and Hedges, L.V. (1993) Meta-analysis: combining the results of independent experiments. In: Design and Analysis of Ecological Experiments (eds S.M. Scheiner and J. Gurevitch). Chapman and Hall, New York, pp. 378–398.

Hägglund, Å. and Sjöberg, G. (1999) Effects of beaver dams on the fish fauna of forest streams. Forest Ecology and Management 115, 259–266.

Hale, J.G. (1966) Influence of beaver on some trout streams along the Minnesota north shore of Lake Superior. Minnesota Bureau of Fisheries Investigative Reports, No: 244, 28 pp.

Halley, D. (1995) The Proposed reintroduction of beavers to Britain - in reply. Reintroduction News 10, 17–18.

Halley, D.J. and Lamberg, A. (2001) Populations of juvenile salmon and trout in relation to beaver damming of a spawning stream. In: The European Beaver in a New Millennium. (eds A. Czech and G. Schwab) Proceedings of 2nd European Beaver Symposium, Bialowieza, Poland . Carpathian Heritage Society, Kraków, Poland, pp. 122–127.

Halley, D.J. and Rosell, F. (2003) Population and distribution of European beavers (Castor fiber). Lutra 46, 91–101.

Hanson, W.D. and Campbell, R.S. (1963) The effects of pool size and beaver activity on distribution and abundance of warm-water fishes in a North Missouri stream. American Midland Naturalist 69, 136–149.

Harig, A.L. and Fausch, K.D. (2002) Minimum habitat requirements for establishing translocated cutthroat trout populations. Ecological Applications 12, 535–551.

Harthun, M. (1999) The influence of the European Beaver (Castor fiber albicus) on the biodiversity (Odonata, Mollusca, Trichoptera, Ephemeroptera, Diptera) of brooks in Hesse (Germany). Limnologica 29, 449–464. (in German with English summary).

Hartman, G. and Törnlöv, S. (2006) Influence of watercourse depth and width on dam building behaviour by Eurasian beaver (Castor fiber). Journal of Zoology 268, 127–131.

Haxton, T.J. and Findlay, C.S. (2008) Meta-analysis of the impacts of water management on aquatic communities. Canadian Journal of Fisheries and Aquatic Sciences 65, 437–447.

Hodder, K.H. and Bullock, J.M. (1997) Translocations of native species in the UK: implications for biodiversity. Journal of Applied Ecology 34, 547–565.

Horan, D.L., Kershner, J.L., Hawkins, C.P. and Crowl, T.A. (2000) Effects of habitat area and complexity on Colorado River cutthroat trout density in Uinta Mountain streams. Transactions of the American Fisheries Society 129, 1250–1263.

Jakober, M.J., McMahon, T.E., Thurow, R.E. and Clancy, C.G. (1998) Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127, 223–235.

Jakober, M.J., McMahon, T.E. and Thurow, R.F. (2000) Diel habitat partitioning by bull charr and cutthroat trout during fall and winter in Rocky Mountain streams. Environmental Biology of Fishes 59, 79–89.

Jeffries, R., Darby, S.E. and Sear, D. (2003) The influence of vegetation and organic debris on flood-plain sediment dynamics: case study of a low-order stream in the New Forest, England. Geomorphology 51, 61–80.

Johnson, J. and Weiss, E. (2006) Catalog of waters important for spawning, rearing or migration of anadromous fishes, southwestern region, Anchorage, Alaska. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services.

Kemp, P.S., Worthington, T.A. and Langford, T.E.L.(2010) A critical review of the effects of beavers on fish and fish stocks. Scottish Natural Heritage Commissioned Report No. 349 (iBids No. 8770).

Kemp P.S., Worthington T.A., Langford T.E.L., Tree A.R.J. & Gaywood M.J. (2012) Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries, 13, 158–181.

Knudsen, G.J. (1962) Relationship of beaver to forests, trout and wildlife in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 25, 1–50.

Kukula, K. and Bylak, A. (2010) Ichthyofauna of a moun-tain stream dammed by beaver. Archives of Polish Fisheries 18, 33–43.

Lang, D.W., Reeves, G.H., Hall, J.D. and Wipfli, M.S. (2006) The influence of fall-spawning coho salmon (Oncorhynchus kisutch) on growth and production of juvenile coho salmon rearing in beaver ponds on the Copper River delta, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 63, 917–930.

Leidholt-Bruner, K., Hibbs, D.E. and McComb, W.C. (1992) Beaver dam locations and their effects on distribution and abundance of coho salmon fry in two coastal Oregon streams. Northwest Science 66, 218–223.

Lever, C. (1994) The proposed reintroduction of beavers to Britain. Reintroduction News 9, 14–15.

Lichatowich, J. (1999) Salmon without Rivers: A History of the Pacific Salmon Crisis. Island Press, Washington, DC.

Likert, R. (1932) A technique for the measurement of attitudes. Archives of Psychology 140, 1–55.

Lindstrom, J.W. and Hubert, W.A. (2004) Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream. North American Journal of Fisheries Management 24, 1341–1352.

Linstone, H.A. and Turoff, M. (2002) The Delphi Method, Techniques and Applications. Addison-Wesley, London.

Lokteff, R.L., Roper, B.B., and Wheaton, J.M. (2013) Do beaver dams impede the movement of trout? Transactions of the American Fisheries Society 142:1114-1125

Lowry, M.M. (1993) Groundwater elevations and temperature adjacent to a beaver pond in central Oregon. Unpublished Master's thesis. Oregon State University, Corvallis.

Maunder, M. (1992) Plant reintroduction – an overview. Biodiversity and Conservation 1, 51–61.

McCaffery, M.L.M. 2009. The influence of an ecosystem engineer on nutrient subsidies and fish invasions in southwestern Montana. Doctoral Thesis. University of Montana, Department of Fish and Wildlife Biology.

McColl, E., Jacoby, A., Thomas, L. et al. (2001) Design and use of questionnaires: a review of best practice applicable to surveys of health service staff and patients. Health Technology Assessment 5, 1–256.

McComb, W.C., Sedell, J.R. and Buchholz, T.D. (1990) Dam-site selection by beavers in an eastern Oregon basin. Great Basin Nat. 50, 273–281.

McPhee, M.V., Tappenbeck, T.H., Whited, D.C. and Stanford, J.A. (2009) Genetic diversity and population structure in the Kuskokwim River drainage support the recurrent evolution hypothesis for sockeye salmon life histories. Transactions of the American Fisheries Society 138, 1481–1489.

McRae, G. and Edwards, C.J. (1994) Thermal-characteristics of Wisconsin headwater streams occupied by beaver – implications for brook trout habitat. Transactions of the American Fisheries Society 123, 641–656.

Miller, B.A. and Sadro, S. (2003) Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. Transactions of the American Fisheries Society 132, 546–559.

Mitchell, S.C. and Cunjak, R.A. (2007) Stream flow, salmon and beaver dams: roles in the structuring of stream fish communities within an anadromous salmon dominated stream. Journal of Animal Ecology 76, 1062–1074.

Moorman, M.C., Eggleston, D.B., Anderson, C.B., Mansilla, A. and Szejner, P. (2009) Implications of beaver Castor canadensis and trout introductions on native fish in the Cape Horn Biosphere Reserve, Chile. Transactions of the American Fisheries Society 138, 306–313.

Müller-Schwarze, D. and Sun, L. (2003) The Beaver: Natural History of a Wetlands Engineer. Cornell University Press, Ithaca, New York.

Murphy, M.L., Heifetz, J., Thedinga, J.F., Johnson, S.W. and Koski, K.V. (1989) Habitat utilisation by juvenile Pacific salmon (Onchorynchus) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences 46, 1677–1685.

Murray, S. and Innes, J.L. (2009) Effects of environment on fish species distributions in the Mackenzie River drainage basin of northeastern British Columbia, Canada. Ecology of Freshwater Fish 18, 183–196.

Naiman, R.J., Melillo, J.M. and Hobbie, J.E. (1986) Ecosystem alteration of boreal forest streams by beaver (Castor canadensis). Oecologia 62, 150–155.

Naiman, R.J., Johnston, C.A. and Kelley, J.C. (1988) Alteration of North American streams by beaver. BioScience 38, 753–761.

Nickelson, T.E., Rodgers, J.D., Johnson, S.L. and Solazzi, M.F. (1992) Seasonal changes in habitat use by juvenile coho salmon (Oncorhynchus kisutch) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Science 49, 783–789.

NRC (1995) National Research Council Committee on Protection and Management of Pacific Northwest Anadromous Salmonids. Upstream: Salmon and Society in the Pacific Northwest. Washington, DC, National Academy Press.

Parker, H. and Ronning, O.C. (2007) Low potential for restraint of anadromous salmonid reproduction by beaver Castor fiber in the Numedalslagen River catchment, Norway. River Research and Applications 23, 752–762.

Patterson, D. (1951) Beaver-trout relationships. Wisconsin Conservation Department Investigational Report No. 822, 34 pp.

Pearson, M.P. and Healey, M.C. (2003) Life-history characteristics of the endangered salish sucker (Catostomus Sp.) and their implications for management. Copeia 2003, 759–768.

Plummer, R. and Armitage, D.R. (2007) Charting the new territory of adaptive co-management: a Delphi study. Ecology and Society 12, 10.

Pollock, M.M., Naiman, R.J., Erickson, H.E., Johnston, C.A., Pastor, J. and Pinay, G. (1995) Beaver as engineers: influences on biotic and abiotic characteristics of drainage basins. In: Linking Species and Ecosystems (ed C.G. Jones and J.H. Lawton). Chapman and Hall, New York, USA, pp. 117–126.

Pollock, M.M., Heim, M. and Werner, D. (2003) Hydrologic and geomorphic effects of beaver dams and their influence on fishes. In: The Ecology and Management of Wood in World Rivers (eds S.V. Gregory, K. Boyer and A. Gurnell). American Fisheries Society, Bethesda, MD, pp. 213–233.

Pollock, M.M., Pess, G.R., Beechie, T.J. and Montgomery, D.R. (2004) The Importance of Beaver Ponds to Coho Salmon Production in the Stillaguamish River Basin, Washington, USA. North American Journal of Fisheries Management 24, 749–760.

Pollock, M.M., Beechie, T.J. and Jordan, C.E. (2007) Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32, 1174–1185.

Pollock M, Wheaton JM, Bouwes N and Jordan CE. 2011. Working with Beaver to Restore Salmon Habitat in the Bridge Creek Intensively Monitored Watershed: Design Rationale and Hypotheses, Interim Report, NOAA Northwest Fisheries Science Center, Seattle, WA, 108 pp.

Pollock M, Wheaton JM, Bouwes N and Jordan CE. 2012. Working with Beaver to Restore Salmon Habitat in the Bridge Creek Intensively Monitored Watershed: Design Rationale and Hypotheses. NOAA Technical Memorandum, NOAA Northwest Fisheries Science Center, Seattle, WA, 63 pp.

Rabe, F.W. (1970) Brook trout populations in Colorado beaver ponds. Hydrobiologia 35, 431–448.

Rasmussen, D.I. (1941) Beaver-trout relationship in the Rocky Mountain region. Transactions of the North American Wildlife Conference 5, 256–263.

Ray, H.L., Ray, A.M. and Rebertus, A.J. (2004) Rapid establishment of fish in isolated peatland beaver ponds. Wetlands 24, 399–405.

Reading, R.P. and Kellert, S.R. (1993) Attitudes toward a proposed reintroduction of black-footed ferrets (Mustela nigripes). Conservation Biology 7, 569–580.

Redman, C.L., Grove, J.M. and Kuby, L.H. (2004) Integrating social science into the long-term ecological research (LTER) network: social dimensions of ecological change and ecological dimensions of social change. Ecosystems 7, 161–171.

Rees, P.A. (2001) Is there a legal obligation to reintroduce animal species into their former habitats? Oryx 35, 216–223.

Riley, R.C. and Lemieux, P. (1998) The effects of beaver on juvenile coho salmon habitat in Kispiox River tributaries. Unpublished report for DFO, Smithers, BC.

Rohde, F.C. and Arndt, R.G. (1991) Distribution and status of the sandhills chub, Semotilus lumbee, and the pinewoods darter, Etheostoma mariae. Journal of the Elisha Mitchell Scientific Society 107, 61–70.

Rosell, F. and Parker, H. (1995) Beaver Management: Present Practice and Norway's Future Needs (Norwegian with English summary). Telemark University College, Bø, Norway, 137pp.

Rosell, F. and Parker, H. (1996) The beaver's (Castor Spp.) role in forest ecology: a key species returns. Fauna (Oslo) 49, 192–211.

Rosell, F., Bozser, O., Collen, P. and Parker, H. (2005) Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems. Mammal Review 35, 248–276.

Rosenau, M. and Angelo, M. (1999) Freshwater Habitat. Pacific Fisheries Resource Conservation Council, Vancouver, BC.

Rupp, R.S. (1954) Beaver-trout relationships in the headwaters of Sunkhaze Stream, Maine. Transactions of the American Fisheries Society 84, 75–85.

Rutherford, W.H. (1955) Wildlife and environmental relationships of beavers in Colorado forests. Journal of Forestry 53, 803–806.

Salyer, J.C. (1935) Preliminary report on the beaver trout investigation. American Game 24, 6–15.

Scheerer, P.D., Kavanagh, P.S. and Jones, K.K. (2004) Annual Progress Report Fish Research Project Oregon. Oregon Department of Fish and Wildlife, Salem, Oregon.

Schlosser, I.J. (1993) Stream fish communities: the role of beaver pond-stream interactions. Bulletin of the Ecological Society of America 74, 428.

Schlosser, I.J. (1995a) Dispersal, boundary processes and trophic level interactions in streams adjacent to beaver ponds. Ecology 76, 908–925.

Schlosser, I.J. (1995b) Critical landscape attributes influencing fish population dynamics in headwater streams. Hydrobiologia 303, 71–81.

Schlosser, I.J. (1998) Fish recruitment, dispersal, and trophic interactions in a heterogeneous lotic environment. Oecologia 113, 260–268.

Schlosser, I.J. and Kallemeyn, L.W. (2000) Spatial variation in fish assemblages across a beaver-influenced successional landscape. Ecology 81, 1371–1382.

Schulte, R. (1989). Dam building of European beavers and its importance for the colonization of fast running streams in the Eifel-mountains. In Abstracts. Fifth international theriological congress: 313. Rome: Nage Snc.

Scott Porter Research and Marketing Ltd (1998) Re-introduction of the European Beaver to Scotland: Results of a Public Consultation. Scottish Natural Heritage, Perth.

Scruton, D.A., Anderson, T.C. and King, L.W. (1998) Pamehac brook: a case study of the restoration of a Newfoundland, Canada, river impacted by flow diversion for pulpwood transportation. Aquatic Conservation: Marine and Freshwater Ecosystems 8, 145–157.

Seddon, P.J. (1999) Persistence without intervention: assessing success in wildlife reintroductions. Trends in Ecology and Evolution 14, 503–503.

Seddon, P.J., Armstrong, D.P. and Maloney, R.F. (2007) Developing the science of reintroduction biology. Conservation Biology 21, 303–312.

Shetter, D.S. and Whalls, M.J. (1955) Effect of impoundment on water temperatures of Fuller Creek, Montmorency County, Michigan. Journal of Wildlife Management 19, 47–54.

Sigourney, D.B., Letcher, B.H. and Cunjak, R.A. (2006) Influence of beaver activity on summer growth and condition of age-2 Atlantic salmon parr. Transactions of the American Fisheries Society 135, 1068–1075.

Smith, J.M. and Mather, M.E. (2013) Beaver dams maintain fish biodiversity by increasing habitat heterogeneity throughout a low-gradient stream network. Freshwater Biology 58, 6.

Snodgrass, J.W. and Meffe, G.K. (1998) Influence of beavers on stream fish assemblages: effects of pond age and watershed position. Ecology 79, 928–942.

Snodgrass, J.W. and Meffe, G.K. (1999) Habitat use and temporal dynamics of blackwater stream fishes in and adjacent to beaver ponds. Copeia 3, 628–639.

Stock, J.D. and Schlosser, I.J. (1991) Short-term effects of a catastrophic beaver dam collapse on a stream fish community. Environmental Biology of Fishes 31, 123–129.

Swales, S. and Levings, C.D. (1989) Role of off-channel ponds in the life cycle of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Coldwater River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46, 232–242.

Swanston, D.N. (1991) Natural processes. In: Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats (ed W.R. Meehan). American Fisheries Society Special Publication 19, Bethesda, Maryland, pp. 139–179.

Talabere, A.G. (2002) Influence of water temperature and beaver ponds on Lahontan cutthroat trout in a high-desert stream, southeastern Oregon. Unpublished Masters Thesis, Oregon State University, Corvallis.

Tambets, M., Jarvekulg, R., Veeroja, R., Tambets, J. and Saat, T. (2005) Amplification of negative impact of beaver dams on fish habitats of rivers in extreme climatic conditions. Journal of Fish Biology 67, 275–276.

Taylor, J.E. (1999) Burning the candle at both ends – historicizing overfishing in Oregon's nineteenth-century salmon fisheries. Environmental History 4, 54–79.

Taylor, B.R., MacInnis, C. and Floyd, T.A. (2010) Influence of rainfall and beaver dams on upstream movement of spawning Atlantic salmon in a restored brook in Nova scotia, Canada. River Research and Applications, 26, 183–193.

Thornton, A. and Lee, P. (2000) Publication bias in meta-analysis: its causes and consequences. Journal of Clinical Epidemiology 53, 207–216.

Thorstad, E.B., Økland, F., Aarestrup, K. and Heggberget, T.G. (2008) Factors affecting the within-river spawning migration of Atlantic salmon, with emphasis on human impacts. Reviews in Fish Biology and Fisheries 17, 345–371.

Venturini, E.M. (2006) A literature review of the interactions between beaver (Castor canadensis) and Atlantic salmon (Salmo salar) and their implications in Maine. Unpublished degree thesis, University of Maine, Orono, Maine.

White, S.M. and Rahel, F.J. (2008) Complementation of Habitats for Bonneville Cutthroat Trout in Watersheds Influenced by Beavers, Livestock and Drought. Transactions of the American Fisheries Society 137, 881–894.

White, P.C.L., Jennings, N.V., Renwick, A.R. and Barker, N.H.L. (2005) Questionnaires in ecology: a review of past use and recommendations for best practice. Journal of Applied Ecology 42, 421–430.

Worthington, T., Tisdale, J., Kemp, P., Williams, I. and Osborne, P.E. (2010) Public and stakeholder attitudes to the reintroduction of the burbot, Lota lota. Fisheries Management and Ecology 17, 465–472.

Historical Distribution of Beaver

James, C.D. and R.B. Lanman. 2012. Novel physical evidence that beaver historically were native to the Sierra Nevada. California Fish and Game 98(2) 129-132

Lanman, R.B., Perryman, H., Dolman, B., and C.D. James. 2012. The historical range of beaver in the Sierra Nevada: a review of the evidence. California Fish and Game 98(2):65-80.

Hydrology

Collen, P., and Gibson, R.J. (2001) The general ecology and beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. Reviews in Fish Biology and Fisheries 10, 439-461.

Gurnell, A.M. (1998) The hydrogeomorphological effects of beaver dam-building activity. Progress in Physical Geography 22, 167-189.

McDowell, D.M., and Naiman, R.J. (1986) Structure and Function of a Benthic Invertebrate Stream Community as Influenced by Beaver (*Castor Canadensis*). Oecologia 68, 481-489.

Naiman, R.T., Johnston, C.A., and Kelley, J.C. (1988) Alterations of North American Streams by Beaver. BioScience 38, 753-762.

Naiman, R.J., Melillo, J.M., and Hobbie, J.E. (1986) Ecosystem Alteration of Boreal Forest Streams by Beaver (*Castor Canadensis*). Ecology 67, 1254-1269.

Rossell, F., Bozser, O., Collen, P., and Parker, H. (2005) Ecological impact of beavers *Castor fiber* and *Castor Canadensis* and their ability to modify ecosystems. Mammal Rev. 35, 248-276.

Westbrook, C.J., Cooper, D.J., and Baker, B.W. (2006) Beaver dams and overbank floods influence groundwater – surface water interactions of a Rocky Mountain Riparian area. Water Resources Research 42.

Live Trapping Beaver for Translocation

Association of Fish and Wildlife Agencies. Best management practices for trapping beaver in the United States, 24 pp.

Range / Grazing / Beaver-livestock interactions

Baker, B.W. 1995. Restoring healthy riparian ecosystems on western rangelands: beaver as a keystone species. Supplement to the Bulletin of the Ecological Society of America 76(2):10

Fouty, S.C., 2003. Current and historic stream channel response to changes in cattle and elk grazing pressure and beaver activity: southwest Montana and east-central Arizona. Ph.D. dissertation. Department of Geography, University of Oregon.

Hosten, P. E. and H. Whitridge. 2007. Vegetation changes associated with livestock exclusion from riparian areas on the Dead Indian Plateau of southwest Oregon. U.S. Department of the Interior, Bureau of Land Management, Medford District.

Ott, G.D., and D.W. Johnson. 2005. Beaver Influence on Fisheries Habitat: Livestock Interactions. A research review.

Resilience to Climate Change

Hood, G.A., and S.E. Bayley. 2008. Beaver (Castor Canadensis) mitigate the effects of climate on the area of open water in boreal wetlands in western Canada. Biological Conservation 141: 556-567.

Lawler, J.J. 2009. Climate chanage adaptation strategies for resource management and conservation planning. The Year in Ecology and Conservation Biology, 2009: Ann. N.Y. Acad. Sci. 1162: 79–98.

Rosemond, A.D., and C.B. Anderson. 2003. Engineering role models: do non-human species have the answers? Ecological Engineering 20, 379-387.

Wohl, E. 2013. Landscape-scale carbon storage associated with beaver dams. Geophysical Research Letters (40) 3631-3636.

Riparian Habitat Condition

Runyon, M.J. 2013. Effects of beaver reintroduction and ungulate browsing on aspen recovery in the Eagle Creek Drainage of the Northern Yellowstone Winter Range. Master of Science Thesis in Animal and Range Sciences, Montana State University, Bozeman, Montana.

Olechnowski, B.F. and D.M. Bebinski. 2008. Response of songbirds to riparian willow habitat structure in the Greater Yellowstone Ecosystem. The Wilson Journal of Ornithology 120(4): 830-839.

Ripple, W.J. and R.L. Beschta. 2006. Linking wolves to willows via risk-sensitive foraging by ungulates in the northern Yellowstone ecosystem. Forest Ecology and Management 230 (1-3): 96-106.

Wright, J.P., Jones, C.G., and Flecker, A.S. (2002) An ecosystem engineer, the beaver, increases species richness at the landscape scale. Ecosystems Ecology 132, 96-101.

Sources of Beaver for Reintroduction Projects

Utah Division of Wildlife Resources. 2000. Final protocol for the transplant and reestablishment of beavers into selected locations in Utah Division of Wildlife Resources' Southern Region. 27 pp.