Baseline Studies in the Elwha River Ecosystem Prior to Dam Removal: Introduction to the Special Issue

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Abstract

The planned removal of two dams that have been in place for over 95 years on the Elwha River provides a unique opportunity to study dam removal effects. Among the largest dams ever considered for removal, this project is compelling because 83% of the watershed lies undisturbed in Olympic National Park. Eighteen million cubic meters of sediment have accumulated in and will be released from the reservoirs, and there is potential for rehabilitating depressed Pacific salmon runs. Researchers from academia, non-profit organizations, federal and state governments, and the Lower Elwha Klallam Tribe are currently assessing baseline ecological conditions of the Elwha River as part of dam removal studies. We introduce dam removal topics, provide a brief history of the dams, and summarize the ecology of the Elwha River basin as an introduction to a special issue devoted to research in the watershed.

Introduction

The 72 km Elwha River in Washington State was historically one of the most productive salmon rivers for its size in the Pacific Northwest (Wunderlich et al. 1994). However, two dams built without provisions for fish passage set off a slew of ecological changes, triggering a rippling effect on wildlife, food webs, and habitat throughout the 833 km^2 watershed, most of which is contained in Olympic National Park (ONP; Figure 1). In 1992, Congress enacted the Elwha River Ecosystem and Fisheries Restoration Act (PL 102-495) directing the Secretary of the Interior to fully restore the Elwha River ecosystem and native anadromous fisheries. After years of studying possible alternatives, the National Park Service (NPS) determined that only the removal of both dams would result in full restoration (DOI 1995). Removal of these dams and subsequent restoration work will constitute the single largest endeavor of this kind ever attempted.

The potential for rehabilitating salmon populations within a large watershed of a National Park is one of the many reasons why the Elwha River dam removal and ecosystem restoration is an alluring project. Tracking the erosion of 18 million cubic yards of sediment that has accumulated in the reservoirs (Childers et al. 2000) and the concomitant effects to the river, estuarine, and marine environments following dam removal also add to the anticipation. Researchers from academia, non-profit organizations, federal and state governments, and the Lower Elwha Klallam Tribe are currently assessing baseline conditions in the watershed and other reference locations, a necessary step in designing studies that utilize a before-after-control-impact (BACI) experimental design (Underwood 1994). The purpose of this special issue is to gather many of the scientific studies occurring in the Elwha River prior to dam removal. Here, we provide general project background and introduce many of the elements common to all of the papers in this issue. Winter and Crain (2008) provide a historical perspective by summarizing the information used leading up to the decision to remove the dams. Woodward et al. (2008) provide a conceptual model approach to provide a framework for integrating research and monitoring studies, while McHenry and Pess (2008) discuss elements critical to long-term monitoring of fisheries and aquatic resources. Shaffer et

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al. (2008) provide an overview of the Elwha River estuary and marine nearshore areas. The rest of the papers are scientific baseline studies.

Economic and Scientific Context of Dam Creation and Removal

Human societies have had a long association with river ecosystems. The abundant goods and services provided by rivers far outweighed the dangers associated with living on floodplains, facilitating the close connection between rivers and people (Vitousek et al. 1997). As societies advanced, they used technology to control rivers in an effort to maximize the acquisition of resources (e.g., Erikson 2000, Heckenberger et al. 2007), while minimizing the dangers associated with rivers by controlling their flow. Perhaps the primary technology that serves both purposes is dam building.

Dams are constructed to provide power, flood control, drinking and irrigation water, transportation, recreation, and even fish habitat (WCD 2000). Historically, dam building in the United States was seen as a prerequisite for settlement of many areas, especially in the arid west (Powell 1879), leading to dams becoming a fixture of the national landscape (Heinz Center 2002). The drive for economically self-sufficient settlement across the western United States, particularly between 1940 and 1970, fueled widespread dam construction (Graf 1999). By the 1970s hydroelectric dams provided about 10% of the Nation's power and 75% of the power in the Pacific Northwest (Lee 1991). During this era, society deemed the economic and societal benefits of dam construction to far outweigh any ecological costs. We argue that the ecological effects of dam construction were dismissed as inconsequential and outweighed by societal benefits, probably because the ecological effects were poorly understood or undervalued.

As scientists began comparing impounded versus free flowing rivers, a better understanding of the physical, chemical, and biological impacts on river ecosystems emerged (reviewed in Ward and Stanford 1987, Hart et al. 2002, Pizzuto 2002). Dams alter downstream riparian (Shafroth et al. 2002) and aquatic habitats (Petts 1984, Munn and Brusven 2004) by changing flow regimes (Richter and Thomas 2007), incising river channels and restricting channel migration (Collier et al. 1996), altering water temperatures (Poole and Berman 2001), and limiting migration of fish (Baxter 1977). Interactions among these factors, coupled with ecological feedback mechanisms, lead to changes in the complex and dynamic interplay between geophysical, fluvial, and biological processes that maintain floodplains and associated habitats (Ward and Stanford 1987, Gregory et al. 2002). This in turn ultimately affects the trophic structure of the ecosystem (e.g., Vinson 2001, de Mérona et al. 2005). The damming of rivers is now appreciated as a resource-use tradeoff, where inherent ecosystem integrity (e.g., Millennium Ecosystem Assessment 2005, Karr *In Press*) is sacrificed to maximize the acquisition of a few key resources valuable to society.

Dam removal as a river restoration technique has recently gained considerable attention (reviewed by Bednarek 2001, Hart et al. 2002, Heinz Center 2002, Stanley and Doyle 2003). As structures reach the end of their design life, natural resource managers and communities must evaluate tradeoffs. These include weighing choices such as the cost of repair versus removal and rehabilitating ecosystem structure and function versus retaining benefits from having a dam in place (Heinz Center 2002). Although over 500 dams have been removed in the United States (Hart et al. 2002), studies assessing ecosystem changes in the physical, biological, and chemical characteristics of rivers and how this ultimately affects restoration potential are limited. The dam removal on Manatawny Creek in Pennsylvania (Bushaw-Newton et al. 2002) and work in Wisconsin on small dam removals (Doyle et al., 2005) are examples where before and after studies were conducted on multiple ecosystem components. Thompson et al. (2005) showed a decrease, likely due to increased fine sediments, in macroinvertebrate abundance and diatom species richness following dam removal, but noted that the overall assemblage structure of these communities was not greatly affected. Ashley et al. (2006) did not find a difference in contaminant levels of the sediments above and below the dams before and after dam removal. Velinsky et al (2006) did not find differences in most water chemistry parameters in their study of dam removal effects on Manatawny Creek. Other studies were limited in scope or duration and focus on few ecosystem components, such as macroinvertebrate communities (e.g., Pollard and Reed 2004) or fish communities (e.g., Catalano et al. 2007). Most of the dam removal studies that exist were conducted on small structures (< 5m), probably because more of these have been removed than larger dams (Poff and Hart 2002).

It is the overarching goal of Elwha River research and monitoring community to contribute to the growing literature of assessing dam removal as a restoration technique (Babbit 2002), by focusing interdisciplinary studies on a large wilderness river with the potential to rehabilitate depressed salmon runs. The Elwha is particularly suited for this role because all of the water above the upper dam is in ONP, a relatively pristine ecosystem where ecological signals gauging rehabilitation will not be confounded by anthropogenic disturbances commonly found in most American river systems (but see below).

The Elwha and Glines Canyon Dams

Built in support of economic development throughout the North Olympic Peninsula, the two dams on the Elwha River have altered the ecosystem for the past 97 years. The construction of the 33 m tall Elwha Dam at river kilometer (rkm) 7.9 from 1910 to 1913 prevented anadromous fish from accessing 130 km of main stem and tributary habitat, limiting anadromous salmon and steelhead to the river below the dam. The Glines Canyon Dam measures 64 m in height and was constructed from 1925 to 1927 at rkm 21.6. Since the mid 1940s, the dams have been largely operated as run-of-the-river, a common hydroelectric operating regime where the amount of water entering the reservoir is released by dam operators. Although the alteration of flow regime is lower compared with other dam operations that seasonally store water, attenuated patterns of discharge emerge below run-of-the-river dams (Richter and Thomas 2007). However, there are exceptions to the run-of-the-river flow regime in the Elwha, as current dam operations directed by the NPS may increase flows into the river by drawing down the reservoir to support endangered Chinook salmon populations and the previous operator regularly stored and released water to increase power production (Brian Winter, ONP Elwha Project Manager, personal communication). The reservoirs created by the dams differ in size and storage capacity, with Lake Aldwell measuring 1.08 km^2 and storing 9.99 x 10^6 m^3 of water and Lake Mills measuring 1.68 km^2 and storing 5.12 x 10^7 m^3 of water. These reservoirs inundate over 9 km of former riverine habitat, trap sediments (i.e., sand, gravel, cobble) and woody debris transported from the upper watershed, restrict transport of organic material and dissolved nutrients, and increase downstream water temperatures (Wunderlich et al. 1994). The trapping of river bed sediments, especially in Lake Mills, has shifted the river substrate composition below the dams towards cobbles and small boulders that are too large for fish spawning (Pess et al. 2008) and has limited the ability of the river to transport bedload (DOI 1995, Childers et al. 2000, Pohl 2004). This has created an unnaturally stable and less diverse riparian zone, reduced the diversity and size of the estuary by about 0.9 km^2, and changed the near shore beach and subtidal communities (Warrick et al. 2008) from those dependent on sandy bottoms to those able to exploit rocky substrates (DOI 1995). Additionally, channel migration has been limited, largely from diminished floodplain dynamics (Kloehn et al. 2008) in the face of reduced wood and sediment budgets, causing incision of the mainstem between and below the Elwha dams (DOI 1995, Pohl 2004).

During the 1980s, controversy arose on the subject of licensing the Elwha dam (which never was licensed) and the relicensing of Glines Canyon Dam. Recognizing that the water above the Glines Canyon dam was located within ONP, public opinion about the dams began shifting and led to early proposals to remove the dams (Wunderlich et al. 1994). In retrospect, a unique combination of factors coalesced to create an atmosphere among the public, conservationists, and politicians favoring dam removal. These included: hesitation about having a dam inside of a National Park; the potential for restoring salmon runs; the cultural, spiritual, and economic concerns of the Elwha Klallam Tribe; the structural integrity of the dams; the economics and other issues involved with obtaining relicensing by the Federal Energy Regulatory Commission; and the business decisions by the dams owners.

Ecological Setting of the Elwha River Basin

The Elwha River originates in the southern Bailey Range of the Olympic Mountains, a coastal range of northwestern Washington State contained within ONP, a World Heritage Site and International Biosphere Reserve. At 833 km^2 the Elwha River basin constitutes nearly 20% of the Park (Figure

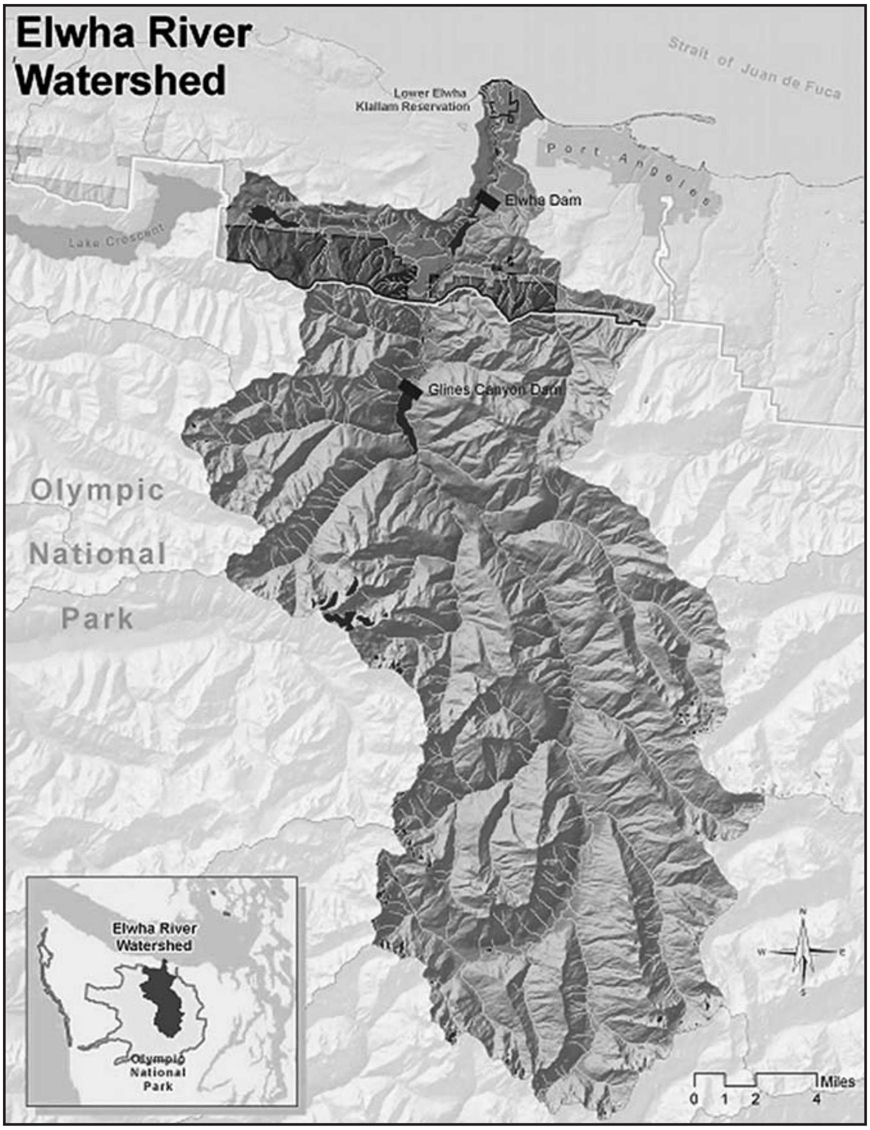

Figure 1. A map of the Elwha River Basin, Olympic Peninsula, Washington, USA

1). The Elwha River flows north for 72 km, and drains into the Strait of Juan de Fuca, the marine passage connecting Puget Sound with the Pacific Ocean. The eight major tributaries (i.e., > third order) to the Elwha River are the Godkin River, Hayes River, Goldie River, Lost River, Lillian River, Long Creek, Little River, and Indian Creek. Elevation ranges from sea level at the mouth of the Elwha to approximately 1372 m at the headwaters on the slopes of Mt. Barnes in the heart of the Olympic Mountains.

The Elwha River Basin lies on the cusp of the rain shadow created by Mount Olympus and the Bailey Range. Consequently, the drainage contains the steepest precipitation gradient on the Olympic Peninsula (Figure 2). The upper basin receives an estimated 550 cm of precipitation annually, whereas the area near the river mouth receives approximately 100 cm annually (Phillips and Donaldson 1972). In the central portion of the watershed, precipitation drops from 500 cm to 250 cm in about 15 km.

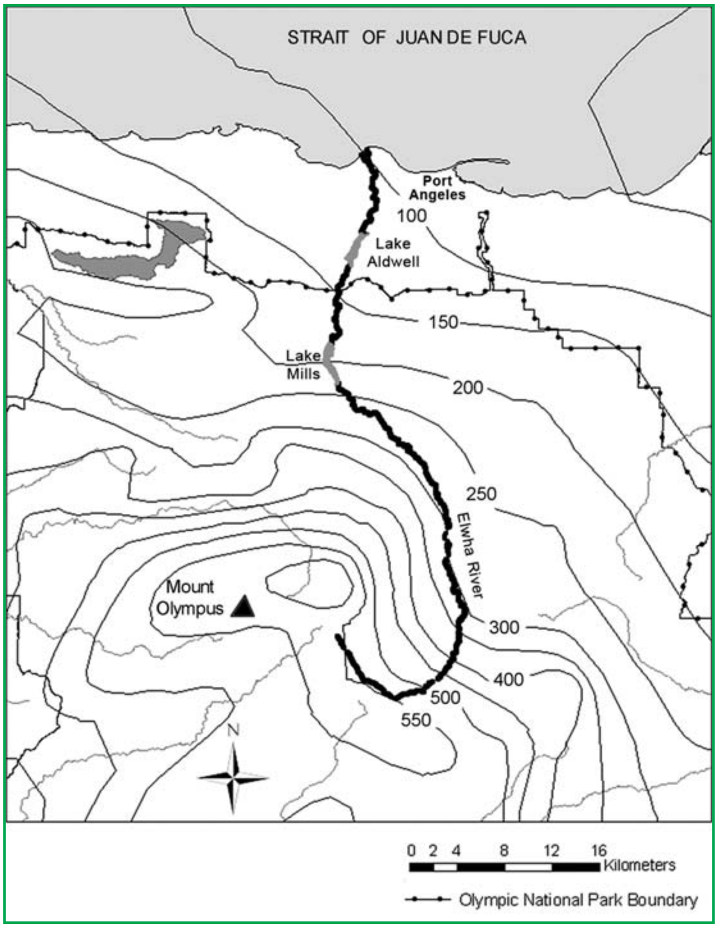

Figure 2. Isolines of estimated precipitation levels on the Olympic Peninsula. Contour lines are at 50 cm intervals.

The climate of the Elwha River basin is generally characterized by dry, warm summers, and cool wet winters (Figure 3). Most precipitation at upper elevations falls as snow with rain predominating below elevations of about 1200 m. Long-term weather records from the Elwha Ranger Station (approximately rkm 18.2, 110 m elevation) indicate an annual average precipitation of 143 cm (WRCC 2007), with the majority falling from October through March (Figure 3). The interaction between temperature and precipitation creates a bimodal seasonal hydrograph in the Elwha River (Figure 4). Discharge increases in the spring when temperatures are warm enough to melt accumulated snow pack. A second increase occurs in the fall and winter due to increased precipitation. The lowest flows occur in the summer, when precipitation and snow pack levels are also lowest.

The upper Elwha basin, from the ONP boundary to the headwaters, is comprised of marine sedimentary deposits composed mostly of sandstone and shale (Schuster 2005; Tabor 1987). At the ONP boundary, the river flows through the Crescent Formation, a horse-shoe shaped feature of basalt. The river below this formation is composed mostly of unconsolidated glacial till and recent alluvial deposits (Tabor 1987). The recent geologic history of the Elwha basin was shaped by both alpine glaciers and the Cordilleran ice sheet (Tabor 1987), the latter of which created glacial Lake Elwha via an ice dam approximately 17,000 ybp.

The geomorphology of the Elwha River basin creates a topography best described as a series of alternating canyons and floodplains (see Figure 1 in Pess et al. 2008). The canyons occur in areas of steep gradient where the river is confined between

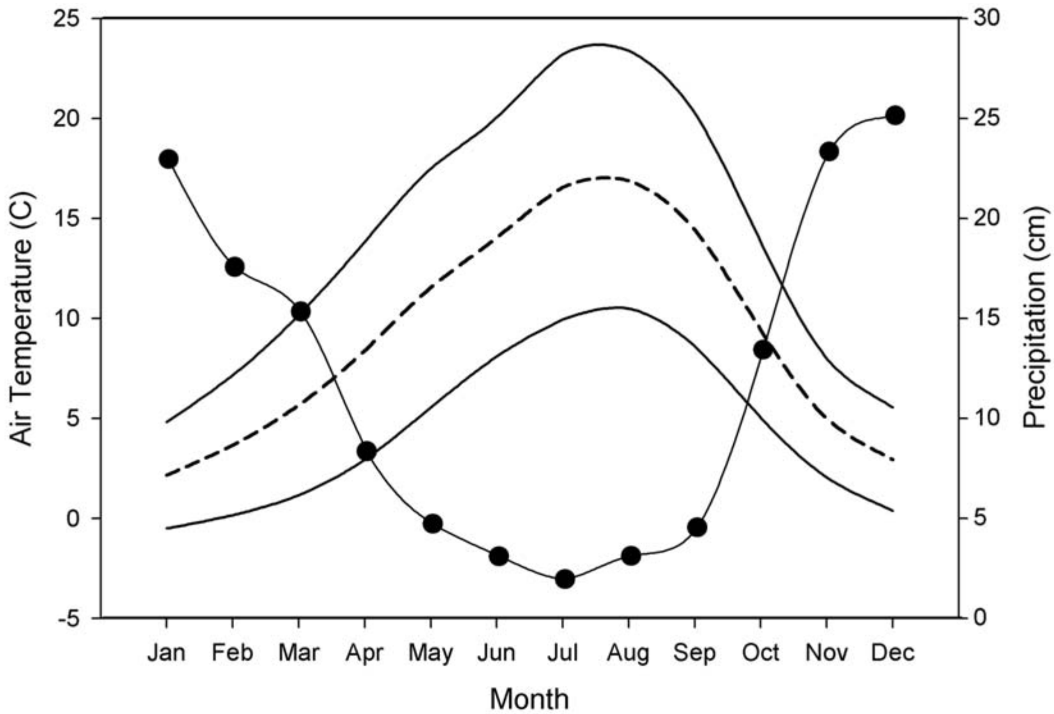

Figure 3. Annual trends in temperature and precipitation in the Elwha River basin. Long-term monthly average (dashed line), maximum (upper solid line), and minimum (lower solid line) temperatures and precipitation (line with circles) were recorded at the Elwha Ranger Station (rkm 18.2) at an elevation of 110 m. The period of record was June 1948 through December 2005.

upright valley walls. These canyons are separated by sections of the river that flow through valley bottoms with a gentle gradient that allows the unconstrained river channel to meander according to a dynamic interplay among sediment, large woody debris, vegetation, and geomorphology (Latterell et al. 2006). The major canyons of the Elwha River Basin, in order of lowest elevation to highest (approximate length in parentheses), are Elwha Canyon (1.7 rkm), Glines Canyon (0.8 rkm), Rica Canyon (1.9 rkm), the Grand Canyon of the Elwha (5.5 rkm), an unnamed canyon above Elkhorn Ranger Station (1.4 rkm), Carleson Canyon (2.3 rkm) between Hayes Ranger Station and Camp Wilder, and another canyon above Camp Wilder (1.2 rkm). Although resident fish utilize fluvial habitat within the canyons, much of the habitat suitable for spawning and rearing of juvenile salmon occurs or will occur within the floodplains.

The Elwha River ecosystem falls within the Olympic Peninsula Province vegetation classification of Franklin and Dyrness (1988). Nearly all vegetation zones of the Olympic Peninsula—typically structured according to topography, climate, and soils (Peterson et al. 1997)—can be found within the Elwha River Valley. Lower elevation forests fall within the western hemlock (*Tsuga heterophylla*) zone and are typically dominated by Douglas fir (*Pseudotsuga menziesii*), mixed with western hemlock and western red cedar (*Thuja plicata*). In the vicinity of Lake Mills and the Lillian River some forests are particularly dry, falling within the Douglas fir zone of Henderson et al. (1989). Here, species more often associated with drier sites, including Rocky Mountain Juniper (*Juniperus scopulorum*), lodgepole pine (*Pinus contorta*), and manzanita (*Arctostaphylos columbiana*) are found. At mid-elevations, forests are in the Pacific silver fir (*Abies amabilis*) zone. At higher elevations dry forests on the eastern ridges are in the subalpine fir (*Abies lasiocarpa*) zone and wetter western ridges have forests in the mountain hemlock (*Tsuga mertensiana*) zone. Forest communities of valley bottoms and river terraces are dominated by red alder (*Alnus rubra*),

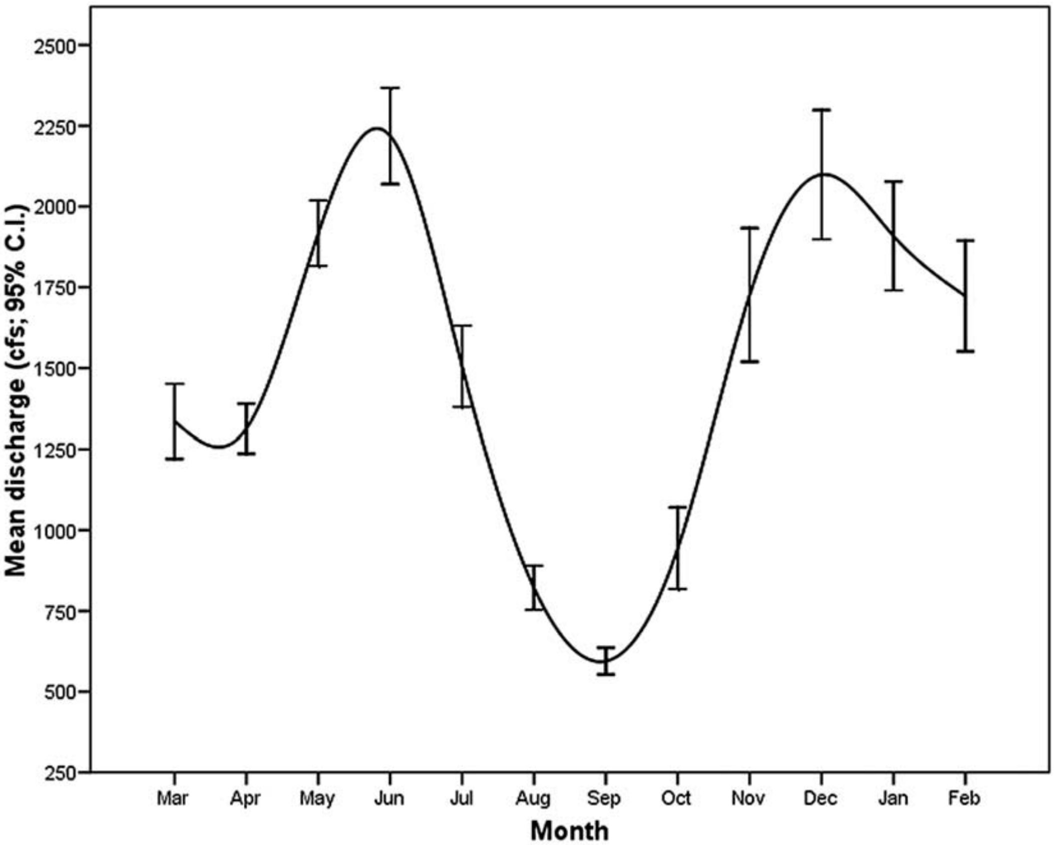

Figure 4. Average monthly discharge (95% CI) for the Elwha River based upon the US Geological Survey gauging station measurements at the McDonald Bridge (rkm 13.8). The period of record was 1928 (the first year following completion of the Glines Canyon dam) through September, 2005.

co-occurring with black cottonwood (*Populus balsamifera ssp. trichocarpa*), grand fir (*Abies grandis*), and bigleaf maple (*Acer macrophyllum*) in varying proportions.

The Elwha River was once home to 10 runs of native anadromous salmon and trout (DOI et al 1994; DOI 1995, 1996a). There was no month of the year when these fish were not migrating upstream, spawning, rearing, or passing juveniles out to sea (DOI et al. 1994, DOI 1995). Salmonid species utilizing the river included coho (*Oncorhynchus kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*), steelhead trout (*O. mykiss,* summer and winter runs) and chinook salmon (*O. tshawytscha* spring and fall runs) that reportedly reached sizes up to 45 kg. Other migratory fish species that utilized the Elwha for at least part of their life cycle included Pacific lamprey (*Entosphenus tridentatus*), coastal cutthroat trout (*O. clarki clarki*), bull trout (*Salvelinus confluentus*), and Eulachon (*Thaleichthys pacificus*; Shaffer et al. 2007). Resident fish (including those found in tributaries) include rainbow trout (*O. mykiss*), multiple species of sculpin (*Cottus* spp.; Wydoski and Whitney 2003), and redside shiner (*Richardsonius balteatus*). Nonnative species were introduced into Lake Mills, Lake Aldwell, and high alpine lakes as recently as 1983 (Brenkman et al. 2008a). Large populations of eastern brook trout (*S. fontinalis*) have become established in sections of the Elwha between the dams and individuals have been reported in the river below Elwha dam. There are unverified reports of eastern brook trout above Lake Mills, although they have not been recorded in numerous contemporary surveys (Brenkman et al. 2008b and references therein). A population of Westslope cutthroat trout (*O. c. lewisi*) in Long Creek, above a migration barrier, has been reported (Adams et al. 1999), although a survey of recently collected genetic material using species-specific genetic markers (Ostberg and Rodriguez 2004) from the Elwha River and Long Creek below the barrier did not find any cutthroat markers (J. Duda, unpublished data).

The existing salmon runs in the Elwha are depressed compared to historic levels (DOI 1995; Pess et al. 2008). Pink and chum salmon have had annual returns of < 100 (odd years only) and < 500 respectively (DOI 1995), with pink salmon being entirely absent in some years. Fall Chinook salmon, coho salmon, and steelhead still spawn in low numbers in the river (approximately 1,500, <500, and <500 respectively), although existing runs are largely the product of hatchery production by the State of Washington and the Lower Elwha Klallam Tribe. The small amount of spawnable area remaining for Chinook salmon (Pess et al. 2008) creates crowding and the fish are susceptible to temperature related outbreaks of *Dermocystidium salmonis*, which has resulted in intermittent high mortality events. Sockeye salmon have been extirpated from Lake Sutherland, although the healthy kokanee (freshwater life history form) population still produces occasional smolts and is expected to contribute to future runs following dam removal. A genetic inventory of salmon and trout stocks by Winans et al. (2008) discusses the existing genetic diversity of the Elwha River in relation to other Puget Sound populations.

The wildlife assemblage of the Elwha basin is typical of Western Washington and the Olympic Peninsula. Large mammals include black bear (*Ursus americanus,* Sager-Fradkin et al. 2008), black-tailed deer (*Odocoileus hemionus*), Roosevelt elk (*Cervus canadensis roosevelti*i), and cougar (*Puma concolor*). Mid-size species include bobcat (*Lynx rufus*), coyote (*Canis latrans*), river otter (*Lontra canadensis*), spotted skunk (*Spilogale putorius*), and beaver (*Castor canadensis*). The present Elwha bird assemblage includes those woodland species familiar in northwestern forests, but with the added influence of the river and two reservoirs. Riverine nesting species include the harlequin duck (*Histrionicus histrionicus*), common merganser (*Mergus merganser*), American dipper (*Cinclus mexicanus*), belted kingfisher (*Ceryle alcyon*), spotted sandpiper (*Actitis macularia*), northern rough-winged swallow (*Stelgidopteryx serripennis*) and bald eagle (*Haliaeetus leucocephalus*). Ospreys (*Pandion haliaetus*) also nest but are much less numerous than the eagles. Although it is undocumented, northern spotted owls (*Strix occidentalis caurina*) probably were found along the Elwha as they were elsewhere in ONP. Since 1990, the spotted owls have been displaced in those areas of the Elwha watershed below 610 m by barred owls (*Strix varia*) expanding their range from the eastern US (Gremel 2005).

In addition to the riverine avifauna, the two lakes formed by the Elwha dams also attract some avian species. Barrow's goldeneye (*Bucephala islandica*), Canada geese (*Branta canadensis*), cackling geese (*Branta hutchinsii*), and hooded mergansers (*Lophodytes cucullatus*) breed on the lakes each spring. Barn (*Hirundo rustica*), cliff (*Petrochelidon pyrrhonota*), and violet-green swallows (*Tachycineta thalassina*) occur in fair numbers around the lakes, benefiting from the reservoirs. All of these swallow species will likely experience sharp drops in abundance when the dams are removed. Small numbers of lesser scaups (*Aythya affinis*), common loons (*Gavia immer*), blue-winged teal (*Anas discors*) and bufflehead (*Bucephala albeola*) have also been seen on the lakes but breeding of these species has not been confirmed and is unlikely. A few species use the lakes as stopping areas in winter including trumpeter swans (*Cygnus buccinator*). Bird abundance on the reservoirs is relatively low, probably because of steep bank elevations and lack of shoreline habitat structure.

Scientific Studies

The Elwha River restoration project is a multi-stage project. Begun in 1992 with passage of the Elwha Restoration Act, Phase 1 involved creation and approval of an Environmental Impact Statement (DOI 1995, 1996a). Phase 2, completed in February 2000 included acquisition of the dams by the NPS. At present, the Project is moving from Phase 3 (planning and design) into Phase 4 (construction of mitigation facilities). The Elwha Restoration Act requires protection of municipal and industrial water supplies from the possible adverse affects of dam removal. A permanent water treatment plant will protect the domestic water supply of Port Angeles while a second plant will protect the Nippon Paper Industries USA pulp and paper mill and two fish propagation facilities only during the sediment release impact period

(Brian Winter, NPS, personal communication 10/30/2007). All needed permits and contracts are now in place and ground breaking for the first of two water treatment facilities occurred in October 2007. Phase 5 (dam removal) is expected to take 2 years and Phase 6 (restoration) will follow over the next several decades.

The papers contained in this volume summarize some of the research conducted in anticipation of dam removal. These scientific studies were informed in part by 4 workshops that brought together researchers to develop study plans focused on key research priorities. These workshops were on sedimentation (Randle et al. 2004), fisheries and wildlife (Schreiner and Winter 2005), nearshore environments (CCMRC 2004), and restoration science (Stolnack et al. 2005). Some of the scientific studies were required for management of the dam removal project (Winter and Crain 2008), represent priority needs of the NPS (Woodward et al. 2008), or seek to advance understanding about dam removal and restoration ecology (e.g., McHenry and Pess 2008).

Certain conventions are generally understood by all researchers working on the river. The "lower river" refers to the section below the Elwha Dam, the "middle river" is between the dams, and the "upper river" refers to the river from above Lake Mills to the headwaters. Temporally, the restoration is a before and after study, with researchers frequently blocking their sampling into the periods before, during, and after dam removal. With respect to topics, the Elwha restoration touches on many areas of biological and physical science. Research projects underway are intended to provide important baselines in such areas as fisheries and wildlife biology, sediment, climate, geomorphology, hydrology, biochemistry, and the fate of large woody debris. Depending on funding levels, these projects intend to follow trajectories of state variables in the years before, during, and following dam removal.

The technical workshops on Elwha dam removal also identified some common assumptions about the biological and physical response of the restoration (summarized by Schreiner and Winter [2005], see also conceptual models in Woodward et al. [2008]) as they relate to the different sections of the river. Since 83% of the watershed is located within the boundaries of ONP, the effect of restoring anadromous populations to the upper river should occur with minimal confounding from other factors associated with human influence. However, the middle and lower reaches of the river differ from the upper reach in this regard, since only a small portion of the middle reach contains old-growth forests, with the remainder of the middle reach and the entire lower reach containing second growth. In addition to effects from the dams, the middle and lower reaches also experience human impacts (e.g., riprap, roads, fisheries, and heavier recreational use) and hence the responses of wildlife abundance, species composition, and the number of nonnative species must be viewed in relation to these factors. Finally, the middle and lower reaches of the Elwha will receive large inputs of sediment eroded out of the reservoirs (DOI 1995, 1996b; Childers et al. 2000, Randle et al. 2004) in the near term. This will affect resident and anadromous populations of fish and be largely responsible for a lag between dam removal and the reestablishment of suitable spawning habitat for anadromous fish.

Conclusion

The Elwha River restoration represents a unique opportunity to study dam removal within a large river ecosystem that is largely protected within the boundaries of a National Park. Although not comprehensive, it is our intention that the information collected in this volume will serve as an important historical record of the scientific studies that have begun in the Elwha River ecosystem.

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