

# 9000 years of salmon fishing on the Columbia River, North America

Virginia L. Butler<sup>a,\*</sup> and Jim E. O'Connor<sup>b</sup>

<sup>a</sup>Department of Anthropology, Portland State University, Portland, OR 97207, USA

<sup>b</sup>U.S. Geological Survey, 10615 SE Cherry Blossom Drive, Portland, OR 97216, USA

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## Abstract

A large assemblage of salmon bones excavated 50 yr ago from an ~10,000-yr-old archaeological site near The Dalles, Oregon, USA, has been the primary evidence that early native people along the Columbia River subsisted on salmon. Recent debate about the human role in creating the deposit prompted excavation of additional deposits and analysis of archaeologic, geologic, and hydrologic conditions at the site. Results indicate an anthropogenic source for most of the salmonid remains, which have associated radiocarbon dates indicating that the site was occupied as long ago as 9300 cal yr B.P. The abundance of salmon bone indicates that salmon was a major food item and suggests that migratory salmonids had well-established spawning populations in some parts of the Columbia Basin by 9300–8200 yr ago.

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## Introduction

In the 19th century, the Columbia River was known as one of the greatest salmon-producing rivers in the world, with annual runs of 10–16 million fish (Northwest Power Planning Council, 2000). Today, populations of all six salmon species known for the basin are severely diminished or extinct. As scientists and resource managers debate the causes of these losses and develop measures to save these fishes from extinction (National Research Council, 1996; Levin and Schiewe, 2001), it is relevant to consider the longer history of salmon in the basin and the role they played in Native American economies.

An area central to discussions of Indian fisheries in the Pacific Northwest is “The Dalles of the Columbia,” where salmon migrating upriver were slowed by a series of falls and chutes through which the river descended 25 m in less than 20 km. The seasonal abundance of salmon and advantageous fishing conditions made this area one of the premier ethno-historic Indian fisheries in North America until inundated by the pool of The Dalles Dam in 1956 (Netboy, 1980). Within this reach, a section known as Fivemile Rapids became the focus of intensive archaeological excavation in the 1950s, directed by Luther Cressman of the University of Oregon, to salvage deposits likely to be affected by the dam (Cressman,

1960). At a site known as “Roadcut” (Fig. 1) (35-WS-8), four radiocarbon ages between 9785 and 6090 <sup>14</sup>C yr B.P. (Table 1) indicated that people had been in the area since the early Holocene, providing some of the earliest and first radiocarbon records for archaeological sites in the Pacific Northwest (Ames et al., 1998; Matson and Coupland, 1995). Additionally, the recovery of an estimated 250,000 salmon remains was used to argue that early peoples on the Columbia River subsisted on salmon (Cressman, 1960; Butler, 1961; Carlson, 1983), resulting in the oft-used expression, “10,000 years of salmon fishing on the Columbia.”

Since this work, researchers have challenged the conclusion that fish bones at the Roadcut site were from human use, suggesting alternatively that they were fluvially deposited carcasses or left behind by scavenging mammals or birds (Browman and Munsell, 1969; Schalk, 1983; Butler, 1993).<sup>1</sup> Given the significance of the site to regional prehistory and questions raised about fishbone origin, we returned to the site for further study. Here, we reevaluate the genesis of the

<sup>1</sup> Bones of scavenging birds (e.g., gull, cormorant, raven, crow, eagle, vulture, condor), known to feast on spawned-out fish were also found in The Dalles deposit. Scholars (Cressman, 1960; Browman and Munsell, 1969; Schalk, 1983; Simons, 1983; Erlandson and Moss, 2001) have debated whether: (1) some or many of the fish remains represent food waste from scavenging birds, (2) the bird remains themselves represent natural death and deposition, and (3) the bird remains represent prey that human hunters captured. According to the last proposal, humans hunted the birds that were in the area preying upon the vast quantities of fish.

\* Corresponding author. Fax: (503) 725-3905.

E-mail address: [butlerv@pdx.edu](mailto:butlerv@pdx.edu) (V.L. Butler).

Table 1  
Radiocarbon dates from The Dalles Roadcut (35-WS-8)

Lab No.	Elevation (m asl)	Context/stratum	Sample description	<sup>14</sup> C yr B.P.	δ <sup>13</sup> C (per mil)	<sup>13</sup> C adjusted age	Cal yr B.P. 2σ
65009	52.20	Feature 1	Multiple charcoal fragments of <i>Pinus ponderosa</i> , from a discrete concentration of charcoal	4640 ± 130	−24.3	4650 ± 130	5,610–4,970
Y-343 <sup>a</sup>	51.47–52.00	Stratum V	Unknown material	6090 ± 80	—	—	7,100–6,750
65007	51.13	Cultural pit fill, feature 2	Charcoal, <i>Pseudotsuga menziesii</i>	6960 ± 120	−26.1	6950 ± 120	7,970–7,580
65006	50.12	Base of stratum 4; adjacent to articulated salmon vertebrae	Charcoal, <i>Salix</i> sp.	7910 ± 130	−28.4	7850 ± 130	9,010–8,410
65008	49.51	Stratum 2	Charcoal	7850 ± 60	−25.3	7850 ± 60	8,780–8,540
65012	49.44	Stratum 2	Charcoal	7960 ± 60	−25.2	7960 ± 60	9,010–8,630
70587	49.36	Stratum 2	Charcoal	7960 ± 70	−25.5	7950 ± 70	9,000–8,630
Y-342 <sup>a</sup>	49.00–49.28	Stratum II	Unknown material	7875 ± 100	—	—	9,000–8,540
65011	49.20	Stratum 2	Multiple charcoal fragments collected from discontinuous carbonized layer	7490 ± 60	−20.7	7560 ± 60	8,430–8,280
Y-341 <sup>a</sup>	47.57–48.67	Stratum I	Charcoal	7675 ± 100	—	—	8,650–8,280
70586	48.21	Stratum 1	Charcoal	8090 ± 90	−25.1	8090 ± 90	9,280–8,700
65005	48.15	Base of 1993 excavation/stratum 1	Charcoal, <i>Populus</i> sp.	7530 ± 100	−23.9	7550 ± 100	8,540–8,160
Y-340 <sup>a</sup>	45.50–47.57	Stratum I	Unknown material; Cressman (1960:23) notes Stratum I contains “decomposing organic matter such as drift and tules and grasses” and that the <sup>14</sup> C date is “a composite for the entire stratum,” suggesting multiple samples from a variety of contexts were included.	9785 ± 220	—	—	11,970–10,500

All 1993 dates are on charcoal and were analyzed by Beta Analytic, Inc. Radiocarbon dates were converted to calibrated calendar years using the CALIB program (v 4.3) based on Stuiver and Reimer (1993) and the bi-decadal atmospheric/inferred atmospheric curve. The conventional half-life, 5568 years, was used and the statistical error does not include a laboratory multiplier. Calibrated ages were obtained using Method B, selecting the age range that falls under the distribution curve at 2 standard deviations that had the highest probability of being correct. Plant remains were identified by N. Stenholm.

<sup>a</sup> 1950s samples: Cressman, 1960; Barendsen et al., 1957. The rest are 1993 samples.

salmon remains at the Roadcut site using new records of archaeologic, geologic, and hydrologic conditions.

### Geologic context and field study

We excavated part of the Roadcut site adjacent to deposits excavated in the 1950s. Both excavations are within deposits partly filling a bedrock hollow at the upstream end of Fivemile Rapids, where the Columbia River flows directly on basalt and has eroded a complex and irregular channel (Fig. 1B). At the head of Fivemile Rapids, the flow of the entire Columbia River contracted from a width of about 550 m into a 2-km-long slot 50–75 m wide. Just upstream of the constriction, annual changes in river stage were between 20 and 30 m, resulting in seasonal exposure of a large sand bar,

known as Fivemile Bar. Sand from this bar and similar ones nearby was blown into dunes that cover much of the rocky valley bottom. During the past 150 yr, the site area has been drastically altered by railroad, canal, dam, and highway construction projects, which have removed, buried, or inundated ancient cultural deposits and geologic features as well as stabilized the historic dune fields.

Cressman's excavation at Roadcut focused on a deposit about 7.8 m thick, but an additional 2 m of overlying sediment had been removed previously during road construction. All the fish remains found by Cressman were in the lowermost 5 m of his excavation, so 1993 work focused on these deeper deposits. We excavated a 1- to 2-m-wide stepped trench through an ~5-m-high section of the bank. Present water levels (because of impoundment behind The Dalles Dam) forced us to cease excavation at 48.05 m above

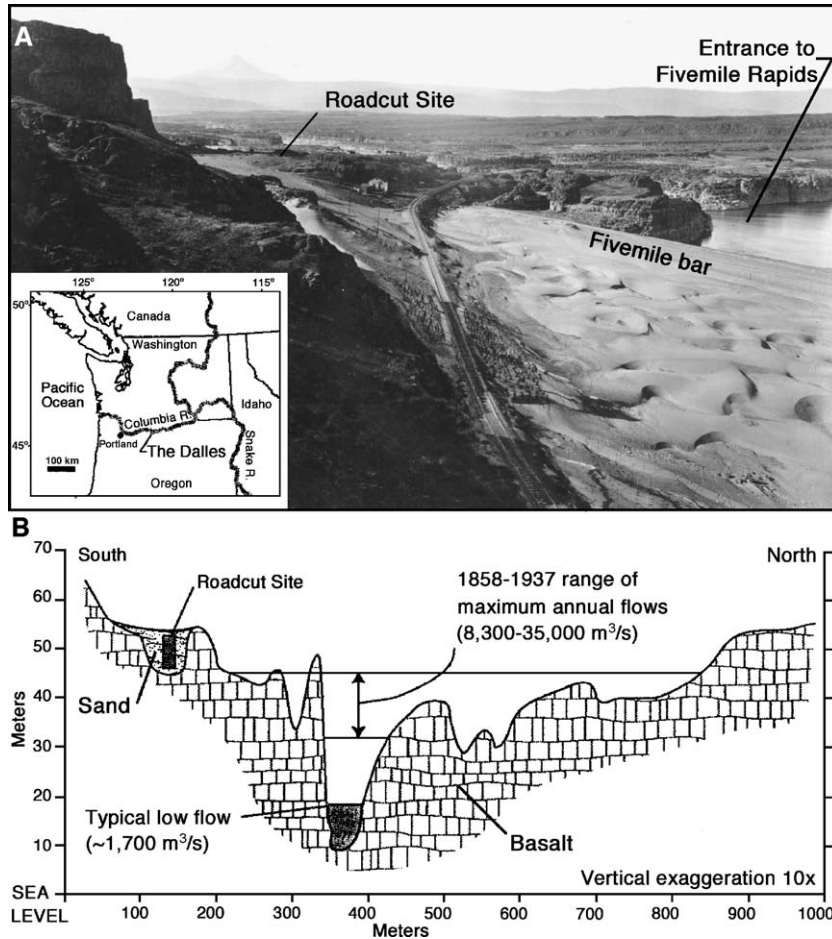


Fig. 1. (A) Carleton E. Watkins photograph of the area near the entrance to Fivemile Rapids as it appeared in 1882. Photograph courtesy of the Oregon Historical Society, Negative Num. ORHI 21648. (B) Geologic cross section of Columbia River valley bottom at the Roadcut site, showing range of preimpoundment maximum annual stages. Topography and stage-discharge relation from Harza and Reineking (1912); maximum annual discharges for unregulated Columbia River flow from the USGS (National Water Information Site, <http://waterdata.usgs.gov/or/nwis>).

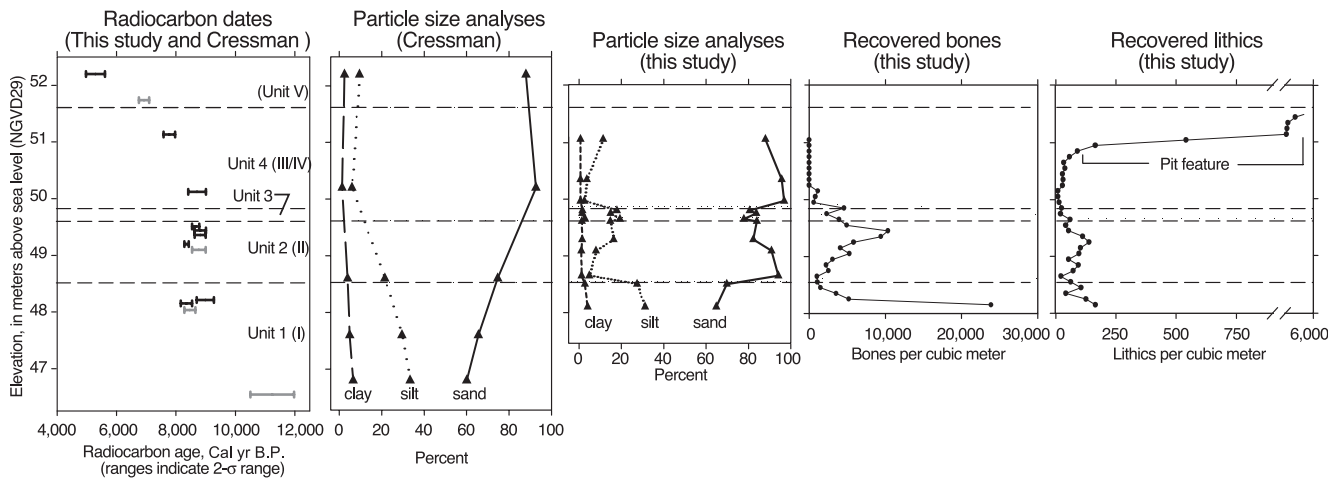


Fig. 2. Summary of stratigraphic records, calibrated radiocarbon dates, particle size, and bone and lithic frequency. Conventional radiocarbon dates from Cressman (1960; in gray) and this study (in black) were converted to calibrated calendar years with the CALIB program (version 4.3), provided by Stuiver and Reimer (1993) (see Table 1). Cressman's calibrated radiocarbon ages are plotted at the midpoint of the elevation range from which the samples were collected. Particle size samples were analyzed by INSTAAR (Institute for Arctic and Alpine Research, Boulder, CO, USA) using the sieve-sedigraph method. Bone frequency includes all specimens, complete and fragmentary, including those not identifiable to taxon. Since almost all of the identifiable faunal remains from the 1993 excavation are from salmon, presumably most of the remains that could not be identified to taxon are also from salmon. Elevation is in meters relative to the National Geodetic Vertical Datum of 1929 (NGVD29).

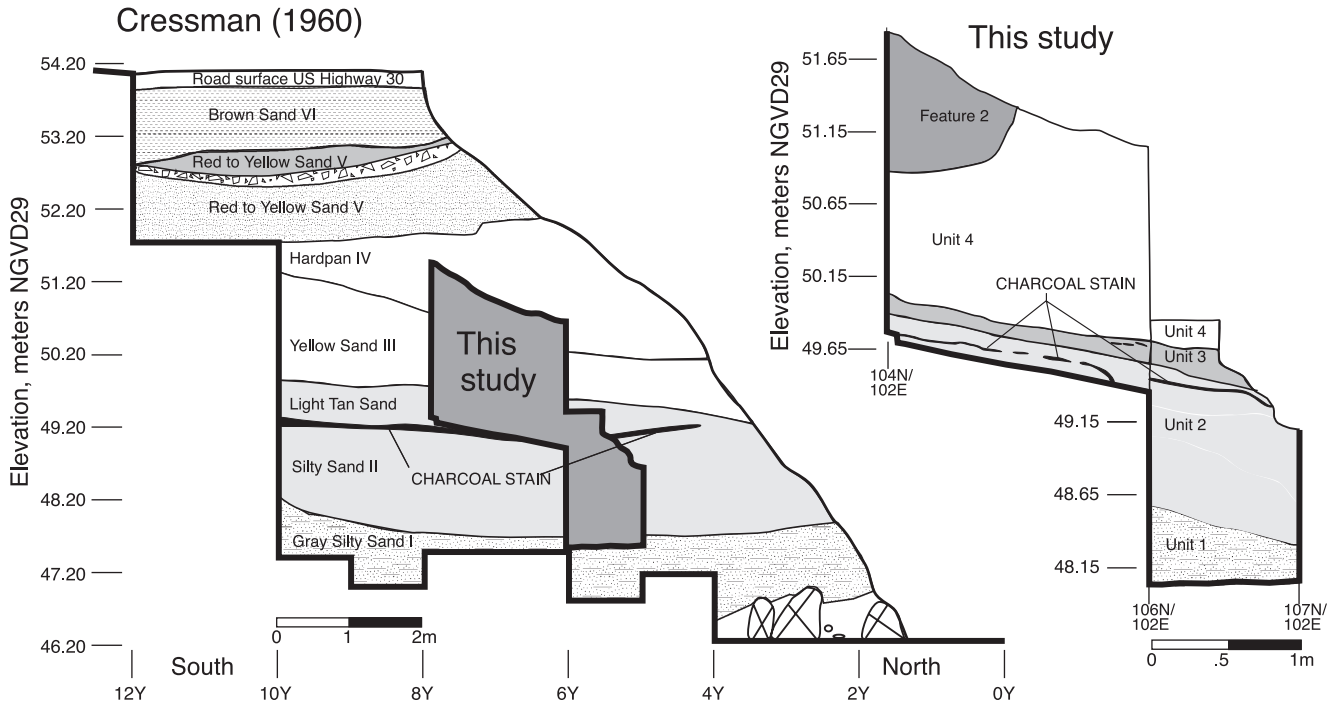


Fig. 3. Stratigraphic profile from 1950s (Cressman, 1960: Fig. 12) and 1993 testing. See text for unit descriptions. 12Y–0Y scale noted along base of Cressman’s profile represents excavation grid unit designations.

sea level, about 2.0 m above the deepest levels reached in the 1950s. Approximately 3.0 m of the original 7.8-m section was examined in detail, and about 10 m<sup>3</sup> of sediment was removed and screened.

**Stratigraphy and chronology**

Stratigraphic units defined in 1993 (labeled 1 through 4, lowest to highest) from sedimentary textures and contacts between deposits were correlated to those recorded during the 1950s excavation (I through V) based on elevation and sedimentologic characteristics (Figs. 2 and 3). The deepest stratum, 1 (I), is a silty sand with relatively high organic content and large quantities of salmon remains. The 1950s excavation recorded several large boulders at the base of this unit. Unit 2 (II) is a sand unit about 1 m thick, capped by a

thin but prominent carbon layer (made of fragmented charcoal, unburned organics). Unit 3 (not distinguished in the 1950s work) is a 10-cm-thick sand unit with abundant



Fig. 4. Articulated salmon vertebrae, found at base of unit 4, 50.10 m asl.

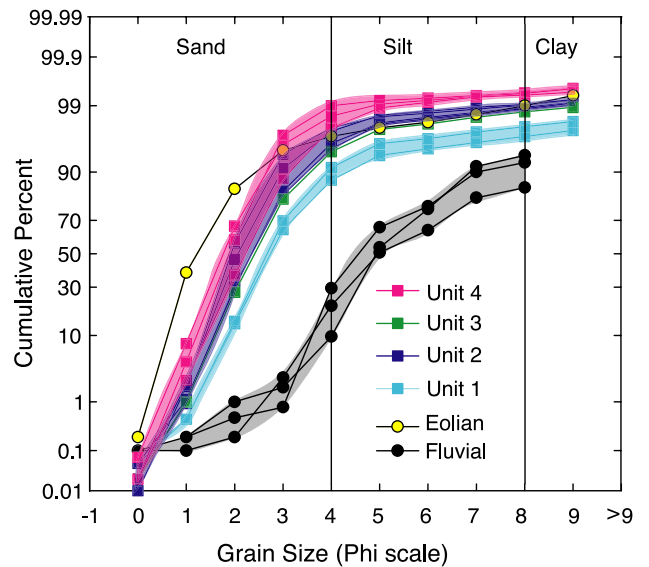


Fig. 5. Grain size analyses from the Roadcut site and nearby eolian and fluvial deposits. Roadcut samples from 1993 excavation grouped by stratigraphic unit. Eolian comparison sample is from dune 2.5 km east of the Roadcut site. Fluvial comparison samples are from shallow Columbia River deposits sampled and analyzed by U.S. Army Corp of Engineers, North Pacific Division Materials Laboratory. Sample locations relative to Columbia River “River Mile”: Bingen Marina, River Mile 171.7; Mayer State Park, River Mile 181; Irrigon Boat Basin, River Mile 282; for reference, Roadcut site at River Mile 194.



salmon bone overlying the carbon-rich top of unit 2. Unit 4 (III–IV) is a massive well-sorted sand unit with little organic matter and sparse bone fragments except for a concentration of articulated salmon vertebrae near the base (Fig. 4). This unit disconformably overlies unit 3 with an irregular contact marked by evidence of local rilling and erosion. A large cultural pit feature was found near the top of unit 4. The 1993 excavation above 51.0 m asl was limited to shovel scraping and sediment descriptions were not obtained, although an intact charcoal concentration was uncovered and dated.

Radiocarbon ages obtained in the 1950s and in 1993 are consistent with stratigraphic position and indicate that the deposits date from perhaps 12,000 cal yr B.P. to about 5000 cal yr B.P. (Table 1). Cressman inferred that the oldest date (11970–10500 cal yr B.P.) represented the earliest human occupation of the site. However, the sample providing this age consisted of multiple organic specimens aggregated from a 2-m-thick section, which included sterile fill (Barendsen et al., 1957), and the association between the dated material and the cultural remains is unclear. A total of eight ages from both excavations in units 1 and 2 (II) range between 9280 and 8160 cal yr B.P. and are closely associated with cultural material. The uppermost and youngest dates are from Cressman's stratum V (7100–6750 cal yr B.P.) and an age of 5610–4970 cal yr B.P. from a charcoal concentration sampled in 1993 during overburden removal.

From the 1993 excavation, we recovered >16,000 faunal remains (including fragmentary and complete specimens); ~5500 specimens could be identified to some taxonomic level (mainly salmonid). About 1600 lithics also were recovered. Distinct bone concentrations were in units 1, 2, and 3. Concentrations of tool-making debris, including about 100 formed objects, such as biface fragments and flaked cobbles, were found in units 1 and 2 and a pit feature was found within unit 4. These distributions are generally similar to those found in the 1950s, except most of the fishbone recovered in the 1950s was from unit II.<sup>2</sup>

## Depositional environment

Depositional environment of Roadcut deposits was inferred from sedimentary characteristics as well as analysis of likelihood of inundation by Holocene floods. Unit 1 is ripple-laminated silty sand, and units 2–4 are primarily sand, locally cross-bedded. Cross-bedding and ripple structures can be left by both water and wind currents, so preserved sedimentary structures were not clearly indicative of depositional environment. However, the well-sorted and high sand content of units 2, 3, and 4 is more like local eolian

sand than fluvial deposits (Figs. 2 and 5). The proximity of the site to sand sources, such as seasonally exposed Fivemile Bar, 200 m to the east, and the abundant photographic and written records of blowing sand and dunes (Fig. 1A) are consistent with at least units 2–4 being eolian, as originally inferred by Cressman. The distinctly finer and less well sorted unit 1 may be fluvial. Unit 4, which is predominantly sand with few bones and lithics, probably resulted from an eolian dune migrating over the site.

Flood frequency analysis also indicates that most of the Roadcut site is above the range of plausible Columbia River floods (Fig. 6) and hence above areas of fluvial deposition of sediment and salmon bones. These flood frequency relations for the Columbia River at The Dalles were compared to stage-discharge relations determined from measurements and computations for a large range of flows at the head of Fivemile Rapids, including the largest historic flood of the Columbia River of 35,100 m<sup>3</sup>/s in 1894. This analysis presumes (1) that there has been little change to the stage-discharge relation at the site (owing to changes in channel and valley morphology) and (2) that the frequency of large floods has not changed systematically over the Holocene because of regional climate or other landscape conditions systematically affecting flood frequency. The likelihood of the first factor affecting results is small since the bedrock channel and valley bottom in this vicinity minimize the possibility of Holocene changes in local stage-discharge relations. The second factor is more difficult to assess, but in the absence of evidence of major Holocene changes in flood frequency, we infer that our analysis from historical records approximates early Holocene flood frequency. With these assumptions and for reasonable uncertainty ranges in both the flood frequency calculations and the stage-discharge relations at Fivemile Rapids, the annual probability of a Columbia River flood reaching the base of the 1950s excavation is perhaps as great as 0.02, consistent with unit 1 being formed from early Holocene floods of 1894 magnitude and greater. In contrast, the annual probability of floods reaching unit 2 and higher parts of the Roadcut site is substantially less than 0.0001.

Since the sedimentology and flood frequency analysis indicate that units 2, 3, and 4 are not fluvial, it is unlikely that the enclosed salmon bones are fluvially deposited carcasses or bones. Are the fish bones the partially digested or defecated remains from nonhuman scavengers? Consistent with this is the presence of bones from scavenging birds at the site. However, the salmon bones show no evidence of pitting or rounding, as would be expected from vertebrate digestive process (Butler and Schroeder, 1998). Moreover, new analysis of bird bone excavated at the site during the 1950s shows that 331 (of 9166 identified specimens) have stone tool marks (Hansel-Kuehn, 2003), supporting the interpretation that humans likely accumulated and deposited the bird remains as well.

Our work suggests the following scenario. Between ~18,000 and 14,000 cal yr B.P., the Missoula floods eroded

<sup>2</sup> Distribution information from 1950s work is from Cressman (1960), Fig. 21, which plots relative frequency of artifact classes by level. This shows declines in several lithic classes (so-called blades, biface choppers, and burins) and complete absence of all vertebrate remains and bone tools above unit III (~49.90 m asl).

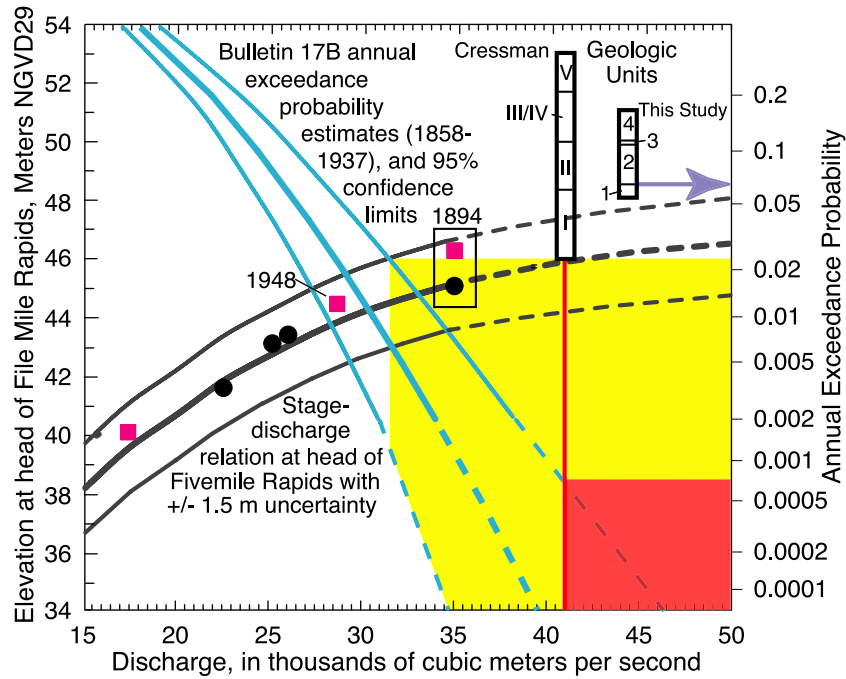


Fig. 6. Stage discharge and flood frequency relations for the Roadcut site. Black lines and points represent stage-discharge relation relative to NGVD29 (National Geodetic Vertical Datum, established in 1929) at head of Fivemile Rapids, approximately 200 m upstream of the Roadcut site, modified from Harza and Reineking (1912; Fig. 12) and dashed where extrapolated beyond measurements. Gray points represent peak discharges as currently reported by the USGS (National Water Information Site, <http://waterdata.usgs.gov/or/nwis>) for 1903, 1880, 1887, and 1894 plotted to corresponding stage value as depicted in Fig. 12 of Harza and Reineking (1912). Uncertainty in the stage-discharge relation owes to possible discrepancy between the elevation datum used by Harza and Reineking and NGVD29. The maximum possible discrepancy is judged less than 1.5 m based on comparison of detailed topographic maps shown in Harza and Reineking (1912; Fig. 1) and Cressman (1960; Map 3). This is corroborated by stage-discharge values reported by the U.S. Army Corps of Engineers (1953) and referenced to NGVD29 (red squares), including stage measurements for flows of 17,000 and 28,600 m<sup>3</sup>/s (1948 flood) and estimated for the 1894 flood on the basis of step-backwater computations. Elevations of geologic units at the Roadcut site, defined by Cressman (1960) and this study, are referenced to NGVD29. Flood frequency analysis (blue lines) relating flood discharge to annual exceedance probability (right vertical axis) conducted on the basis of 1858–1937 annual peaks (the unregulated period) for the Columbia River USGS streamflow station at The Dalles (Station 14105700) using Bulletin 17B guidelines (U.S. Water Resources Council, 1981). Dashed lines show extrapolation beyond annual exceedance probabilities of less than 0.002 (the “500 year flood”). The base of unit I, as measured by Cressman, is about 1.0 m above the measured 1894 peak flood stage, corresponding to a discharge of 42,000 m<sup>3</sup>/s (vertical red line) and an annual exceedance probability less than 0.001 (red shaded area), but perhaps as great as 0.02 considering the maximum plausible uncertainty in the Harza and Reineking survey data and the 95% confidence limits in the flood frequency analysis (indicated by yellow shaded area). In either case, the elevation of the base of unit I was likely inundated by Columbia River floods several times over the Holocene. In contrast, the bottom of unit 2/II requires a discharge substantially greater than 50,000 m<sup>3</sup>/s (horizontal blue arrow), even allowing for uncertainty in survey data, corresponding to annual exceedance probabilities substantially less than 0.0001.

the ragged basalt surface of the valley bottom and the chute containing the historic Columbia River. Boulders at the base of the Roadcut deposit were deposited by Pleistocene floods or by rock fall from the valley margins. The scoured depression or side channel began to fill with fluvial and perhaps eolian deposits after about 12,000 cal yr B.P., forming unit 1 of the Roadcut deposit. Between 9300 and 8200 cal yr B.P., relatively coarse and well-sorted sand covered the site, almost certainly of eolian origin and perhaps representing a dune. Abundant stone tools, well-preserved salmon bone, butchered bird bone, and high carbon content indicate human use of the site during this time. The presence of bedding and associated artifacts, and the sequence of similar radiocarbon ages, suggests periodic stability and human use over a relatively short period. Continued additional accretion of thin units by wind and cultural deposition of fish remains and stone tools formed the

tops of unit 2 and unit 3. The well-sorted and bedded sand of unit 4 probably indicates deposition of another sand dune at the site sometime shortly after 8200 yr ago. The scarcity of bone and lithics in this unit (see also Cressman, 1960: Fig. 21) suggests that deposition was relatively rapid, limiting human use of the site area between ~8200 and 8000 cal yr B.P. (Figs. 2 and 3). Subsequent surface stability and renewal of cultural occupation are indicated from the construction of the large pit after 7970–7580 cal yr B.P. Human occupation continued at the Roadcut locale until at least 5610–4970 cal yr B.P. Twentieth century site disturbance almost certainly obliterated an even more recent record of human occupation at this particular locale, but nearby excavations on both sides of Fivemile Rapids indicate intensive Native American use of this area throughout the late Holocene up to and including the historic period (Butler, 1958; Cressman, 1960; Strong et al., 1930).

## Conclusions

We conclude that the salmon bones in units 2 and 3, with their locally coincident high concentrations of lithics (Fig. 2), are most likely the remains of human food preparation on surfaces episodically formed by eolian sand deposition. The abundance of salmon bone, recovered from the large-scale excavation in the 1950s (Butler, 1993), indicates that salmon was a major food item and suggests that migratory salmonids had well-established spawning populations in some parts of the Columbia River Basin by 9300–8200 yr ago.

Records from The Dalles and other Columbia River archaeological sites dating throughout the Holocene (e.g., Minor et al., 1999; Livingston, 1985) confirm that salmon have been important to native peoples for roughly 10,000 yr. Records also show that subsistence was highly variable; in some locales and time periods terrestrial resources and other fishes were as important if not more important to human subsistence, perhaps due to changes in salmon and other prey abundance and social organization and technology (Schalk, 1986; Chatters, 1995; Chatters et al., 1995; Butler, 2000). In addition to their relevance to questions of ancient human activities, geoarchaeological records like these help establish baseline conditions for animal populations prior to Euro-American arrival and provide additional context for understanding long-term trends in salmonid distribution and abundance (e.g., Finney et al., 2002).

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## References

Ames, K.M., Dumond, D.E., Galm, J.R., Minor, R., 1998. Prehistory of the Southern Plateau. In: Walker, D.E. (Ed.), *Handbook of North American Indians, Plateau*. Smithsonian Institution Press, Washington, DC, pp. 103–119.

Barendsen, G.W., Deevey, E.S., Gralinski, L.J., 1957. Yale natural radiocarbon measurements III. *Science* 126, 908–919.

Browman, D.L., Munsell, D.A., 1969. Columbia Plateau prehistory: cul-

tural development and impinging influences. *American Antiquity* 34, 249–264.

Butler, B.R., 1958. Archaeological Investigations on the Washington Shore of The Dalles Reservoir, 1955–1957. Contract 14-10-434-126 between U.S. National Park Service and the University of Washington.

Butler, B.R., 1961. The Old Cordilleran Culture in the Pacific Northwest. *Occasional Papers of the Idaho State College Museum* 5, Pocatello.

Butler, V.L., 1993. Natural versus cultural salmonid remains: origin of The Dalles Roadcut bones, Columbia River, Oregon, U.S.A. *Journal of Archaeological Science* 20, 1–24.

Butler, V.L., 2000. Resource depression on the northwest coast of North America. *Antiquity* 74, 649–661.

Butler, V.L., Schroeder, R.A., 1998. Do digestive processes leave diagnostic traces on fish bones? *Journal of Archaeological Science* 25, 957–971.

Carlson, R.L., 1983. The far west. In: Shutler Jr., R. (Ed.), *Early Man in the New World*. Sage Publishers, Beverly Hills, pp. 73–96.

Chatters, J.C., 1995. Population growth, climatic cooling, and the development of collector strategies on the Southern Plateau. *Journal of World Prehistory* 9, 341–400.

Chatters, J.C., Butler, V.L., Scott, M.J., Anderson, D.M., Neitzel, D.A., 1995. A paleoscience approach to estimating the effects of climatic warming on the salmonid fisheries of the Columbia River Basin. In: Beamish, R.J. (Ed.), *Climate Change and Northern Fish Populations*. Canadian Special Publications in Fisheries and Aquatic Sciences, vol. 121, pp. 489–496. Ottawa.

Cressman, L.S., 1960. Cultural sequences at The Dalles, Oregon: a contribution to Pacific Northwest prehistory. *Transactions of the American Philosophical Society* 50 (Philadelphia).

Erlanson, J.M., Moss, M.L., 2001. Shellfish feeders, carrion eaters, and the archaeology of aquatic adaptations. *American Antiquity* 66, 413–432.

Finney, B.P., Gregory-Eaves, I., Douglas, M.S.V., Smol, J.P., 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. *Nature* 416, 729–733.

Hansel-Kuehn, V.J., 2003. The Dalles Roadcut (Fivemile Rapids) Avifauna: Evidence for a Cultural Origin. Washington State University, Pullman. M.A. thesis.

Harza, L.F., Reineking, V.H., 1912. The Columbia River Power Project near The Dalles, Oregon. Bulletin No. 3. Office of the State Engineer, Salem, OR.

Levin, P.S., Schiewe, M.H., 2001. Preserving salmon biodiversity. *American Scientist* 89, 230–239.

Livingston, S., 1985. Summary of faunal data. In: Cambell, S.K. (Ed.), *Summary of Results, Chief Joseph Dam Cultural Resources Project*, Washington. Office of Public Archaeology, Institute of Environmental Studies, University of Washington, Seattle, pp. 365–419.

Matson, R.G., Coupland, G., 1995. *Prehistory of the Northwest Coast*. Academic Press, New York.

Minor, R., Toepel, K.A., Greenspan, R.L., 1999. Bob's Point: further evidence of pre- and post-Mazama occupation in The Dalles area of the middle Columbia River valley. *Archaeology in Washington* 7, 37–56.

Netboy, A., 1980. *The Columbia River Salmon and Steelhead Trout: Their Fight for Survival*. University of Washington, Seattle.

National Research Council, 1996. *Upstream: Salmon and Society in the Pacific Northwest*. National Academy Press, Washington, DC.

Northwest Power Planning Council, 2000. Estimates of hydropower-related losses Technical Appendix F. Columbia River Fish and Wildlife Program, Portland.

Schalk, R.F., 1983. Cultural Resource Investigations for the Lyons Ferry Fish Hatchery Project, near Lyons Ferry Washington. Laboratory of Archaeology and History, Washington State University, Pullman.

Schalk, R.F., 1986. Estimating salmon and steelhead usage in the Columbia Basin before 1850: the anthropological perspective. *Northwest Environmental Journal* 2, 1–29.

Simons, D.D., 1983. Interactions between California condors and humans in prehistoric far western North America. In: Wilbur, S.R., Jackson, J.A. (Eds.), *Culture Biology and Management*. University of California Press, Berkeley, pp. 470–494.

Strong, W.D., Schenck, W.E., Steward, J.H., 1930. Archaeology of The Dalles–Deschutes region. University of California Publications in American Archaeology and Ethnology 29 (Berkeley).

Stuiver, M., Reimer, P.J., 1993. Extended  $^{14}\text{C}$  database and revised CALIB radiocarbon calibration program. Radiocarbon 35, 215–230.

U.S. Army Corps of Engineers, 1953. Reservoir regulation, The Dalles Project. Design Memorandum No. 10, Portland.

U.S. Water Resources Council, 1981. Guidelines for determining flood flow frequency. Bulletin No. 17B, Hydrology Committee. U.S. Government Printing Office, Washington, DC.