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Biological Evaluation of Potential Impacts of a Recreational Boat Dock on Anadromous Fish Migrating Through Camas-Washington Reach of the Columbia River

October 16, 2021

Prepared for:
U.S. Army Corps of Engineers, Seattle District
Regulatory Branch

Contents

[1]Multiple sources including <https://wdfw.wa.gov/species-habitats/species/oncorhynchus-keta>

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1 Introduction

1.1 Need

Robert and Susan Nevin own a recreational boat and have been on a waiting list for a mooring slip at the marina operated by the Port of Camas-Washougal for more than four years. Because a mooring slip at the port is not likely to be available for a long time they want to install a small dock on their property located at 2462 SE 11th Ave., Camas, WA 98607.

The dock, 6 feet wide and 32 feet long, will be built elsewhere, floated to the river bank at the south end of their property and be secured by sliding attachments to 12-inch diameter hollow steel pilings.

Because this is new construction in the Columbia River, and there are several ESA-listed fish species that migrate through this area, this Biological Evaluation will provide the National Marine Fisheries Service with scientifically-sound information for preparation of a Biological Opinion that will justify the US Army Corps of Engineers' decision to approve installation of this recreational boat dock.

1.2 Location

The Nevin's property is immediately west of the marina operated by the Port of Camas-Washington and immediately east of two residential properties each having a recreational boat dock extending from the river bank uplands into the water (Figure 1.1).

Because this location is between existing in-river docks out-migrating juvenile fish most likely will avoid the northern river area and in-migrating adult fish will continue to use the deeper water near the center of the river.

The river's depths in this reach (as measured by the US Army Corps of Engineers as part of their navigational channel maintenance responsibilities) are shown in Figure 1.2.

Figure 1.1: The Nevin's property is between the marina immediately to the east and the residential properties with the docks to the west.

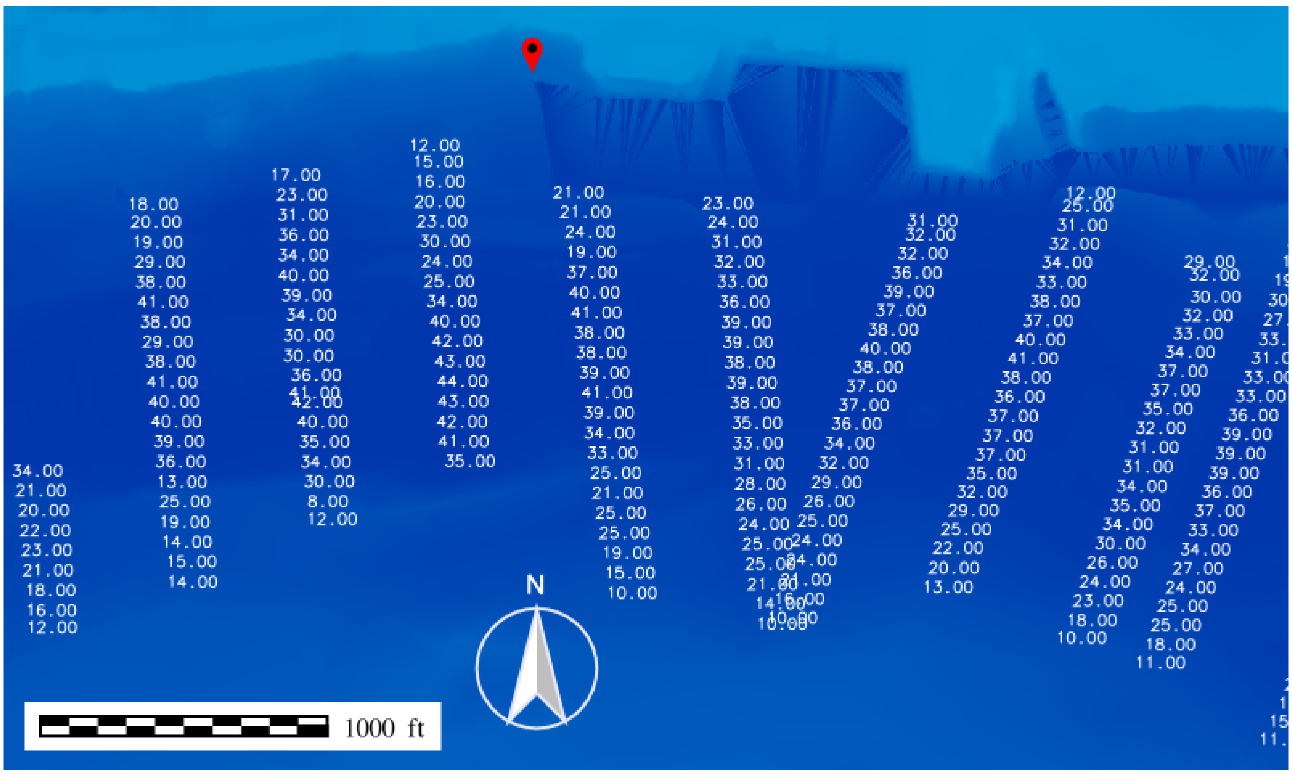

Figure 1.2: River bathymetry (depths) in the Columbia River along the Camas-Washougal boundary. The location of the proposed recreational boat dock is shown by the red pin symbol. The background shows high-resolution depth measurements using LiDAR (Light Detection and Ranging); the marina and covered berthing slips are immediately to the right of the Nevin's property. The depth measurements are from the Corps of Engineers 2010 channel cross-section transects.

2 Fish

2.1 Introduction

There are many resident and anadromous fish species present throughout the year along this Camas-Washougal reach of the lower Columbia River. The ESA-listed species of concern include chinook salmon (*Oncorhynchus tschawtscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*; ocean-rearing rainbow trout), sockeye salmon (*O. nerka*), chum salmon (*O. keta*), white sturgeon (*Acipenser transmontanus*) bull trout (*Salvelinus confluentus*), Pacific lamprey (*Entosphenus tridentatus*). and Pacific smelt (eulachon; *Thaleichthys pacificus*).

While green sturgeon (*Acipenser medirostris*) are present in the lower Columbia River their distribution is limited to the salt water estuary in the lower 40 (±) miles of the river. White sturgeon have a much larger distribution extending well upriver from the Portland/Vancouver area.

Different populations (stocks, runs) of these species reproduce and rear in tributaries of the Columbia and Snake River systems but both juveniles and adults will migrate through this river reach.

Life histories and migratory behaviors of Pacific salmon are described in Groot and Margolis (1991). There are juvenile and adult salmonids migrating through the lower Columbia River in the region of the proposed dock throughout the year. Their specific behaviors and survival are controlled primarily by agents not under human control, including ocean conditions and river temperatures.

> "The lower Columbia River serves as rearing habitat and a migration corridor for multiple endangered and threatened salmonid species. There is growing concern that summertime Columbia River water temperatures, which have been increasing for several decades, are inducing thermal stress on populations of these fish that utilize the river during this period. In response to this concern the Lower Columbia Estuary Partnership, with funding from EPA, completed a multi-year, three phase study to document the extent and quality of cold-water inputs to the lower Columbia River which are, or potentially could be, utilized by summer migrating salmonid species for thermal respite from warm Columbia River mainstem water." (Marcoe et al., 2018)

2.2 Species' behaviors in lower Columbia River

2.2.1 Bull trout

Bull trout are a species of charr, a group in the salmonid family distinct from other trout and salmon. Other North American charr species include Dolly Varden, lake trout, brook trout, and arctic charr.

Bull trout are the only charr species native to Oregon. Charr are distinguished from trout and salmon by a lack of black spots on the body, small scales, and being highly adapted to very cold water. [1]

Bull trout are native throughout the Pacific Northwest. In Oregon, bull trout were historically found in the Willamette River and its major tributaries on the west side of the Oregon Cascades, the Columbia and Snake Rivers and their major tributaries, and in streams in the Klamath basin. Currently, most bull trout populations are confined to headwater areas of tributaries to the Columbia, Snake, and Klamath rivers.

Bull trout occur in the coldest waters of the state, typically where temperatures rarely exceed 60°F. Besides very cold water, bull trout require stable stream channels, clean spawning gravel, complex and diverse cover, and unblocked migration routes.

Bull trout are native, not anadromous; they do not migrate to and from the Pacific Ocean. Bull trout are not found in the lower mainstem Columbia River in the vicinity of the proposed dock in Camas.

2.2.2 Chinook salmon

There are two races of chinook salmon: stream-type and ocean-type.

Stream-type

- Long freshwater residence as juveniles.
- Adult runs in spring and summer.
- Adults enter freshwater months before spawning.
- Variation in age of seaward migration (years).
- Variation in age of maturity for both males and females.
- Variation in time of return to natal stream: February–July.
- Variation in fecundity but high fecundity.

Ocean-type

- Short freshwater residence as juveniles.
- Adult runs in summer and autumn.
- Adults spawn soon after entering fresh water.
- Variation in time of seaward migration (weeks).
- Variation in length of estuarine residence (weeks).
- Variation in age of maturity for both males and females.
- Variation in time of return to natal streams: July–December.
- Variation in fecundity but low fecundity.

[1] Extracted from `https://www.fws.gov/oregonfwo/articles.cfm?id=149489411`

2.2.3 Chum salmon[2]

Chum salmon are large, strong swimmers and are capable of swimming in currents of moderate to high velocities. The maximum swimming speed recorded is 3.05 m/sec (10 ft/sec) or 67% of the maximum burst speed of 4.6 m/sec (15 ft/sec). Chum salmon are not leapers and are usually reluctant to enter long-span fish ladders. Therefore, they are generally found below the first barrier of any significance in a river.

Male chum salmon develop large "teeth" during spawning, which resemble canine teeth. This many explain the nickname dog salmon.

Chum use small coastal streams and the lower reaches of larger rivers. They often use the same streams as coho, but coho tend to move further up the watershed and chum generally spawn closer to saltwater. This may be due to their larger size, which requires deeper water to swim in, or their jumping ability, which is inferior to coho. Either way, the result is a watershed divided between the two species, with all the niches filled.

Like coho, chum can be found in virtually every small coastal stream. In the fall, large numbers of chum can often be seen in the lower reaches of these streams, providing opportunities to view wild salmon in a natural environment.

Chum fry do not rear in freshwater for more than a few days. Shortly after they emerge, chum fry move downstream to the estuary and rear there for several months before heading out to the open ocean.

2.2.4 Coho salmon

Coho salmon are distributed In the lower Columbia River, from the ocean to the Bonneville Dam and in tributaries other than the Willamette River. Throughout this range, native coho salmon populations return to their natal streams to spawn from early fall to late spring. Fry emerge from redds between early March and July, rear in fresh water for a year, and migrate to the sea the next season. They return to spawn after spending 5 to 20 months in the ocean.

Coho salmon populations show timing differences from fry emergence to time of adult spawner returns. Coho salmon show freshwater, estuarine, and ocean migratory patterns apparently determined by the geographic area of their natal streams. Homing and spawning behavior is complex and would suggest a selection mechanism that appears sufficient to reduce gene flow from nonnative populations. However, available evidence shows that the massive and extensive disruptions documented in coho salmon populations in the lower Columbia River have depleted native populations enough that population differences have been largely eliminated.

Coho salmon in the lower Columbia River might already be extinct according to the US Geological Survey.[3]

[2] Multiple sources including <https://wdfw.wa.gov/species-habitats/species/oncorhynchus-keta>
[3] <https://www.usgs.gov/faqs/how-far-do-salmon-travel>

Figure 2.1: Penny Postcard: Smelting, Sandy River, Troutdale, Oregon. Divided Back, "Sandy River, Oregon.". Published by Western Color Sales Inc., Portland, Oregon. Card #K1806. In the private collection of Lyn Topinka.

2.2.5 Eulachon (Pacific smelt)

> "The eulachon is an anadromous species, leaving the ocean to ascend rivers and streams to spawn. Adults enter fresh water and spawn from February to mid-May. Typically, males enter the rivers first, followed shortly by the females. Most spawning eulachon are three years old though they can live up to five years. Spawning is done in large masses and usually during the night. The females' eggs and the males' sperm are dispersed together into the water column and the fertilized eggs quickly attach to gravel, wood or the sandy bottom of rivers. Most adults die shortly after spawning. The 7,000 to 60,000 eggs per female hatch in five to six weeks. Because of its small size the larval eulachon are rapidly swept downstream and out into the estuaries and open ocean."[4]

Across from Camas, WA, is Troutdale, OR, and the confluence of the Sandy River into the Columbia River. Troutdale is known for its (former) large smelt runs and the dip-netters who collected buckets full of these fish above the bridge at Glen Oaks Park (Figure 2.1).

[4]Pacific State Marine Fisheries Commission, 2013, Smelt fact sheet

2.2.6 Pacific lamprey

Pacific lampreys were common in the lower Columbia River in the past; now the largest populations are in the Willamette River where tribal members net the fish at Willamette Falls. Along the main stem Columbia River lamprey migrate past the project location to sites further upriver and in the Snake River.

Pacific lampreys spawn between March and July. Males and females both construct nests–redds–by moving stones with their mouths. Adults typically die within 3-36 days after spawning.

After larval lamprey (ammocoetes) hatch, they drift downstream to areas with slower water velocity and fine sand for them to burrow into. Ammocoetes will grow and live in riverbeds and streambeds for 2 to 7 years, where they filter feed primarily on algae.

The changes of Pacific lamprey from ammocoetes into macropthalmia (juveniles) occurs gradually over several months. During this process they develop eyes and teeth, and emerge from the substrate to swimming in the open water. This transformation typically begins in the summer and is completed by winter.

Juvenile lampreys drift or swim downstream to the estuaries between late fall and spring. They mature into adults during this migration and in the open ocean.

Adult Pacific lampreys are parasites: they use their sucker-like disc mouth to feed on a variety of marine and anadromous fish species.

After 1–3 years in the ocean, Pacific lampreys stop feeding and migrate to fresh water between February and June. They overwinter in freshwater habitat—shrinking in size by up to 20 percent—before they resume their spawning journey.

After spawning adult lampreys die, but their bodies provide valuable food for insects and macroinvertebrates that other species, including other lamprey, use for food.

2.2.7 Sockeye salmon

Most sockeye salmon return from the ocean as four-year-olds, but some return as young as three or as old as eight. All require a lake at the headwaters of their chosen stream in which to rear. The adults pass through the lake to smaller, tributary streams where the females dig their redds. The female releases an average of 3,500 eggs. After hatching in early spring, the young fish move immediately into the lake. Most will spend a full year there before migrating to the ocean.

Perhaps the most famous lake where sockeye return is Redfish Lake in Idaho. The lake got its name from the red color of the returning sockeye salmon. To get to the lake, sockeye swim a journey of 897 miles and climb over 6,500 feet in elevation.

In the lower Columbia River sockeye salmon pass by the project site on their way upriver to spawning lakes or downriver to the ocean.

2.2.8 Steelhead trout

> "For anadromous Pacific salmon (*Oncorhynchus* sp.), ocean conditions during their initial entry into the marine environment can greatly affect their survival. Different life history

> types or stocks may experience different conditions during their marine entry because routes of early marine migration can differ among types or stocks. Steelhead (*O. mykiss*) from the Columbia River are believed to migrate offshore quickly once they enter the ocean, but little is known about whether life history or stock-specific differences in early marine migration exist." (Van Doornik et al., 2019)

Unlike most anadromous salmonids, summer steelhead overwinter in rivers rather than the ocean for 6–10 months prior to spring spawning. Overwintering in rivers may make summer steelhead more vulnerable to harvest and other mortality sources than are other anadromous populations. Within the regulated lower Columbia-Snake River hydrosystem dams an estimated 12.4% of fish that reached upper Columbia/Snake Rivers spawning areas had overwintered in the lower Columbia River. (Keefer et al., 2008)

High spill volume at dams can create supersaturated dissolved gas conditions that may have negative effects on fishes. Water spilling over Columbia and Snake River dams during the spring and summer freshet creates plumes of high dissolved gas that extend downstream of dam spillways and creates gas supersaturated conditions that do not equilibrate in reservoirs. (Johnson et al., 2005)

Migration depth plays a central role in the development and expression of gas bubble disease because hydrostatic compensation reduced the effects of exposure at greater depth. Migration paths of 28 individual fish tagged with radio storage data devices were monitored in the tailraces of Bonneville and Ice Harbor dams and correlated well with output from a two-dimensional dissolved gas model to estimate the degree of uncompensated exposure .

The tagged adult steelhead spent a majority of their time at depths deeper than 2 m, providing at least 20% hydrostatic compensation, interspersed with periods lasting minutes at depths shallower than 2 m. The longest successive time and individual fish was observed shallower than 1 and 2 m was 17 h and 8.5 d, respectively. Steelhead spending the longest durations of time near the surface (< 2 m) were likely near the mouth of a Columbia River tributary based on body temperatures obtained from recorded water temperature data that were cooler than the mainstem Columbia River.

2.2.9 White sturgeon

The largest populations of white sturgeon in the Columbia River are in the estuary of the Columbia River. The migration of sturgeon from ocean water to fresh water occurs between January and July, with runs less consistent and less frequent than those of salmon, since they spawn only every two to eight years. During their migration sturgeon feed on freshwater clams, eel, anchovies, salmon, steelhead, smelt and shad.

> "Spawning and early life history of white sturgeon, *Acipenser transmontanus*, were studied in the lower Columbia River downstream from Bonneville Dam from 1988 through 1991. From white sturgeon egg collections, we determined that successful spawning occurred in all four years and that the estimated spawning period each year ranged from 38 to 48 days. The spawning period extended from late April or early May through late June or early July of each year. Spawning occurred primarily in the fast-flowing section of the river downstream from Bonneville Dam, at water temperatures ranging from 10°–19° C. Freshly fertilized white sturgeon eggs were collected at turbidities ranging from 2.2 to 11.5 nephelometric turbidity units (NTU), near-bottom velocities ranging from 0.6 to 2.4

m/sec, mean water column velocities ranging from 1.0 to 2.8 m/sec, and depths ranging from 3 to 23 m.

Bottom substrate in the river section where freshly fertilized eggs were most abundant was primarily cobble and boulder. White sturgeon larvae were collected from river kilometer (Rkm) 45 to Rkm 232, suggesting wide dispersal after hatching. Larvae were collected as far downstream as the upper end of the Columbia River estuary, which is a freshwater environment. Young-of-the-year (YOY) white sturgeon were first captured in late June, less than two months after spawning was estimated to have begun. Growth was rapid during the first summer; YOY white sturgeon reached a minimum mean total length of 176 mm and a minimum mean weight of 30 g by the end of September. Young-of-the-year white sturgeon were more abundant in deeper water (mean minimum depth ~12.5 m) of the lower Columbia River. The results indicate that a large area of the lower Columbia River is used by white sturgeon at different life history stages." (McCabe Jr and Tracy, 1994)

3 Lower Columbia River hydraulics

3.1 Introduction

Water flows in the lower Columbia River are as important as temperature, dissolved oxygen, other water chemistry constituents, and river bank structures in salmon migration both toward the ocean and returning to fresh water.

The US Geological Survey has a gauge (number 14144700) attached to a west-side structure of the I-5 bridge at Vancouver[1]. The parameters of interest, and their period of record are presented in Table 3.1.

3.2 Flows below Bonneville Dam

Lower Columbia River flows vary seasonally with storm events and snowmelt runoff. The flows also fluctuate weekly based on power generation at Bonneville Dam. Electric power demands in the greater Portland metropolitan area increase over the weekend so more dam discharge is directed through the generator turbines from Thursday through Sunday which increases downriver water levels, discharge, and velocities. These hydraulic parameters can vary greatly each day. Monthly mean values[2] more clearly show this variability in Figures 3.1, 3.2, and 3.3. It is important to notice the very high variabilities from month-to-month and to understand that anadromous fish migrating past the proposed project area are well adapted to this variability.

[1] `https://waterdata.usgs.gov/monitoringl-ocation/14144700/#parameterCode=00065&period=P7D`

[2] The gauge was out of order from November 24, 2020 10:55 AM to January 8, 2021 4:55 PM.

Table 3.1: Hydraulic and water quality parameters measured at the USGS Vancouver, WA, gauge 14144700 and the period of record for values.

Parameter	Start Date	End Date
Discharge	March 3. 2016	August 31, 2021
Gauge height	October 1, 2007	August 31, 2021
Velocity	March 3, 2016	August 31, 2021
Suspended sediments	September 9, 2018	August 31, 2021
Turbidity	April 16, 2016	August 31, 2021

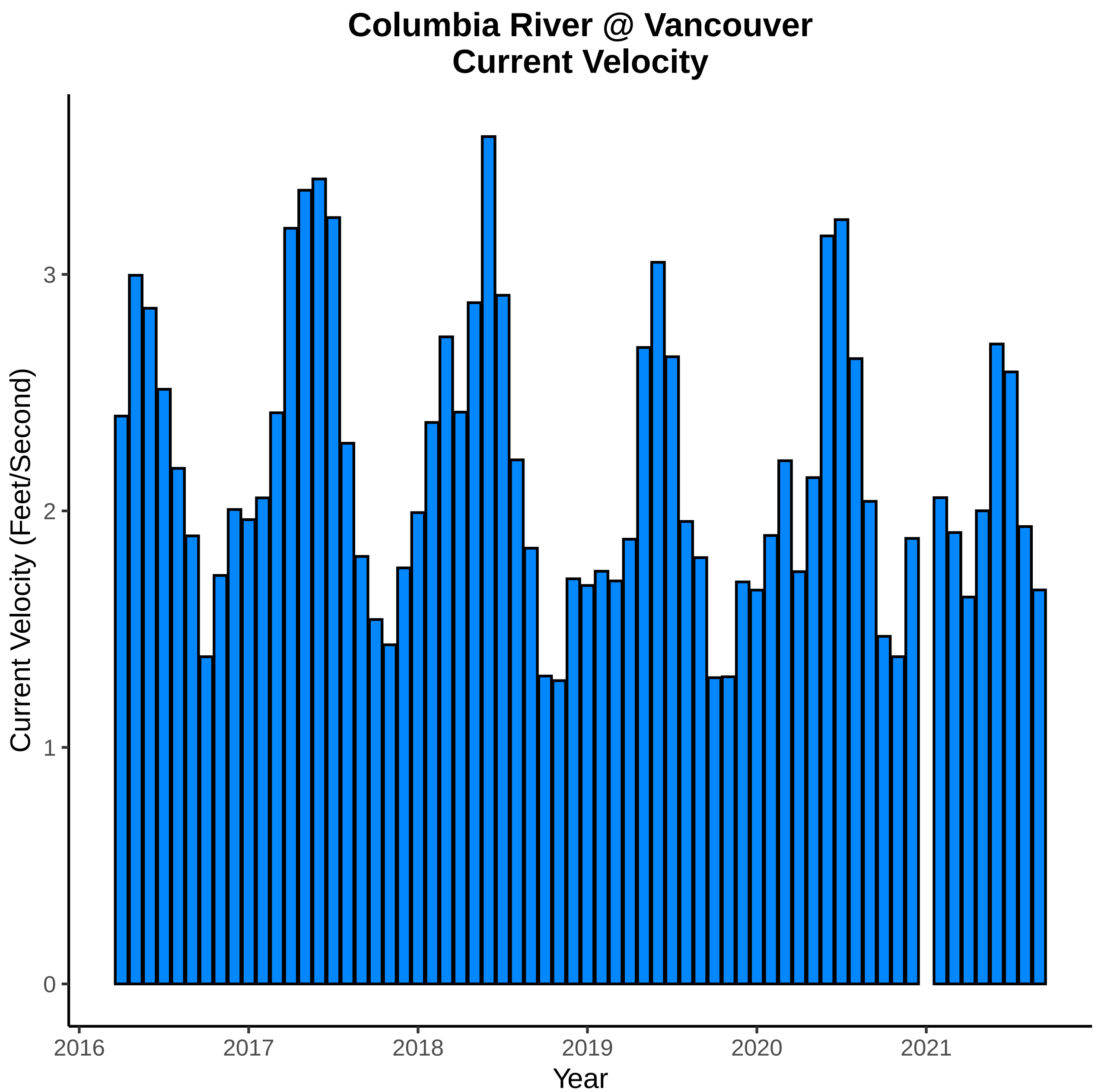

Figure 3.1: Current velocities at the USGS gauge along the north bank of the Columbia River at Vancouver; monthly mean values in feet per second.

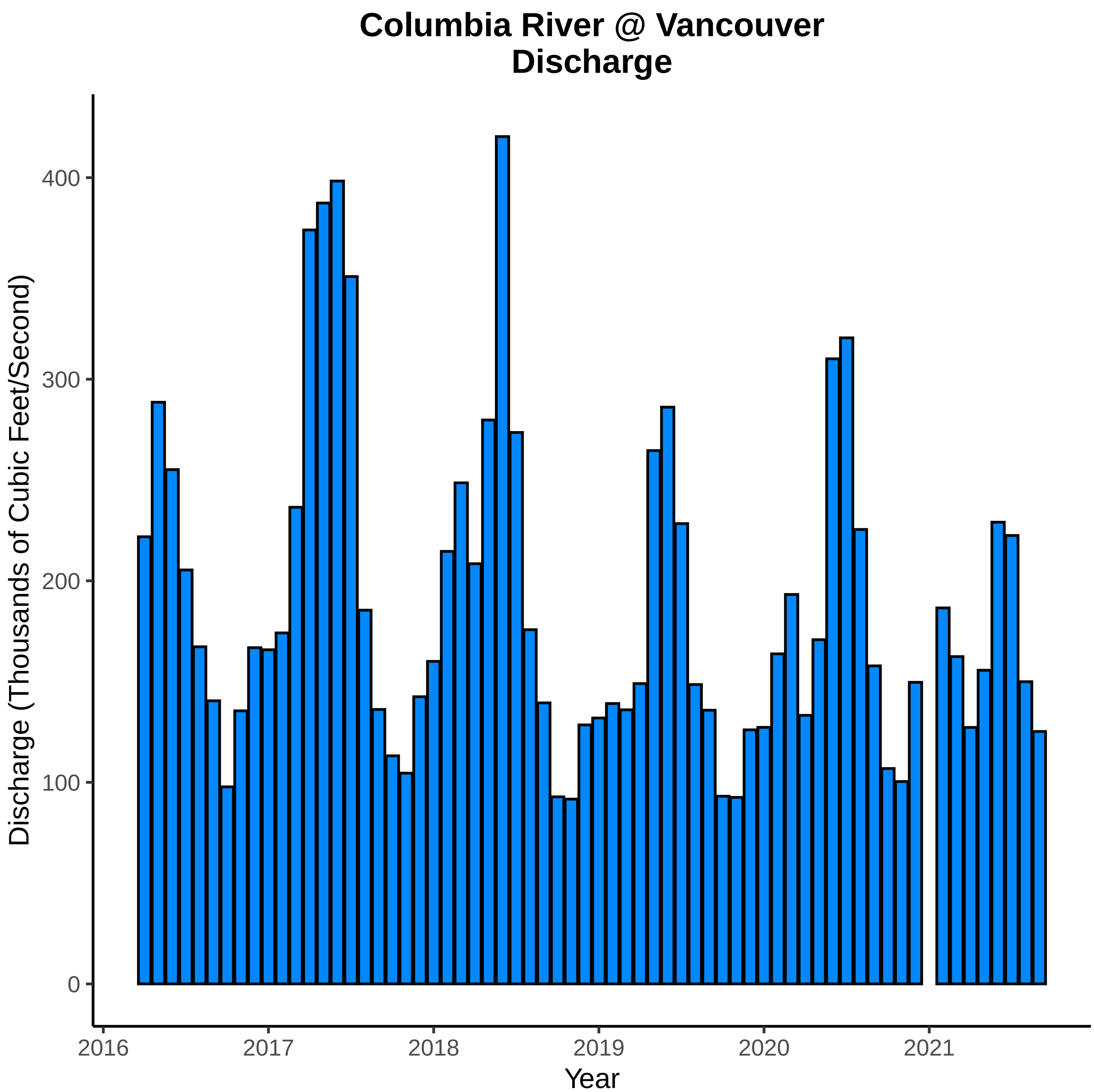

Figure 3.2: Discharge of the Columbia River gauge at Vancouver, WA; mean monthly values in cubic feet per second.

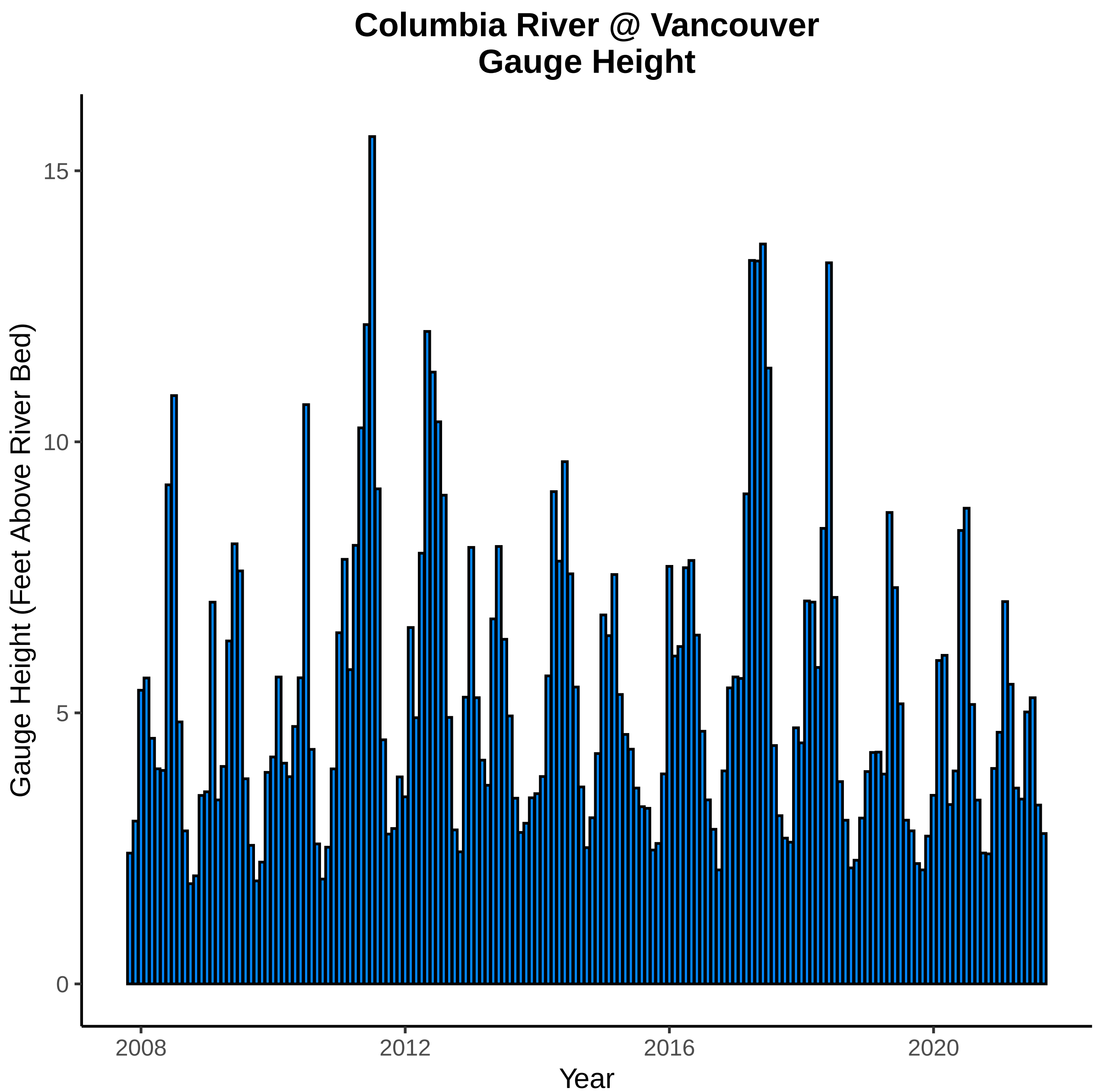

Figure 3.3: Stage height (the depth of water) at the gauge in Vancouver, WA; mean monthly values in feet.

3.3 Sediments and turbidity

The only water constituents measured and recorded at the USGS Vancouver gauge are related: suspended sediments and turbidity. Suspended sediments are fine sands, clays, and muds held in suspension while turbidity measures all factors that reduce the clarity of the water, including color and dissolved solids, in addition to suspended solids. Both of these measures vary greatly on an annual basis as shown in Figures and 3.5. Notice the extreme variability in turbidity with peak months differing from year-to-year and multiple peaks of monthly mean values within a year.

Migrating fish have acclimated to these variable conditions over generations and the addition of a 192 square foot recreational dock with a boat moored to it between the large marina to the east and two existing docks immediately to the west will not add to any behavioral changes in aquatic biota.

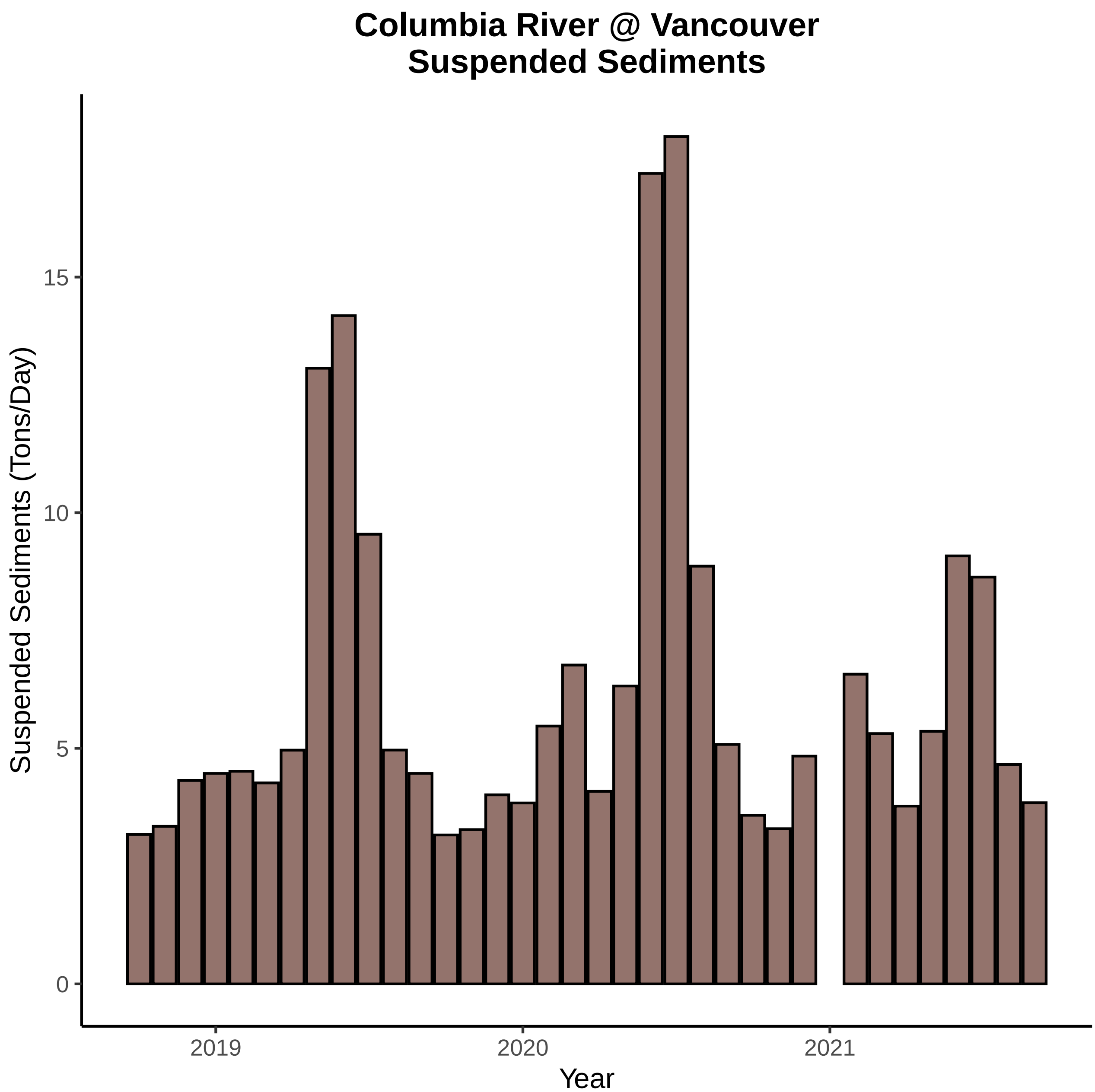

Figure 3.4: Suspended sediments in the water column at the Vancouver, WA, gauge. Units are mean monthly tons per day.

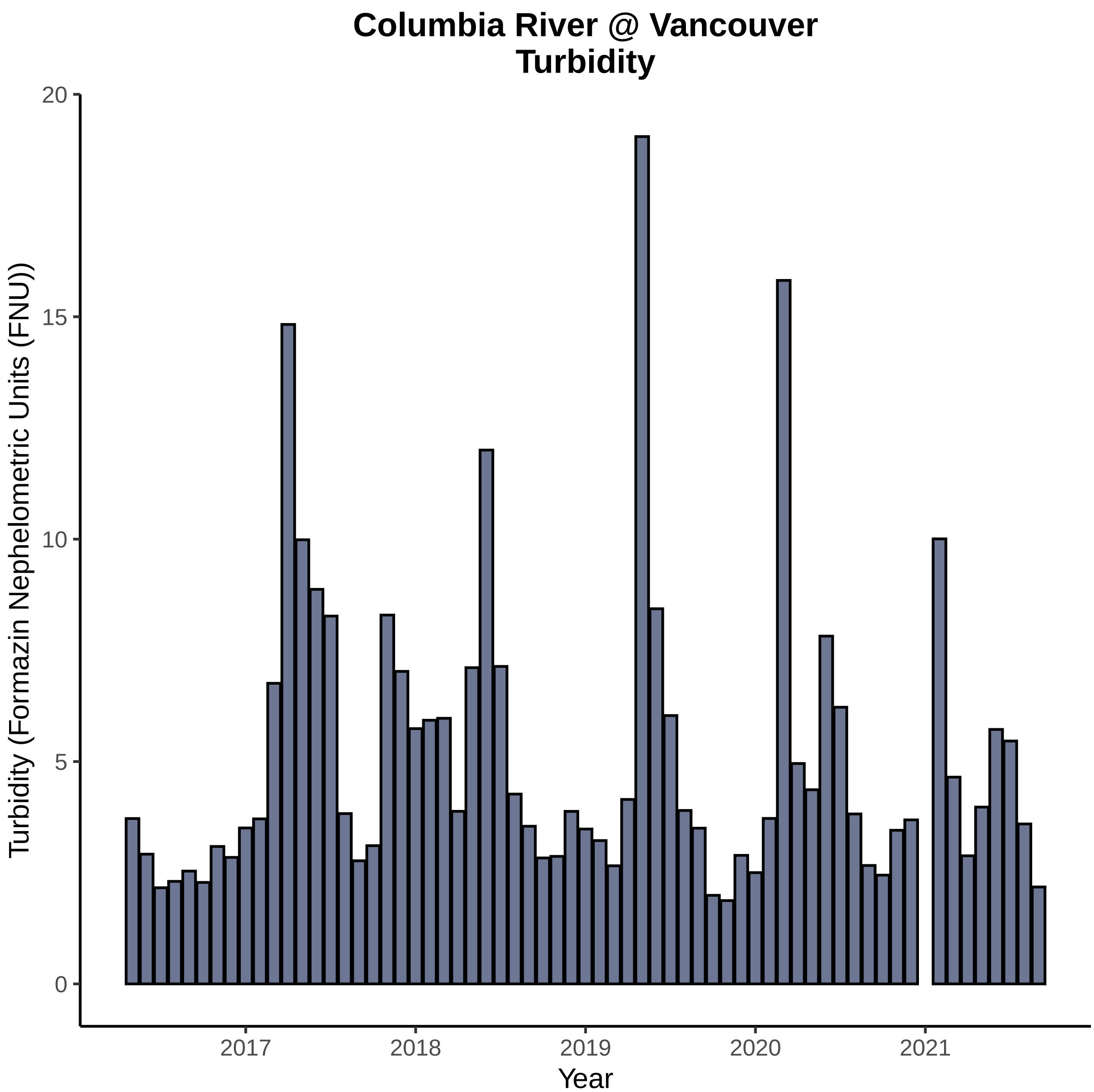

Figure 3.5: Turbidity of the water at the Vancouver, WA, gauge. Values are mean monthly Formazin Nephelometric Units (FTU).

4 Climate change and ESA-listed fish species

The western US from southern Washington to Mexico and between the Rocky and Coast Mountain ranges is in the 21st year of a megadrought; the most severe in 1,200 years. In 2020 the upper reaches of the Missouri River in Montana were dry for the first time in recorded history.

The effects of climate change experienced in the Pacific Northwest, exhibited most recently by the abnormally high temperatures for several successive days at the ends of June and August 2021, seriously stressed returning adult salmon in the Columbia and Snake Rivers, including the reach between the Pacific Ocean and Bonneville Dam.

Summer returning salmon have an optimal water temperature range of 44–67°F. In the summer of 2021 temperatures were much warmer. For example, between July 21st and 29th Columbia River water temperatures in the Gorge ranged from about 70.7°F to 72.5°F stressing and killing salmon[1].

For a comprehensive overview of how water temperature affects salmon, charr, and trout read the summary report submitted to the Policy Workgroup of the EPA Region 10 Water Temperature Criteria Guidance Project (Poole et al., 2001).

The purpose of the EPA guidance is to help Pacific Northwest states and tribes adopt water temperature standards that:

- Meet the biological requirements of native salmonids (Pacific salmon, trout, and charr) species for survival and recovery pursuant to the Endangered Species Act (ESA).
- Provide for the protection and propagation of salmonids under the Clean Water Act (CWA).
- Meet the salmonid rebuilding needs of federal trust responsibilities with treaty tribes.

The addition of a 192 square feet recreational boat dock, and the boat moored to it, will have no affect on water temperatures that would stress migrating anadromous fish.

[1] https://www.columbiacommunityconnection.com/the-dalles/high-water-temps-killing-fish-in-the-columbia-river

5 Summary

The location of a 192 square feet recreational boat dock on the Nevin's property is between the large, mostly covered marina operated by the Port of Camas-Washougal and similar docks at the two neighbors immediately to the west. With these structures surrounding the proposed dock its installation will not change river hydraulics, sediment transport characteristics, or water temperature in any measurable way. The existing structures' effects on migrating anadromous fish (both up- and downriver) would be applied before they pass the Nevin's property.

The most important factors affecting fish passage in the lower Columbia River are water temperatures given the rate of climate change and fish condition related to ocean conditions (returning adults) and upriver conditions (out migrating juveniles). We have no way of controlling these factors.

6 About the author

Dr. Richard Shepard is an stream ecologist and fluvial geomorphologist with 40 years of professional experience. His capabilities are presented in the attached curriculum vitae.

Since starting his sole consultancy practice in 1993 (to assure that all work products are technically sound and legally defensible) he has addressed Columbia River fish issues when obtaining commercial dredging permits in the navigation channel and Sandy River delta. He also served a term on Oregon's Independent Multidisciplinay Science Team (IMST) which provides scientific guidance in the state's implementation of its Salmon Plan. IMST members are appointed by the Governor and approved by the Senate.

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Curriculum Vitae

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Summary

Dr. Shepard is an applied ecosystems ecologist/environmental scientist specializing in regulatory science, environmental chemistry (water, sediments, soils), aquatic ecology, fluvial geomorphology (watersheds and the rivers that drain them), hydrology, and environmental data analyses using advanced statistical and spatio-temporal models and established ecological theory. His expertise and experience includes water quality, fish, invertebrates, wildlife, wetlands, hydraulics, and sediment transport.

He has experience in objectively and effectively addressing concerns raised by regulators and others involving the Clean Water Act (CWA), Endangered Species Act (ESA), National Environmental Policy Act (NEPA), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA). His environmental impact assessment expertise led to the objective approach explained in his book published by Springer: *Quantifying Environmental Impact Assessments Using Fuzzy Logic*. For more than 35 years he has consulted on these subjects to natural resource companies and served as a consulting and testifying expert in environmental litigation.

Education

1972 **BA (Honors)**, *Quinnipiac College*, Hamden, CT.
Biology/Chemistry

1974 **MS**, *University of Illinois*, Urbana, IL.
Quantitative Limnology/System Ecology

1980 **PhD**, *Idaho State University*, Pocatello, ID.
Quantitative Stream Ecology/Fluvial Geomorphology/Radiochemistry

1984 **Post-doctoral Research**, *Idaho State University*, Pocatello, ID.
Assessment of Macroinvertebrate Species Assemblages in Stream Ecosystems

Expertise

- Aquatic biota (fish, benthic macroinvertebrates, algae, macrophytes).
- Aquatic and environmental chemistry.
- Clear and effective communication of complex environmental issues to non-technical decision makers.
- Environmental Risk Assessment/Analysis
- Ecosystem structure and function: modeling and computer simulation; synthesis and overview.
- Environmental data analyses using advanced statistical and spatial models.

- Environmental permitting and compliance: Clean Water Act (CWA); Endangered Species Act (ESA); National Environmental Policy Act (NEPA).
- Environmental risk management.
- Fluvial geomorphology.
- Forensic ecological/environmental science expert.
- Hydraulics.
- Hydrology.
- Sampling program design.
- Sediment distribution and transport.
- Watersheds.
- Wetlands.
- Wildlife.

Research

Hyporheic Communities of the Mill River, Connecticut, *Quinnipiac College*, Hamden, CT.
B.A. thesis research.

Comparison of the oxygen consumption and carbon-14 assimilation methods of measuring primary productivity in aquatic ecosystems, *University of Illinois*, Urbana, IL.
M.S. thesis research

Distribution of land snails with regard to elevation and aspect in the Great Smoky Mountains, Tennessee and North Carolina, *University of Illinois*, Urbana, IL.

Benthic invertebrate recolonization and use of artificial substrata in the Sangamon River, Illinois, *University of Illinois*, Urbana, IL.

Fish distribution in three streams of southeast Idaho, *Simplot Phosphate Co.*, Soda Springs, ID.

The role of aquatic insect feces in stream ecosystem energetics, *Idaho State University*, Pocatello, ID.
Ph.D. dissertation research

A method for assessing aquatic macroinvertebrate species population assemblages in lotic ecosystems, *Idaho State University*, Pocatello, ID.
Post-doctoral research

The effects of a low-head hydroelectric dam on fish in the Snake River, Idaho, *Idaho State University*, Pocatello, ID.

Transport of low-level radioactivity from disposal areas by ground squirrels, *Idaho National Engineering Laboratory*, Arco, ID.

Movement patterns of pronghorn antelope on the Idaho National Engineering Laboratory site, *Idaho National Engineering Laboratory*, Arco, ID.

Fish distribution in the Big Lost River, *Idaho State University*, Pocatello, ID.

Development of a method for measuring soil moisture in high-clay-content soils, *Idaho National Engineering Laboratory*, Arco, ID.

Ecological aspects of mosquito control, *Ben Gurion University of The Negev*, Beer Sheva, Israel.

Publications and Presentations

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