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Review of Biological Research on Juvenile and Adult Salmonid use of Vancouver Lake



Prepared by:
Portland District U.S. Army Corps of Engineers
Environmental Resources

Abstract

This document provides a synthesis of known biological research on juvenile and adult salmonids at Vancouver Lake, Vancouver Washington. This review of literature was prepared to support the Portland District U.S. Army Corps of Engineers involvement with the Vancouver Lake Watershed Partnership under the Corps Section 536 program. This specialized Corps program authority promotes the improvement of tidally influenced off-channel habitat in the Lower Columbia River. The goal of this report is to provide the Corps of Engineers the best information available to make management decisions on whether or not to move forward with improving habitat for salmonids at Vancouver Lake.

Background and Lake History

Vancouver Lake (approximately 2,600 acres) provides a variety of functions to the surrounding community including wildlife habitat, flood control, boating, bird watching, hiking, hunting and other recreational activities as well as environmental education and stewardship opportunities.

The Lower Columbia River has been impacted over the past 100 years by the implementation of navigation features associated with the Columbia and Lower Willamette Rivers Navigation Channel, urban and rural development, federally funded flood control projects, and flow fluctuations attributable to the Federal Columbia River Power System. The cumulative effect of these actions has contributed to the degradation of the quality and quantity of the off-channel habitat in the Columbia River Basin.

With funding from the Port of Vancouver, Vancouver Lake underwent several improvements to restore habitat and to improve water quality from 1977 through 1983. First, a flushing channel was built to reconnect the main stem of the Columbia River to Vancouver Lake which would allow water to enter the lake at the south eastern side. At the head of the channel a tidal gate was installed to allow the throttling of water to and from the lake. Additionally, a large amount of material was dredged from the lake reconnecting the mouth of Lake River with the flushing channel. The dredge spoils were used to create a 50+ acre island at the west end of the lake.

An operations and maintenance (O&M) program was integral to the restoration program of the late seventies and early eighties. However, O&M activities were not executed as planned. Subsequently, the lake silted in and has remained quite shallow with an average depth of approximately 3 feet. Currently water circulation at Vancouver Lake is in a degraded condition and has high water detention time. Research has shown that approximately 2% of the total volume of Vancouver Lake is turned over in a given day taking over 1.5 months to exchange the full volume of the lake (U.S. Army Corps of Engineers. Portland District. 1990. Vancouver Lake, Washington, flood control: interim

feasibility report). The absence of effective hydrologic ingress and egress has greatly contributed to the poor water quality. Additionally, algal blooms, e-coli contamination and other toxic contaminants cause occasional public closures of the lake.

Recognizing the need to address the lake in a planned and methodical fashion, the Lake Vancouver Watershed Partnership (LVWP) was formed. The partnership's membership comprises:

Port of Vancouver
City of Vancouver Dept. of Public Works
Vancouver-Clark Parks & Recreation
Clark County Dept. of Public Works
Fruit Valley Neighborhood Association
Clark County Health Department
Port of Ridgefield
Clark Public Utilities
Washington Dept. of Natural Resources
Washington Dept. of Fish & Wildlife
Washington Dept. of Ecology
Lower Columbia River Estuary Partnership

The partnership's charter is to improve the lake's water quality and restore the lake to a level that facilitates safe recreation for the community. In 2006, the Corps of Engineers (USACE) proposed investigating the lake to determine if there was potential for using the Section 536 program to help improve the salmonid habitat of the lake. Water quality is not one of the directives or specific products of the Section 536 program however, improving hydraulic conditions and water quality in the interest of improving fish habitat would be acceptable and could potentially help address key issues now facing the LVWP. The partnership agreed to allow USACE to conduct a Preliminary Restoration Plan (PRP) study. Portland District conducted PRP study in May 06 and concluded that there was potential for the improvement or development of salmonid fish habitat.

Critical Assumptions, Constrains, Concerns

The Corps interest in improving Vancouver Lake is focused on improving off-channel rearing habitats for juvenile salmonids. The constraints of the 536 program give focus to this report and the pertinent information necessary to make program direction decisions. Historically there has been concern from State and Federal agencies about what impacts the lake modifications may or could have on salmonids. Critical concerns are as follows:

- What is the history of salmonid use of Vancouver Lake both pre and post flushing channel construction and lake dredging?
- What is the present year-to-year abundance of salmonids in Vancouver Lake
- Is the lake being used it as rearing habitat and are salmon successfully returning to the main stem of the Columbia?
- What are the current predator fish populations and how will they impact juveniles that migrate through the lake?
- What is the quality of Vancouver Lake rearing habitat for migrating juveniles and can it be improved?

- If fish enter the lake will they become disoriented and incur increase mortality from predation or adverse water quality or both?
- Will increased Columbia River water flowing through the lake via the flushing channel and out via Lake River attract upriver bound adults and delay and possibly increase mortality of these fish?
- Will the increased flushing and dredging of the lake cause changes to resident warm-water fish species?
- Is the flushing channel culvert system impacting juveniles and impeding adults due to trash rack gap size and debris impingement?

Salmonid Use History Prior to Lake Modifications

Historic Vancouver Lake was likely a significant piece of off-channel Columbia River habitat for salmonids. Before diking of the system in the early to mid 1900's, the lake complex was larger and integrated with small braided streams and shallow water habitats that supported the rearing of salmonid species, and the geomorphology allowed elevated water from the Columbia's spring freshet to over run low lying riparian lands. Diking created a shallow lake environment that disconnected the side channel areas causing higher water temperatures which is more suitable to warm water species, many of which are known predators of juvenile salmonids.

Regional Recommendations Prior to the Start of Construction (Flushing Channel & Dredging).

In a July of 1979, a letter was issued to the Port of Vancouver (Attention: Mr. Richards F. Gorine, Director, of Planning and Government Relations) stating the opinion of Washington Department of Fish (WDF) and other experts in salmonid fisheries (U.S. Fish and Wildlife Service-USFWS, National Marine Fisheries Service-NMFS). This letter was in response to the proposed construction work at Vancouver Lake which included the creation of the main flushing channel and the dredging operations.

WDF expressed concerns about entrainment of juvenile salmonids through the flushing channel with a nominal flow of approximately 600cfs. The implications from the department were that juveniles that were entrained would suffer unacceptable losses due to predation or residualism in passing through the lake and Lake. Several facts (see WDFW Report) and results from past research lead WDF to recommend a reduced flow culvert system (300cfs) that was compatible with protection of juvenile and adult salmonids.

The primary species of concern between March and June were migrating sub-yearling Chinook and Chum since they are more shoreline oriented and would be most vulnerable to entrainment into the flushing channel. WDF recommended that the flushing channel be closed from March to June each year to protect these migrants. Juvenile salmonids passing the mouth of the channel in the July through September time period are primarily upriver spring chinook and steelhead that migrate as larger yearlings. WDF determined that these fish would be far less vulnerable to entrainment because of there different

migration habits. Experts also had concerns about the smaller sub-yearling salmon being preyed upon at a higher rate in Vancouver Lake by northern pikeminnow and largemouth bass.

Another concern raised by the group was the potential for attraction of adult salmon into Vancouver Lake because of the proposed flow of Columbia River water through the lake. With the recommendation of the flushing channel to be closed from March through June the regional experts felt that the bulk of the adult run would bypass the inlet to Lake River due to the lack of flow. Additionally, once the flushing channel was reopened in July fish would have several choices of upstream passage, the flushing channel and Bachelor Island Slough. Regional managers identified this risk but felt that it was small since adult fish had opportunity to return to the main stem.

U.S. Fish and Wildlife Preconstruction Survey Findings (1976-77)

Prior to the start of flushing channel construction and dredging (1976-77) the Port of Vancouver (Mr. Dick Gorini, PM) requested that the U. S. Fish and Wildlife Service conduct a gill net survey in Vancouver Lake. This survey was to provide the Port with some baseline abundance estimates as to what species were most prevalent in the lake during both the summer and winter months at locations that were to be disturbed during the construction phase. In a letter dated 4 March 1977, the USFWS reported back to the Port with their findings.

From August through February of 1976-77, USFWS researchers surveyed by gillnet a representative proposed dredge site as well as the Burnt Bridge Creek channel. The focus of the survey was specifically to look for salmonids in the by-catch and to also assess predator abundance. Both summer and winter surveys produced only 1 salmonid in all of their sampling effort. The bulk of the catch at both sites consisted of both White and Black Crappie and Yellow perch. Of a total of 561 fish collected a total of 446 or 79% of the total catch were from these 3 species. Peamouth chub and carp were 4th and 5th in the overall total with only small amounts of these fish present in the samples.

Vancouver Lake Post Construction Monitoring of Salmonids (Envirosphere Inc 1984).

In December 1984 a final report titled "*Revised Final Report for the Fisheries Monitoring Program, Vancouver Lake Restoration Project*" was completed. The purpose of this study was to determine the effects of the restoration of Vancouver Lake on Anadromous and resident fishes. The Vancouver Lake Restoration Project included dredging of Vancouver Lake and connecting the lake to the Columbia River via a one-mile long flushing channel.

Fisheries agencies expressed interest in the affect of these alternatives on Columbia River migrating salmon and steelhead as well as Vancouver Lake resident game fish. Specifically, they were concerned that juvenile salmon that enter the lake through the flushing channel would suffer from poor water quality and rearing habitat, incur

predation by resident fish, and be unable to find their way downstream to the estuary. There was also concern that migrating adult salmon may stray into the lake via Lake River and be unable to find their way back to the main stem of the Columbia. These studies that began in April 1982 and were completed in September of 1984, sought to answer these concerns.

Species Abundance Estimates

The report found that the lake's fish populations were dominated in number of fish by black crappie and in weight by carp, while the adjacent Columbia River population was dominated in number of fish by American shad, threespine stickleback, and juvenile chinook salmon, and in overall weight by largescale sucker, carp, and peamouth chubs.

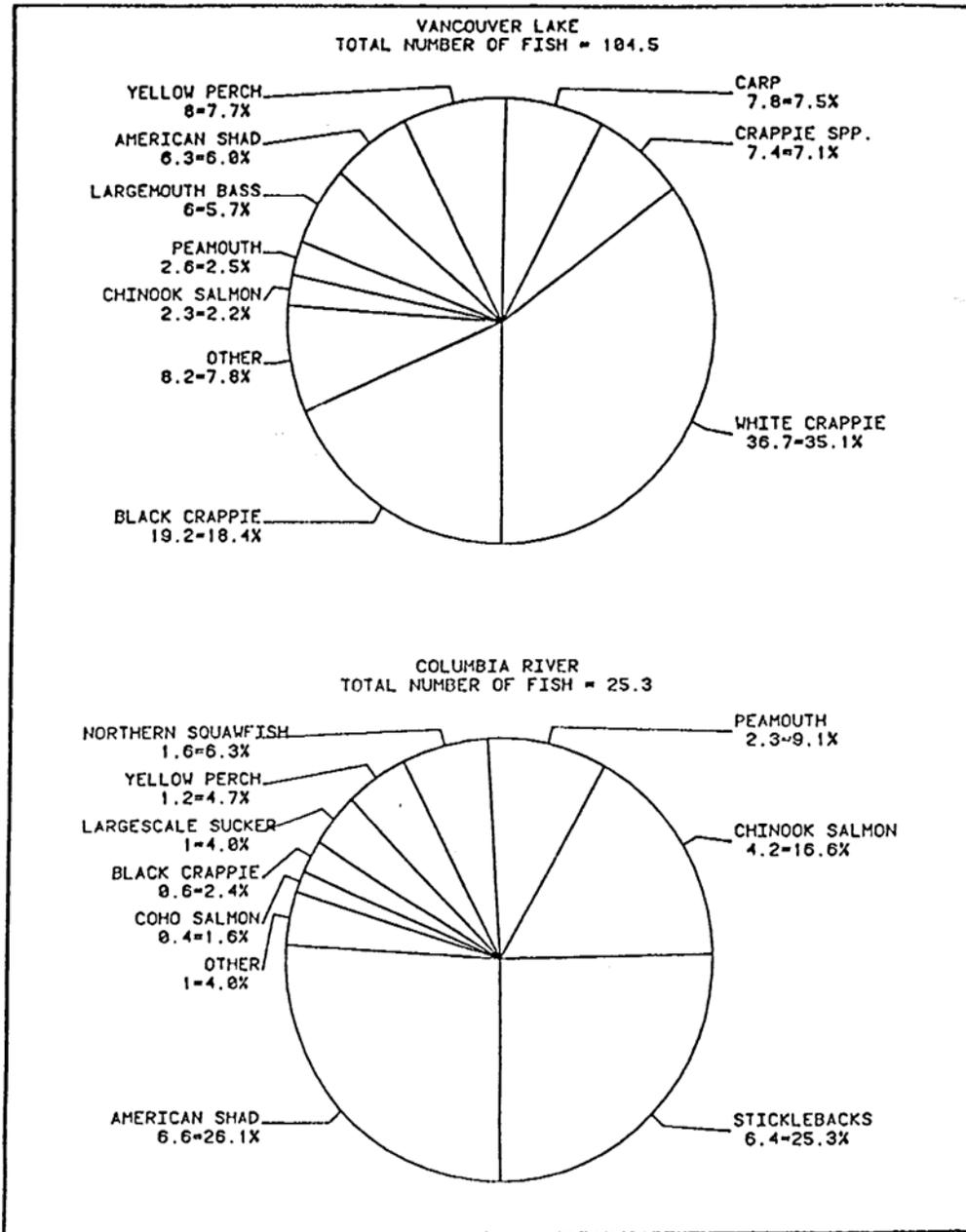


Figure 1. Average monthly density of fish captured by beach seine in Vancouver Lake and Columbia River from Nov. 1982 to Sept. 1984, presented as number of fish per 1000 square meters and percent of total number of fish (Evirosphere, 1984).

Juvenile Salmon and Steelhead

Juvenile abundance was found to be linked to season, tidal gate operation, and river-lake hydraulics. For example, there was no apparent increase in densities of Chinook salmon juveniles subsequent to opening the flushing channel in June 1983, but when it was left open in April and May of 1984, the abundance of Chinook salmon, coho and steelhead juveniles increased significantly, particularly at the flushing channel-lake confluence.

The large size of the juvenile Chinook salmon present at the confluence in June and July when compared to the adjacent CR fish also indicated that they had entered the lake earlier and had grown substantially. Researchers also found that fish seemed to congregate at the confluence of the flushing channel and the lake in late June and early July due to the attraction of cooler Columbia River water entering through the flushing channel, and by mid July, the abundance of juvenile salmonids in the lake had declined. Although the sampling could not determine the exact fate of the fish, researchers speculated that the majority of fish probably left the lake through the tide gate culverts when receding river levels resulted in less or even reverse flow, and that some fish may have also migrated down Lake River.

Table 1. Estimated number of Chinook salmon juveniles entering Vancouver Lake through the flushing channel based on fyke net catches (Enviroshpere, 1984).

Salmon	Numbers of Chinook			
	June 1983	July 1983	June 1984	July 1984
Fyke net catch (total) ^{a/}	51	17	40	4
Average net catch/day	25.5	8.5	13.3	1.3
Number entering lake/day ^{b/}	166	55	87	9
Estimated total entering lake	5,000	1,700	2,600	270

^{a/} No other salmon or trout were captured in 1983. During June 1984, two coho salmon, one rainbow trout, and one cutthroat trout (all juvenile) were captured. During July 1984, one coho salmon juvenile was captured.

^{b/} Average net efficiency used was the average of all tests (43 recoveries/279 marks = 15.4 percent). The range of efficiency was 12.4 percent to 40 percent (see Appendix A).

Water Quality and Predation

Water quality in the lake was not observed or believed to be a direct cause of salmon mortality in the lake, but the high temperatures after mid June were thought to have retarded their growth. Researchers speculated that deepening of the lake from dredging also allowed for a larger cool water refuge. No direct predation on salmonids was observed in the lake and the small size of the potential predatory fish observed in 1984

suggested that there was a small amount of large predator fish present to contribute to the mortality of juvenile salmonids.

Adult Abundance

Only one adult coho salmon, three adult steelhead, and five adult cutthroat trout were captured in a weir fished on Lake River in 750 hours of sampling. Although approximately half of the fish traveling up Lake River could have passed by the weir, the low catch suggested the number of adult salmon entering the lake was small. Adult steelhead can find their way to the flushing channel as indicated by sport catches at the confluence. Researchers also speculated that the culverts length, darkness, and velocities were not considered to hinder passage of adult back to the Columbia River. White Sturgeon and American shad were the most abundant anadromous fishes, other than salmonids present in the lake.

Resident Game Fish

The major resident game fish species found were white and black crappie, largemouth bass, and yellow perch. In June 1093, abundance of the young of white and black crappie, and largemouth bass were apparently affected negatively by falling water levels, also yellow perch abundance may have been adversely affected by dredging. Abundance of all four species appeared to be increasing by the end of sampling in 1984, suggesting recovery from the dredging period.

Speculated Improvements from 1980's Lake Construction Actions

Researchers speculated that the improvements had created many potential and actual improvements for fish. The deepening of the lake was said to benefit all species found in the lake. The deeper dredged area created an area of cooler water during the hot parts of day allowing salmonids more refuge from temperature changes, also the cooler water temperatures would be preferred by yellow perch during the summer. Additionally, the deeper habitat may be more stable, which could help stimulate development of a benthic community and improved fish habitat.

The lake deepening was also thought to help lessen wind-induced turbidity. Reduced turbidity could enhance feeding of game fish, and deep areas are also considered important for over-wintering largemouth bass. The deeper channels were also helpful in buffering the cold water temperatures that can be harmful to resident warm water game species.

Envirosphere's Recommendations for Flushing Channel Operations (Year to Year OPS)

As required by the Washington Department of Fisheries (WDF), the monitoring program was performed to help develop recommendations as to how the channel should be operated in order to protect salmonids. On the basis of the biological data obtained from

the Envirosphere study, they recommended that the flushing channel be opened throughout the year. They also recommended raising the tide gates during periods when salmonids are concentrated at the confluence (March- July). Justifications for these recommendations are based upon the following observations:

1. The lake, during most of the winter and spring appears to constitute a good rearing environment for juvenile salmon. Growth appears to be excellent; predation appears to be minimal; and water quality is not a problem until summer.
2. Salmon and steelhead can and apparently do leave the lake through Lake River and the flushing channel. They apparently departed via the flushing channel most readily during periods of low or reversed flows, researchers speculated that small fish are pulled back through the culverts during low river conditions when tide can reverse pulling fish back to the Columbia.
3. Over 100 million juvenile salmon pass by Vancouver Lake annually, but data indicate relatively few enter the lake. Fyke net catches were relatively low in June and July and beach seine catch data inside the lake during April and May indicated relatively low numbers of fish inhabiting the lake during these months.
4. The majority of downstream migrants moving during April and May remain offshore and do not encounter the flushing Channel. Subyearling Chinook that are more shore oriented in June and July but apparently didn't enter the lake in high numbers.
5. Some of the juvenile salmon and steelhead appear to enter via Lake River.
6. Adult salmon and trout apparently are attracted to Vancouver Lake via Lake River, but only in low numbers. Those entering the lake appear to reach the flushing channel and were thought to not encounter minimal obstacles returning to the Columbia River.

Fisherman Environmental Services LLC Flushing Channel Phase 1 Investigation

On June 18th of 2002, Fisherman Environmental Services, LLC (FES) submitted a "*Summary of Results Report*" to the Port of Vancouver. This report was requested by the Port and was part of a phased effort to determine the following:

1. Are existing habitat conditions in the channel adequate for juvenile salmonid rearing?
2. Does channel habitat favor native and non-native predator species over salmonids?
3. Are the sluice and flap gates having an adverse effect on juvenile salmonids?
4. Is stranding of juvenile salmonids in the channel between the Columbia River and Vancouver Lake a problem?

This study was a preliminary (Phase I) effort by FES to determine if existing information is adequate to address the issues identified above. The focus of the report was to complete a literature review of key flushing channel documents, answer any questions

from the one's above and to then identify data gaps that need further investigation (Phase II).

FES Conclusions

The following numbered items correspond to the numbered questions from above and are a summary of FES findings.

1. *Are existing habitat conditions in the channel adequate for juvenile salmonid rearing?*
The observed presence of juvenile chinook indicates that current habitat conditions do not preclude the use of the flushing channel by ESA-listed salmonids. Suitability of habitat is likely seasonal, depending on water quality conditions and Columbia River levels.
2. *Does channel habitat favor native and non-native predator species over salmonids?*
Current habitat conditions are not ideal for either predator species or juvenile salmonids, but both types of species were found in fyke net samples at the outlet of the channel in both 1983 & 1984. The current level and type of interaction between these two groups of species are unknown.
3. *Are the sluice and flap gates having an adverse effect on juvenile salmonids?*
There are no clear indicators of adverse effects, such as impinged fish, during the brief in-water survey. The size between the trashrack bars is larger than stated in earlier reports. When clean, it is not likely to present an impingement risk to juvenile salmonids. Water velocities may present a barrier to juveniles attempting to swim from Vancouver Lake to the Flushing Channel through the 4-inch gap gate observed by a Port-contracted diver in 1998. In addition, the debris on the trash rack may decrease the size of the openings to the point where it may impede or impinge adult salmonids.
4. *Is stranding of juvenile salmonids in the channel between the Columbia River and Vancouver Lake a problem?*
The question could not be answered with the available information. Stranding in the channel due to shoaling at the Columbia River end of the channel may be a problem, depending on water level, water quality and sediment loads, and wave action patterns from wind and commercial river traffic.

FES Identified Data Gaps

- The existence of a set of detailed as-built drawings has been documented in various reports but has not been located in Port archives.
- The extent of current salmonid use of the channel and lake is unknown.
- Water quality and temperature data for the lake are extremely limited.

- Current water quality conditions during low flow periods in the flushing channel are unknown.
- Salmonid, warm water and resident river community population dynamics in the channel and lake have not been recently examined. The current extent of predation on juvenile salmonids by piscivorous fishes and birds in the channel and the lake are unknown, and recent years has become an issue of concern to NMFS and WDFW, who frequently raise it during the Port's permit review process.
- The risk of stranding listed fishes in the channel at low Columbia River levels due to sand accumulation at the Columbia River end of the channel has not been quantitatively examined.

Research Summary

Washington Department of Fisheries

Prior to the modifications at Vancouver Lake in 1977 (Flushing Channel Construction & Dredging) regional fish managers such as WDF, USFWS and NMFS voiced their concerns about pulling juvenile salmonids from the main stem of the Columbia River into Vancouver Lake via the flushing channel. Because of the vast unknowns of the lake and available predators at that time managers were apprehensive as to the fate of juvenile fish attracted from the main stem into the lake. Because of these concerns managers recommended that the flushing channel be closed during the bulk of the juvenile spring migration period (March-June). There were also concerns raised about adult attraction into Lake River and the Lake once the flushing channel was reopened in July each year.

US Fish and Wildlife Service

Fish abundance netting surveys were conducted prior to the start of lake modifications by the USFWS in 1976-77. Researchers found only one juvenile salmonid over a 6 month long netting program with the bulk of the catch being made up of White and Black Crappie and Carp.

Envirosphere Inc.

In 1983 and 1984 Envirosphere, the contactor hired by the Port of Vancouver published their lake sampling results. Seining and fyke net traps were set and retrieved at various points inside the lake as well as the flushing channel to record post construction use for both juvenile and adult salmon as well as warm water and resident river species.

Findings were:

- Juveniles entering the lake via the flushing channel were comprised of yearling and subyearling Chinook.
- Juveniles were seen in good numbers and thought to be rearing and moving out via Lake River or the flushing channel when temperatures rose and water levels dropped in early July.
- Researchers didn't think water quality was a factor for salmonid rearing and the new dredging sites provided cool water refuges as water temperatures rose.
- Large predatory fish were found in small numbers and were thought to not be a problem for migrating and rearing smolts.
- Only small numbers of adults were observed in the samples and were thought to be able to move out of the lake by either the culverts or Lake River.
- Researchers also speculated that deepening the lake helped reduce the wind-induced turbidity. Thought that less turbulence would enhance the formation of the benthic community.

- Cold water refuges were seen as beneficial to Largemouth Bass and yellow Perch.

Fisherman Environmental Services (FES), LLC

In 2002, Fisherman Environmental Services was contracted by the Port of Vancouver to evaluate salmonid use of the flushing channel and existing culverts and flap gates.

Questions posed were the following:

- Are existing habitat conditions in the channel adequate for juvenile salmonid rearing?
- Does channel habitat favor native and non-native predator species over salmonids?
- Are the sluice and flap gates having an adverse effect on juvenile salmonids?
- Is stranding of juvenile salmonids in the channel between the Columbia River and Vancouver Lake a problem?

The overall themes from this report were that both salmonids and warm water species utilized the channel seasonally but were not enumerated by FES researchers. Many unknowns such as safe fish passage through the culvert trash racks, debris interactions, and lower water impacts from the stage of the Columbia River during low summer water events and entrance shoaling of the flushing channel remain unanswered within the limited scope of work. FES recommended studies to answer many of these data gaps.

Considerations for Future Research

Because of the limited amount of biological data about salmonid use at Vancouver Lake the need to gain high quality, detailed and scientifically sound salmonid use information should be reassessed by the Vancouver Lake Partnership and its members. New information needs to be collected to base strategic decisions as to whether or not Vancouver Lake will be suitable off-channel habitat for salmonids. Key questions that should be addressed when developing research are:

1. Many assumptions have been made as to fish behavior without supporting data. Research needs to be focused to remove assumptions and gain detailed information on use and survival of salmonids entering the lake and their fates.
2. Investigate best available methods to track juvenile and adult salmonid using Vancouver Lake, the Flushing Channel and Lake River (Radio or Acoustic Tracking, etc)
3. Conduct a detailed temperature and thermocline evaluation at critical areas of Vancouver Lake.
4. Investigate impacts of structures to fish passing via the flushing channel and culvert system.
5. Conduct detailed assessment of predator fish and abundance at Vancouver Lake.
6. Conduct detailed quality assessment of available riparian habitat and their use by salmonids.

Literature Cited

- Bottman, B. to S. O'Brien. 1977. Metals and pesticide levels found in fish taken from Vancouver Lake [memo; May 19]. Olympia, WA: Washington Dept. of Ecology. [<http://www.fishlib.org/bibliographies/vlwp/documents/bottman1977.html>]
After the Pilot Dredge Study (Dames & Moore 1978a), the levels of metals and certain pesticides were at significant concentrations. A one time study was done to establish if these concentrations were affecting fish populations.
- Buell, J.W. n.d. Anadromous salmonid fishery problems, possible solutions and other considerations relating to the proposed flushing channel for Lake Vancouver, Washington.
- Cooper Consultants, Inc. 1983. Program description: Vancouver Lake post construction monitoring: draft. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/cooper1983.html>]
“The post construction monitoring program at Vancouver Lake is intended to determine and document the flushing, fishery, water quality and related effects of the lake restoration project. A small work element involving the establishment of wetland vegetation suitable for wildlife habitat is also included in the program.”
- Dames & Moore [to R.F. Gorini]. 1979b. Fisheries—Vancouver Lake operations plan [memo; July 12]. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/dames1979memo.html>]
Explains the concerns and addresses how these concerns will be mitigated during operation of the flushing channel into Vancouver Lake. The fisheries of concern include the now endangered Chinook salmon and other salmon species wandering into the lake through the flushing channel or Lake River.
- Dames & Moore. 1980. Operations plan: Rehabilitation of Vancouver Lake. Seattle, WA: Dames & Moore. [<http://www.fishlib.org/bibliographies/vlwp/documents/dames1980.html>]
“The purpose of this operations plan is to provide specific criteria and recommendations for implementing the measures and actions presented in the 1977 Master Plan for the Rehabilitation of Vancouver Lake.”
- Envirosphere Co. 1983-1985. Vancouver Lake fisheries catch data report for ... [1982-1984]. Bellevue, WA: Envirosphere. [<http://www.fishlib.org/bibliographies/vlwp/documents/envirospherecatchdata.html>]
Annual reports to analyze catch data for fisheries in Vancouver Lake. Each provides a summary of the species found in the lake according to the methods set out in the monitoring and evaluation program of the Vancouver Lake Restoration Project.

- Envirosphere Co. [to Cooper Consultants, Inc.]. 1983-1984. Report for Vancouver Lake restoration fish sampling[memo]. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/envirospheresamplingmemo.html>]
Quarterly report to summarize fish sampling data for the time period.
- Fishman Environmental Services, LLC. 2002. Vancouver Lake flushing channel phase 1 investigations: summary of results. Vancouver, WA: Port of Vancouver. [<http://www.fishlib.org/bibliographies/vlwp/documents/fishman2002.html>]
Preliminary effort to determine current conditions of Vancouver Lake and to determine if there is enough data to establish answers to questions about salmonid habitat.
- HDR Engineering, Inc. 2002. Salmon Creek limiting factor analysis. Portland, OR: U.S. Army Corps of Engineers ; Vancouver, WA: Clark Public Utilities. [<http://www.fishlib.org/bibliographies/vlwp/documents/hdr2002.html>]
Evaluates the Salmon Creek basin for biological and habitat constraints that limit salmonid survival in all freshwater life stages. Identifies those areas that most need improvement and makes recommendations to remedy those problems with the highest mortality.
- Harvester & Willie. 1989. An adult and juvenile salmonids population estimate and habitat evaluation in the Salmon Creek Basin. Olympia, WA: Washington Dept. of Ecology.
- Houghton, S.A. [to K. Robbins, D. Gorini]. 1979. Evaluation of potential salmonids losses at Vancouver Lake [memo; Oct 16]. Vancouver, WA: Port of Vancouver.
- Kincheloe, J.W. [to D. Gorini]. 1977. Summary of the Fish and Wildlife Service's gill net survey in Vancouver Lake [memo; March 4]. Portland, OR: U.S. Fish and Wildlife Service.
- Knutzen, J.A. & R.D. Cardwell. 1984. Fisheries monitoring program: Vancouver Lake restoration project (revised). Bellevue, WA: Envirosphere Co. [<http://www.fishlib.org/bibliographies/vlwp/documents/knutzen1984.html>]
Reservations about the Vancouver Lake Restoration Project included concerns that the flushing channel might divert migrating salmonids into the lake which would affect their upstream migration as the flushing channel is designed as a one-way system. Resident fish would also be affected by the introduction of Columbia River water which was predicted to have a major affect on the lake's system. Monitoring and evaluation were proposed to ensure the survival of resident fish as well as the affects on migratory paths of salmonids.
- Parente, W.D. and J.G. Smith. 1981. Columbia River backwater study: phase two. Vancouver, WA: U.S. Fish & Wildlife Service, Fisheries Assistance Office.

Grant application for the Clean Lakes Program for the Environmental Protection Agency to assist with the massive rehabilitation effort to restore acceptable water quality to Vancouver Lake and its tributaries.

Summary of the efforts of the Port to restore Vancouver Lake, most likely a press release on the project.

Sheely, Terry W. 2002. Washington State fishing guide. 8th ed. Black Diamond, WA: TNScommunications.

Contains complete descriptions of water bodies throughout the state of Washington with information on fish species found within each.

U.S. Army Corps of Engineers, Portland District. 1976. Inventory of riparian habitats and associated wildlife along Columbia and Snake Rivers. V.IIA-B Lower Columbia River. Portland, OR: the District.

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The Federal Hydroelectric projects on the Columbia and Snake Rivers proposed a change to a power peaking system rather than steady production to better include thermal electricity production. This study was undertaken to better understand how power peaking would affect fish and wildlife in various sections of the Columbia and Snake Rivers.

U.S. Army Corps of Engineers. Portland District. 1990. Vancouver Lake, Washington, flood control: interim feasibility report. Portland, OR: the District.

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“The primary purpose of this study was to determine the feasibility of, and potential Federal interest in, developing flood control improvements for the protection of existing commercial, industrial and agricultural areas and proposed (zoned) light industrial development lands which are located in the flood plain adjacent to Vancouver Lake, Washington.”

U.S. Fish and Wildlife Service. 1980. Columbia River backwater study. Vancouver, WA: USFWS.

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Websites:

See listing of Links on website:

<http://www.fishlib.org/bibliographies/vlwp/links.html>