Structural hydrology and limiting summer conditions of San Juan County fish-bearing streams

Russel Barsh

With the assistance of Chris Cassidy, Kari Due, Andria Hagstrom, Monica Kezar, and Dennis Linden

June 2010

KWIÀHT
Center for the Historical Ecology of the Salish Sea
PO Box 415, Lopez, WA 98261

Structural hydrology and limiting summer conditions of San Juan County fish-bearing streams

Russel Barsh – Kwiáht

Summary

Instream flow stages and summer pool conditions (depth, temperature, dissolved oxygen, fish presence and activity) were measured in seven Orcas Island streams and one San Juan Island stream where native fish (coho, chum, cutthroat, rainbows, sticklebacks) had been observed by Wild Fish Conservancy water typing surveys in 2004-2007. Most of the fish consistently observed were coastal cutthroat (*Oncorhnchus clarki clarki*).

Results indicate that while island salmonid stocks seem relatively tolerant of high summer pool temperatures, low levels of dissolved oxygen, and exposure to mammal and bird predators in confined shallow waters, a minimum continuous stream flow of 0.1 was required for salmonid survival, and minimum flow of 0.25 cfs was necessary to maintain some degree of pool connectivity by glides. Underwater video confirmed that cutthroat were actively feeding in daytime conditions as extreme as 20^{o}C and 3 mg/L of dissolved oxygen. Video records and redd surveys also confirmed that cutthroat adults enter island streams from late August to December and spawn in March-April; and that juveniles tend to spend their first summer in isolated stream pools before emigrated in fall.

Summer stream flows are a function of the summer reservoir capacities of island watersheds. Natural water storage features such as vernal pools, bogs, and other wetlands have been drained, diverted, excavated and impounded extensively, reducing the summer flows in many streams. Changes in island weather patterns, including drier summers and more extreme precipitation events in the winter, will increase the need for summer water storage while reducing infiltration rates and the proportion of winter precipitation stored. Artificial reservoirs—ponds and modified lakes—can be harnessed to replace some of the islands' lost natural storage capacity, but can lose as much as half of the stored water to summer evaporation. Salmonid survival and recovery in San Juan County is impossible without effective protection of the islands' remaining natural reservoirs, and expansion of capacity by a combination of recreating wetlands (for example by modifying ponds) and regulating outflow from ponds and lakes.

Additional concerns, such as continued introduction of invasive fish and frogs and persistent construction of roads with inadequate culverts, are also discussed.

Priority action is recommended for the Garrison watershed (San Juan Island), and the West Beach and Bayhead watersheds on Orcas, on the basis of historical fish use, the potential for habitat improvement, and sea-accessibility. Ongoing surveys of Lopez, San Juan Island and Shaw streams may identify additional priority targets for action.

Structural hydrology and limiting summer conditions of San Juan County fish-bearing streams

Table of Contents

Structural hydrology and limiting summer conditions of San Juan County fish-bearing streams

Methods and Overview

The Wild Fish Conservancy has been mapping habitat structure and fish presence in San Juan County streams since 2004. Most Orcas Island streams, and some streams on San Juan Island, were completed in 2008. Additional streams and stream reaches on San Juan Island, Lopez, Shaw and Waldron continue to be surveyed.

Surveys have thus far located two streams with significant populations of coastal cutthroat (*Oncorhynchus clarki clarki*) and three streams with marginally small cutthroat populations, one of which appears to have already been extirpated by development while this study was underway. Rainbow trout or steelhead (*Oncorhynchus mykiss*) were found in three streams albeit two represented the descendants of documented planting. Juvenile Chum salmon (*Oncorhynchus keta*) and Coho salmon (*Oncorhynchus kisutch*) were seen in four streams. Only the cutthroat trout have been documented repeatedly with multiple age classes demonstrating instream reproduction.[1]

Whether these salmonid populations are "natural", as opposed to being planted or introduced, is not a legal requirement for habitat protection, but descriptions of individual streams include whatever evidence we have gleaned from the recollections of landowners and fishermen. Genotyping will be necessary to resolve the origins of island cutthroat and steelhead stocks reliably. Our laboratory genotyped an initial sample of 54 Garrison and Cascade cutthroat specimens using the Wenberg microsatellite marker set (Wenberg et al. 1998, and Wenberg and Bensen 2001). The two populations are genetically distinct from one another and internally relatively homogeneous.[2] Relative homogeneity of fish from Cascade Creek, Mountain Lake (the stream source), and Cascade Lake suggests that WDFW planting of cutthroat fry in the lakes has overwhelmed any native stocks. Further sampling and genotyping is recommended to identify genetically distinctive native stocks with confidence.

As a local partner in these surveys, Kwiáht has focused on two related questions: Why are Pacific salmonids and other native fish species only surviving in a small number of streams where there is seemingly adequate habitat in terms of riffles and pools, gravels and shade? What has changed, and is still changing in habitat conditions that restricts the current distribution of Pacific salmonids in San Juan County, and threatens the survival of these existing island salmonid populations?

Based upon our previous understanding of island hydrogeology, we hypothesized that summer drought conditions are the limiting factor for salmonid survival. Unless fish leave island streams by May or June, they face low to zero flows, isolation in small pools

[1] Some rainbows are reproducing in lakes where they were planted and have been observed foraging—but not necessarily spawning—farther downstream. Juvenile False Bay Creek chum observed in May 2010 are almost certainly the offspring of fish spawning in that stream, but only one generation has yet been seen.

[2] Complete unpublished genotyping data are available upon request as an Excel spreadsheet.

with gradually warming water, and possible hypoxia, as well as increased vulnerability to predators such as mink, river otters, herons, and kingfishers. If trout over-summer before migrating to sea—or if they are land-locked residents—then they must: (1) tolerate warm, hypoxic and relatively exposed conditions, and/or (2) be restricted to streams that retain a certain minimum summer stream flow that must be maintained, for trout survival, against pressures from riparian development and climate change. As described below, our results indicate both relatively high toleration of summer pool conditions, and the necessity of at least some continuous summer flow.

This is consistent with studies elsewhere in our region (e.g. Wigington et al. 2006) suggesting that intermittent streams can be productive, albeit fragile salmonid habitat.

Methods

Instream flow stages and summer pool conditions (depth, temperature, dissolved oxygen, fish presence and activity) were measured in seven Orcas Island streams and one San Juan Island stream where native fish (coho, chum, cutthroat, rainbows, sticklebacks) had been observed by Wild Fish Conservancy water typing surveys in 2004-2007.

Stream flows: Flow velocity was measured with a Global Water Flow-Probe held in mid-channel for 3 minutes; average flow in feet per second was recorded as computed by the instrument. Most flow measurement stations were culverts, making it possible to calculate water volume precisely from the cross-sectional area of the filled portion of the pipe. Where measurements were of necessity made in a natural stream channel, a broad, relatively flat and shallow point in the stream was chosen to minimize distortions from an irregular cross-section, or differences in velocity from the center to edges of the flow.

Stream pool depths and dissolved oxygen: Enameled steel staff gauges marked in whole centimeters were bolted to meter-long steel posts pounded into the substrate at the deepest point of each monitored pool. Volunteer stream monitors visited and read gauges 2-3 times per month, also measuring dissolved oxygen and water temperature at the pool surface using an EX-TECH Pro dissolved oxygen instrument, and noting flow conditions, wildlife, fish, and weather. This was organized both as a data-gathering exercise, and as a means to mobilize local citizen support for longer term monitoring and protection.

Stream temperature records: HOBO Water-Temp Pro loggers were strapped with cable ties to the bottom ends of staff gauges in monitored pools, and programmed to take temperature readings every 15 minutes. Staff gauges were positioned so that the HOBO instruments measured temperatures at the substrate or just above it, *i.e.*, at pool bottoms. Volunteers measured pool surface temperatures 2-3 times per month using their Ex-Tech dissolved oxygen instruments, hence for a number of summer dates there are comparable surface and bottom records.

Fish behavior: An Ocean Systems DeepBlue digital underwater video camera was used to make hour-long, fixed-point observations of fish in selected pools at intervals of two to three weeks in summer and fall 2007-2008, when stream flows were lowest. From February to May 2009, stream riffles were walked to locate redds.

Summary of results

The threatened status of San Juan County streams is reflected in a summary of the flow conditions we observed in mid-July 2007. Each solid block in the flow column represents from one-half cfs to a maximum of 2 cfs. Gray represents less than 0.1 cfs, and blank means the stream glides were dry. Glide refers to whether there was at least one inch of water in the channel flowing between pools. Fish refers to whether salmonids were present.

Table 1: Summer flows and fish presence (July 2007)

Island	*Watershed*	*Sampling station*	*Flow*	*Glide?*	*Fish?*
Lopez	Hummel	Cross Road		No	No
	Davis Bay West	Davis Bay Road	░	No	No
	Davis Bay East	Davis Farm		No	No
	Jasper Cove	Blue Fjord Cabins	░	No	No
Orcas	Cascade	Pt Lawrence Road	████	**Yes**	**Yes**
	Crow Valley	Margo's Lane	░	No	No
	Doe Bay	Doe Bay Resort	███	**Yes**	**Yes**
	Skull Creek	Deer Harbor Road	█	No	No
	Bayhead-Victorian	Meadowbrook Lane	██	No	**Yes**
	West Beach	West Beach Road	░	No	**Yes**
San Juan	Beaverton Valley	University Road	█	No	No
	False Bay	Bailer Hill Road		No	No
	Westcott Bay	Westcott Drive		No	No

Midsummer stream flows of 0.1 cfs or greater were a necessary, but not sufficient condition of salmonid presence. Pool conditions vary within streams; key factors such as temperature and dissolved oxygen may reflect pool depths, riparian vegetation, substrate characteristics and biological oxygen demand (BOD) from decaying organic materials, as much as the availability of stream flow. Tables 2 and 3 summarize conditions in several stream pools we monitored in summer 2007 and summer 2008.

In two streams—Doe Bay and West Beach—we observed cutthroat in a deep pool but not a shallower and better oxygenated pool less than 20 meters away. Temperature is not the issue: the shallower pool in each pair was not significantly warmer. Food supply is a possible explanation, but we believe that a more plausible explanation is refuge from predators. Cutthroat appear to retreat to the deepest pools available as summer flows fall, even if this means that they risk hypoxia. We note that only sticklebacks were seen in the shallow pools monitored on Crow Valley Creek—and they disappeared when oxygen fell below 30 percent in September 2007. Sticklebacks also disappeared from the dug pond on the West Beach system when oxygen levels fell below 30 percent in 2008.

Note too the survival of cutthroat in a dug pond in the Garrison system at very high (surface) temperatures. We filmed these fish resting on the bottom during the day, and only rising in the evening to feed on floating insects.

Table 2: Pool conditions and fish use (July-September 2007)

Stream	Site	Pool conditions			
		Highest ^oC	Lowest DO%	Lowest depth	Fish use
Cascade	Olga tank	15.5	94.3	36	Cutthroat
	Footbridge	14.9	88.6	30	Cutthroat
Crow Valley	Big pool	15.6	23.4	49	Sticklebacks
	Stream pool	15.5	43.2	23	Sticklebacks
	Long pool	13.5	29.7	25	Sticklebacks
Doe Bay	Plunge pool	14.1	38.5	51	Cutthroat
	Stream pool	14.1	50.5	12	None
Garrison	Alpaca pond	23.9	65.8	160	Cutthroat
West Beach	Stream pool	15.5	76.5	24	None
	Plunge pool	15.7	62.8	54	Cutthroat

Depths recorded in centimeters

Table 3: Pool conditions and fish use (June-October 2008)

Stream	Site	Pool conditions			
		Highest ^oC	Lowest DO%	Lowest depth	Fish use
Cascade	Olga tank	16.1	75.4	28	Cutthroat
	Footbridge	16.1	72.2	25	Cutthroat
Doe Bay	Stream pool	18.0	70.6	41	None
	Plunge pool	16.2	69.5	44	Cutthroat
Garrison	States Inn	17.1	64.3	26	Cutthroat
	Troutbeck	16.0	66.0	17	Cutthroat
West Beach	Plunge pool	19.0	52.5	56	Cutthroat
	Pottery pond	19.0	11.6	62	Sticklebacks

Depths recorded in centimeters

A mitigating condition in Cascade Creek was relatively high summer flows (never below 0.25 cfs) that maintained glides. This presumably afforded salmonids opportunity to evade predators that they would have lacked in isolated pools. In 2008, Cascade pools were even lower, but still sustained juvenile cutthroat.

Temperature fluctuations were recorded every 15 minutes in pools in five streams where we found cutthroat or sticklebacks (Appendix II). Diurnal and seasonal variation was greater at Cascade, Crow Valley and West Beach than at either Garrison or Doe Bay, but with no obvious consequences for fish survival. Average summer temperatures were well within the reported comfort range for cutthroat in 2008-2009, but it should be borne in mind that summer weather can vary considerably from year to year. An unusually warm summer—or the removal of shading vegetation—could easily raise stream pool temperatures from a comfortable 14-16^{o}C to a potentially dangerous 20^{o}C or greater.

We originally predicted that salmonids in isolated pools would all behave like the cutthroat in the dug pond at Garrison in 2007: resting close to the bottom, at least during daytime, and only rarely actively foraging or interacting. Our video monitoring of pools (Appendix I) found cutthroat active most of the time, however, not only feeding both at the surface but on the bottom, but engaging in aggressive behavior with each other and, in the case of West Beach, other fish (sticklebacks and pumpkinseeds) in the same pools.[3] This suggests that island cutthroat populations are relatively well adapted to the extremes of temperature and oxygen that we observed: 19^{o}C (and possibly greater at the bottom of the dug pond on the Garrison system) and 38.5 percent dissolved oxygen (at least briefly in the Doe Bay system). However, there are clearly limits. No fish survived less than 30 percent dissolved oxygen, equivalent to roughly 3 mg/L, and no pool continued to harbor fish if summer flows ceased altogether.

Video records also suggest migration times when unimpeded passage is critical. Mixed aggregations of adult and juvenile cutthroat were filmed in the estuary of Cascade Creek on August 31 and in the plunge pool beneath the first waterfalls on November 20. Redds were observed the following April. In the Garrison system, a mix of juvenile and adult cutthroat were filmed at States Inn in March and November 2008; redds were seen in April that year as well. Adults appear to enter these streams from August to November and spawn in March and April. Some but not all juveniles migrate out in fall as adult fish are arriving. Those that remain abandon their summer pools and range more widely. The trigger is presumably the onset of fall precipitation, which gradually increases flows and re-connects pools and glides.

This cutthroat life cycle necessitates that 0+ age fish remain in the stream for their first summer. Summer pool conditions therefore determine the survival of each cutthroat generation. Pool conditions depend on stream flows, which in turn are a function of the limited summer water storage in wetlands and lakes.

[3] Aggressive behavior included tail following and sudden lunges.

General observations

Summer water storage is the principal natural limitation on salmonid survival and reproduction in San Juan County. Natural water storage features such as wetlands (bogs, marshes, vernal pools, wet deciduous woodlands) and lakes are necessary for maintaining summer stream flows that irrigate, cool and oxygenate the stream pools where salmonids retreat in the dry months. Diverting, impounding, or degrading natural reservoirs reduces summer flows and forces pool conditions beyond levels that salmonids can tolerate.

Island soils are post-glacial: young, thin, and clay-rich with poor infiltration. The deepest and most porous island soils are "mucks" (mainly decomposed vascular plants) and "peat" (incompletely decomposed vascular plants such as sedges or sphagnum moss) that accumulated for millennia in depressional wetlands. Apart from a few natural lakes filling glacial potholes such as Hummel and Killebrew, island streams rely upon wetlands and wetland soils for summer storage capacity.

Our study of 19th century maps and recent soil surveys suggests that as much as 50 percent of the islands' total area comprised shallow seasonal wetlands 150 years ago. Most large island wetlands are "vernal pools" that fill in winter, with up to several feet of standing water, then slowly drain and evaporate in summer. Typically these features hold water because they are relatively shallow and bottom into watertight glacial clays. Their soils range from Coast Salish peoples planted camas and other staple foods in shallow wetlands, and when settlers brought European farming practices to the islands in the 19th Century, they too found the best soils and growing conditions in vernal pools.

Incompletely decomposed plant material—peat, broadly speaking—absorbs water literally like a sponge, in fibrous vascular structures. Sphagnum peat can absorb as much as ten times its volume: a saturated sphagnum peat is 90 percent water. Some peats float on water, furthermore, providing a cap that minimizes evaporation. Floating peat can be seen at Summit Lake on Mount Constitution, and is also found in the Deer Harbor (Fish Trap Creek) watershed, among others. All peats drain slowly into any available natural or artificial outflow channel; their capacity depends on depth and integrity. Removing the peat to create an open artificial reservoir simply accelerates evaporation, so that up to half of the stored water is lost each summer rather than flowing downstream.

Unlike Coast Salish peoples, 19th Century settlers wanted drier fields for summer row crops, hay and livestock, so they drained wetlands, often by excavating large ponds down to the clay. Peat bogs were excavated, and sometimes mined or burned. Beavers, which had continually created shallow short-lived ponds in wetlands by diking them with brush and mud—leaky dikes that actually contributed to stream flows—were trapped out, leaving deeper, less vegetated, and generally less leaky artificial ponds for reservoirs. On the whole, digging ponds reduced net water storage capacity due to increased evaporation –and took much of the storage capacity "off line" by stopping leaks and seeps. Ponds did not increase water retention in the islands, but the contrary.

Lacking snow pack to hold winter precipitation until summer, the islands depend mainly on wetlands—in particular wetlands with thick peat deposits—to ensure summer stream flows naturally. Unfortunately, the islands' wetlands continue to be compromised by development notwithstanding the laws aimed to protect them. Arguably a major issue is the lack of a biologically meaningful standard for prioritizing wetlands for protection. A natural bog that drains into a stream with freshwater fish is far less expendable than an accumulation of water above an improperly culverted roadbed; however, we encountered evidence, speaking with landowners in the course of our field studies, of variances given for the destruction of critical bogs and enforcement actions over unintended wetlands that resulted from poor infrastructure engineering. Credible consistent enforcement is needed, to help stabilize what remains of the islands' natural surface water storage capacity.

When storage capacity declines, summer stream flows not only decrease, but also may cease altogether in mid- to late summer. A growing number of island streams stop flowing for weeks to months each year. And as storage capacity continues to decline, the length of time that streams are dry increases. When flows cease in summer, fish become isolated in small pools that slowly grow warmer and less oxygenated until flows resume.

The present study found salmonids in isolated pools where there is at least some flow—as little as 0.1 cfs—throughout the summer. No fish survived in pools that had no flow for any period of time. The only significant populations of salmonids we observed, in the Cascade and Garrison streams, enjoyed at least 0.25 cfs throughout the dry season. This should not be taken to be a benchmark for healthy salmonid populations, but rather as an absolute minimum for their survival. Summer flow of 0.25 cfs is required in all the streams we studied to maintain at least some summer glides between pools—connectivity of pools and foraging habitat. Higher summer flows would be better.

Climate change will continue to affect the ability of island watersheds to maintain summer stream flows. In the rain shadow of the Olympic Mountains and the Vancouver Island Coast Range, the San Juan Islands tend to be relatively dry, with annual rainfall on the south end of Lopez and San Juan Island averaging as little as 14 inches. Rain shadow effects are strongest to the south and weakest to the north of San Juan County. The north end of Lopez enjoys nearly twice the annual rainfall of the south end. Eastsound tends to be nearly three times as wet as southern Lopez. Elevation also matters: the highest peaks and ridges in the islands—which also happen to be northerly—are the wettest parts of the county, and sources of the county's largest streams. But throughout the archipelago there has been a trend towards milder winters, more extreme winter precipitation events (more rainfall per minute), and drier summers. This results in a larger proportion of winter rain running off rather than infiltrating in soils and aquifers; at the same time that it increases the need for natural water storage features to maintain summer stream flows. Declining winter infiltration and summer precipitation have probably been factors in the loss of summer stream flows and salmonid populations in San Juan County over the past 75 years—particularly in the driest southerly parts of the county—and climate models predict that this trend will continue.

Human activity has also played a growing role in degrading island streams and diminishing salmon habitat. Early British and American settlers drained wetlands, leveled stream channels and planted reed canary grass, excavated the peat from bogs, and built dikes in salt marshes and estuaries to enlarge their pastures and produce "salt hay". More recently, wet season infiltration has been further compromised: by the addition of impervious area; as well as the tightline plumbing of stormflows to ditched conveyances, stream channels, or straight to Puget Sound. The combined effect of climate change and degrading our natural water retention features has exacerbated the pattern of seasonal stream flow seen today.

In 2007, a large reach of the Garrison stream between the States Inn and Blazing Tree Road was dry from August 3 to October 20. Many other streams on Orcas and San Juan Island did not begin flowing until October, and their glides did not fill enough to re-connect stream pools even later the season. In the following table, “first flush” refers to a measurable flow greater than 0.1 cfs. Fish use refers to conditions in summer 2007 in the same reach as the sampling station or above it.

Table 4: Dates of first fall flush and glide restoration (2007)

Island	*Watershed*	*Sampling station*	*Fish use*	*First flush*	*First glide*
Orcas	Bayhead-Victorian	Meadowbrook Lane	Cutthroat	November 5	December 5
	Crow Valley	Margo’s Lane	Stickleback	November 13	November 20
	Doe Bay	Doe Bay Resort	Cutthroat	November 13	November 28
	Fish Trap Creek	Cormorant Bay Road	None	January 27	March 10
	Pickett Springs	Johnston’s Pond	None	November 13	January 18
	Skull Creek	Deer Harbor Road	None	November 20	December 27
	West Beach	West Beach Road	Cutthroat	October 8	October 8
San Juan	Garrison	Blazing Tree Road	Cutthroat	November 21	November 28

Several streams remained functionally disconnected for four to eight months after midsummer, including most (or all) of the window for the return of adult cutthroat in the autumn. Late streams had no salmonids (like Pickett) or only resident salmonids (Doe Bay). Hydrographs of late streams (Appendix III) illustrate the effects of ponds that must fill completely before they can spill over into the channel downstream. Upstream ponds also result in abrupt cessation of stream flows in early summer, potentially stranding fish in de-watered glides.

Historical processes of water storage loss and stream dismemberment may explain the loss of some island salmonid populations that were fished recreationally as recently as the 1970s, and the marginal status of others, such as West Beach and Doe Bay cutthroat.

While it may sometimes be feasible and desirable to restore natural water storage features—for example, by partly filling, widening, and re-vegetating ponds so that they function more like natural vernal pools or beaver ponds—there is also a potential role for using existing artificial reservoirs as resources for maintaining summer stream flows. As described in this report, regulated summer discharges of water from existing dug ponds can enhance habitat conditions in some island streams. The choice between taking water from a pond, and restoring the wetland that preceded it, is not simply a matter of cost, but also one of results. Rebuilding wetlands and restoring the natural processes they support creates off-channel habitat for fish, amphibians, bats and birds. Ponds are more likely to attract nuisance species such as bullfrogs, geese, and (if ponds are stocked with fish) otters and to require aeration and periodic dredging to control algae and bacterial sludge.

In addition to reducing the water storage capacity of island watersheds, draining and excavating wetlands continues to create barriers to fish passage. Most of the islands' streams alternate between steep and relatively low gradient reaches. In more flat terrain, stream channels tend to meander, wander and fragment producing side channels; winter flooding maintains extensive shallow seasonal wetlands shouldering the channel. Excavating deep ponds directly in the channel drains the wetlands and disconnects the stream. Even in the absence of dam or weir—a physical barrier to fish passage—constructed ponds experience elevated warming, eutrophication, and hypoxia in summer, which can make them inhospitable to fish and as effective a barrier as a physical obstruction. The negative water quality impacts resulting from constructed ponds are not localized; they can compromise water quality for some distance downstream from the ponds as well.

Natural barriers to fish passage also abound in the islands. Bedrock ledges create waterfalls with steep drop-offs. Where streams cut through glacial clays, there are often steep slippery chutes. In some island streams, a natural barrier is located at the sea's edge and all freshwater fish are necessarily residents, for example at Doe Bay. Other streams, such as Cascade, are divided into distinct reaches by a series of natural barriers, including a small sea-accessible reach—with salmonid populations in each reach, some anadromous or sea-run, and others resident.

Land-locked salmonids can result from fish planting by landowners, sportsmen or state agencies, of course, but they may also be relics of natural sea-run populations that gradually became landlocked by post-glacial rebound and changes in relative sea levels in the islands. Relative post-glacial sea level change on the Turtleback, as witnessed by the fossil mud flat (complete with entombed soft shell clams) at the headwaters of Fish Trap Creek, has been +382 feet. Cascade Lake was a bay when salmon returned to the islands in the wake of retreating glaciers. Cutthroat, steelhead, and other salmonids presumably colonized many island streams when they were sea-accessible; and some of those that can switch relatively easily to land-locked life histories—notably the "trout"—have survived.

Indeed, *downstream* fish passage and gene flow have continued, without upstream fish passage or gene flow. One-way connectivity of island salmonids with their Salish Sea metapopulations is interesting from an evolutionary viewpoint, and may contribute to regional salmonid genetic diversity and resilience (*see* Schindler et al. 2010). Genetic analysis of the origins of San Juan County's freshwater salmonid populations, and their current relationships with each other and with mainland stocks, were beyond the scope of the present study; but would be relevant to the recently reopened USFWS review of coastal cutthroat for listing under the Endangered Species Act.

Resident island salmonid populations can be sustained, and potentially contribute to regional salmonid survival, even if they continue to reproduce above one-way natural barriers. Nor is it certain that removing or overcoming the natural barriers, for example by use of fish ladders, will enable isolated populations to expand; opening these streams to upstream migration may simply provide an opportunity for other stocks to colonize the streams. Protecting and improving habitat and natural processes within streams—more spawning riffles, better summer flows and summer pool conditions, and more consistent connectivity of pools—should be considered before contemplating artificially creating anadromous access through natural barriers.

Most of the natural and artificial barriers we observed in fish-bearing streams are located on private property and can be addressed as a part of cooperative programs with landowners—such as the evolving restoration process in the Garrison watershed launched by the Wild Fish Conservancy in 2009. County government also has an important role to play with respect to the design and maintenance of its infrastructure, mainly roads. In the course of this study, we found inappropriate or failed road culverts on every fish-bearing and potentially fish-bearing stream. Unimpeded stream, fish, sediment, and wood passage should be criteria in all future road design, construction and maintenance performed or permitted by the County.

Table 5: Summary of road crossing issues

Watershed	*Fish use*	*Culvert locations*	*Issues*
Bayhead	Cutthroat	Killebrew Lake Road	Perched/failing culverts (3)
		Meadowbrook Lane	Perched culvert
Cascade Creek	Cutthroat	Point Lawrence Road	Undersized culvert
Crow Valley	Potential	Deer Harbor Road	Undersized span
Doe Bay	Cutthroat	Point Lawrence Road (3)	Perched/failing culverts (3)
Fish Trap Creek	Potential	Channel Road	Undersized span
		Cormorant Bay Road	Undersized failed culvert
Pickett Springs	Potential	Point Lawrence Road	Perched box culvert
Skull Creek	Rainbow*	Deer Harbor Road	Perched undersized culvert
West Beach	Steelhead	West Beach Road	Perched failing culvert
Garrison	Cutthroat	West Valley Road	Undersized failing culvert

*Planted but naturalized and likely partly sea-run (steelhead)

The field surveys conducted for the present study noted visible potential sources of contaminants such as effluent pipes, dumped trash, residential density, and production activities. Actual measurement of toxics in water, sediments or fish was not included, but any contamination would most likely be associated with homes and gardens. Thus far the principal toxic threats to aquatic wildlife identified in San Juan County are the pyrethroid pesticides found in home and garden products; anionic and non-ionic surfactants found in cleaning products as well as adjuvants in herbicides, pesticides, fertilizers, motor oils and fuels, paints and other garden, motor vehicle and boating products; metals such as copper and zinc used in marine anti-fouling treatments; and polycyclic aromatic hydrocarbons or PAHs found in creosote, asphalt, tar, motor oils and incompletely burnt fuels (Barsh et al. 2008; 2009; and forthcoming). A focal study of these toxics in the False Bay (San Juan) Creek aquatic food web is underway and results will be published by December 2010.

Existing countywide data suggest that all outdoors use of products containing the pyrethroid pesticides or surfactants should be reduced. A simple way to begin is to spot-apply all pesticides and herbicides, rather than area spraying. Spot application minimizes collateral damage to non-target species such as beneficial soil arthropods and pollinators, and largely eliminates the adsorption of chemicals to soil, and their transport to wetlands, streams and bays in runoff water. As the WSU Extension program stresses, moreover, it is essential to learn to recognize pests and weeds, remove them manually if possible, and use chemicals sparingly and selectively only when they are really needed. Pyrethroids and surfactant-rich herbicides are also used commercially by pest control operators, some builders and landscapers in the county, and these practices should be reviewed and where possible, made more compatible with the "short run to the sea" hydrology of the islands.

Roads and marinas are also significant sources of the existing toxic threats to fish in San Juan County streams and nearshore habitats. Many roads lack sufficient ditches or swales to prevent water from running off directly to nearby wetlands and bays. Indeed in Lopez village, roadside ditches have increasingly been tight lined to the bay and channel. Bioremediation features, such as constructed wetlands, are few. The Friday Harbor and Eastsound storm sewer systems exit directly into marine habitats without treatment. In a county where roads are perched along the seashore or cut across wetlands on causeways, more attention should be given to managing toxics in road runoff.

One other important issue cross-cutting our assessment of local habitat conditions for salmonids is competition from invasive non-native fish species. Our surveys located more non-native fish stocks than native ones. Most commonly seen were large and small mouth bass, pumpkinseeds, and bluegills—all "warm water" fish native to the Southeastern United States. Bass are voracious predators of fish eggs and larvae, incompatible with salmonids. They were observed in Killebrew Lake, Hummel Lake (with bluegills), and Sportsman's Lake. Brook trout, a char native to the Eastern U.S., are abundant in the Cascade watershed, introduced only within the past decade. They too are voracious consumers of eggs and larval fish, compete with native fishes for limited food and habitat resources, thereby posing a serious threat to native salmonids. Fathead minnows have been introduced extensively in private ponds. American bullfrogs, an Atlantic species, have been introduced for food and (misguidedly) aesthetics repeatedly; they are incompatible with native fish, and most native amphibians and turtles as well.

Plantings of hatchery salmonids have also been widespread over the years. Most serious and, we believe, inappropriate has been the recent heavy planting of cutthroat fry in Mountain Lake, the source Cascade Creek, which appears to have overwhelmed native coastal cutthroat genetically. Rainbows have been planted widely by private landowners for example in the Lakedale Lakes (San Juan Island). Triploid rainbows planted by State agencies in Egg Lake and Hummel Lake cannot reproduce but do compete with other fish for prey. Local sportsmen have introduced Coho fry in island streams for two or three generations, although anecdotal evidence suggests that most were unsustainable. Schools continue to release Chinook and other salmon fry into island streams, but these efforts are also unsustainable, as far as we have been able to determine.

Stocking—in particular the introduction of non-native fish such as bass and Brook trout, and non-native amphibians—should not be permitted in any watershed with native salmonids, or where salmonid restoration is contemplated. In view of the potential harm to other native fish (sticklebacks or freshwater sculpins), locally scarce amphibians (Red-legged frogs, Northwestern salamanders, Long-toed salamanders, Western toads) and any remaining Western pond turtles, introduction of any fish or amphibian should be avoided, at least until a thorough assessment has been made of the watershed to determine whether any native species are present that may be affected.

Recommended actions

Priority action is recommended for the Garrison watershed (San Juan Island), and the West Beach and Bayhead watersheds on Orcas, on the basis of historical fish use, the potential for habitat improvement, and sea-accessibility. Ongoing surveys of Lopez, San Juan Island and Shaw streams may identify additional priority targets for action. Criteria for our selection of priority watersheds were applied as follows:

- Garrison sustains the largest salmonid population we have yet identified in the islands that is not clearly the result of recent introductions. Sufficient summer flows in the upper reaches of the watershed can be extended downstream by a combination of removing barriers, recreating a lost part of the stream channel, and providing supplemental water from an artificial lake that already drains to the stream. Landowners are favorably inclined towards restoration.
- West Beach sustains the relic of an historical recreational cutthroat fishery and steelhead have also been identified in its seaward reach. Failure to act quickly will probably result in the loss of these stocks as stream conditions continue to deteriorate. Replacing a county road culvert; improving summer water flows and fish passage through a single in-line pond; and augmenting summer flows by re-vegetating the source area and improving its water retention capacity are relatively inexpensive, and will re-connect thousands of feet of shaded gravel. Introduced fish (Pumpkinseeds) are present but not a serious threat. Many, if not all landowners are amendable to restoration.
- Bayhead-Victorian sustained a small native sea-run cutthroat escapement until 2007 when flows were reduced by upstream impoundments. Prompt action is not a guarantee of restoring this run but would (at a minimum) provide access to nearly two thousand feet of shaded gravels by coastal cutthroat, Coho, and or Chum. Removing a low concrete weir and replacing two perched culverts would restore fish passage, and regulated summer discharges from a privately owned pond would restore adequate summer pool conditions. Landowners of the lowest reach of the stream have been interested in restoration.

Considerations according lower priority to other watersheds include invasive fish, significant natural barriers to fish passage, and challenges to augmenting flows. Cascade is included in this list in part because the most serious issue we identified—an undersized road culvert—is already being addressed by the county. Importance of the fish to genetic diversity and sustainability of salmonids has also been considered.

- Cascade Creek hosts the largest extant cutthroat population in the islands, but with the Washington Water Trust's recent acquisition of water rights for fish, continued protection of the headwaters by Moran State Park, and protection of most of the stream corridor by private landowners, habitat conditions are relatively secure at this time. The one significant artificial barrier—a culvert under Point Lawrence Road—is already scheduled for replacement by a span. The only major remaining barriers are waterfalls; the lowest waterfall could be overcome by a fish ladder or "stepping stones". Countervailing factors are a growing invasive Brook trout population; and State cutthroat fry planting in the headwaters, which reduces the value of these fish for genetic diversity.

- Doe Bay has a small, potentially unique land-locked cutthroat stock, isolated above a coastal waterfall. Restoring upstream fish passage over this barrier is neither feasible nor necessarily desirable. Stream conditions between the two points where the stream crosses Point Lawrence Road—the upper and lower plunge pools described in this report—can be enhanced by replacing perched road culverts with bottomless culverts. Greater summer flows would enhance conditions appreciably, but we did not locate a promising source.
- Pickett Springs does not appear to have had sustained salmonid use since the 1950s. Three ponds dissect the seaward thousand feet of stream channel, and summer flows are restricted by additional ponds above Point Lawrence Road and near the source on Mount Pickett A spawning channel could be built by excavating the seaward 200 feet of the stream, which is shallow, choked with reed canary grass, and periodically blocked by sediments and driftwood after winter storms. Considerable construction would be required to create passage farther upstream, and recreate a suitable channel above the high-tide mark. It is plausible that salmonids would utilize a spawning channel if built; summer flows will be a limiting factor.
- Skull Creek hosts rainbow trout that escape downstream from a stocked pond on the upstream side of Deer Harbor Road; they functionally become sea-run steelhead if they can overcome a modest waterfall at the sea's edge. Channel habitats between the sea and Deer Harbor Road are suitable, but flows can be erratic and inadequate. The sources are the stocked pond, and a second larger pond above it that actually diverts water from the Deer Harbor watershed. As a result winter flows have increased sharply while summer flows are nil. The two ponds would need to be regulated to restore habitability of the stream.

Monitoring

Data collected for the present report can provide only a snapshot of conditions in San Juan County fish-bearing streams. Much more can be learned, by using this study as a baseline for long-term monitoring, much of which could be carried out by volunteers—like the volunteers that gathered data for this report. Some key parameters and methods for monitoring fish-bearing streams include:

- The date that stream flow ceases (or glides disappear) in summer, and the date that flow resumes in autumn. The total number of dry days is directly related to pool conditions such as temperature and dissolved oxygen, and is a function of climate as well as human activities that divert flow from stream channels.

- Flow (if any), temperature, and dissolved oxygen in stream pools bearing fish, during the islands' driest period—typically June through September. Weekly or biweekly data collection would be desirable. Small flows can be measured easily with a bucket and stopwatch. An electronic instrument such as the YSI ODO is costly but durable, reliable and precise for temperature and oxygen.
- Redds can be counted by walking stream riffles every second or third week—for cutthroat in the islands, between mid-February and early May.
- A representative sample of salmonids in each stream (minimum ten) should be brought to hand by hand-seine, hand-net or electrofishing as appropriate every three to five years for fin clips and genotyping. Genotyping will identify any changes in the composition of stocks and exchange of genes with other stocks, and is the least intrusive method for estimating the size of a salmonid stock.

References

Barsh, R., J. Bell, H. Halliday, M. Clifford, and G. Mottet. 2008. Preliminary Survey of Pyrethroid Pesticides and Surfactants in San Juan County Surface Waters. KWIAHT (Center for the Historical Ecology of the Salish Sea), Lopez, WA, October 2008.

Barsh, R., J. Bell, E. Blaine, C. Daniel and J. Reeve. 2009. Pyrethroid Pesticides and PCBs in Bivalves from East Sound, San Juan County, WA. KWIAHT (Center for the Historical Ecology of the Salish Sea), Lopez, WA, September 2009.

Barsh, R., C. Clark, and T. Stephens. 2010. Sediment Quality in Fisherman Bay and Friday Harbor, WA: Petroleum Residues, Polycyclic Aromatic Hydrocarbons, Pyrethroid Pesticides, and Toxic Metals. KWIAHT (Center for the Historical Ecology of the Salish Sea), Lopez, WA, forthcoming.

Schindler, D.E., R. Hilborn, C. Chasco, C.P. Boatright, T.P. Quinn, L.A. Rogers, and M. S. Webster. 2010. Poulation diversity and the portfolio effect in an exploited species. Nature 465 (3 June): 609-612.

Wenberg, J.K., and P. Bentzen. 2001. Genetic and behavioral evidence for restricted gene flow among Coastal Cutthroat trout populations. *Transactions of the American Fisheries Society* 130: 1049-1069.

Wenberg, J.K., P. Bentzen, and C.J. Foote. 1998. Microsatellite analysis of genetic population structure in an endangered salmonid: the coastal cutthroat trout (*Oncorhynchus clarki clarki*). *Molecular Ecology* 7: 733-749.

Wigington P.J., Jr., J.L. Ebersole, M.E. Colvin, S.G. Leibowitz, B. Miller, B. Hansen, H.R. Lavigne, D. White, J.P. Baker, M.R. Church, J.R. Brooks, M.A. Cairns, and J.E. Compton. 2006. Coho salmon dependence on intermittent streams. *Ecological Society of America* 4 (10): 513-518.

Bayhead – Victorian Valley – Mount Woolard

Orcas Island

Sources

The stream that meets salt water at Bayhead Marina, Orcas, rises from three main sources: (1) a string of wetlands to the north of Bayhead along Victorian Valley Road; (2) a string of wetlands to the northeast of Bayhead and east of LaPorte Road; and (3) several dug ponds (former wetlands) in the open fields on the south side of Killebrew Lake Road. The LaPorte wetlands capture some runoff from the southwest slopes of Mount Woolard, and appear from topography to have long been the largest of the stream's sources. In this report we refer to the Victorian wetlands and channel as the west branch, and the LaPorte wetlands and channel as the east branch of the Bayhead system

Most of the Victorian and LaPorte source wetlands today are former pastures with numerous dug ponds impounding downstream flows. Reed canary grass dominates these wetlands, but the west channel where it runs along LaPorte Road, and much of the stream below the confluence of its west and east branches, flows through cedar-shaded ravines.

One large native alder-sedge wetland survives on the west side of LaPorte Road—clearly visible on the map. There is no culvert under the county road, however, so flows from this wetland run south along the west side of LaPorte Road, thence west along road drainage ditches on the north side of Killebrew Lake Road, to dug residential ponds north of the Bayhead Marina driveway, never entering the Bayhead stream.

Barriers

There is a shallow plunge pool at the downstream end of a corrugated steel culvert under Meadow Brook Lane. The culvert is perched 8-10 inches above the pool even with high winter-spring stream flows, and holds barely an inch of water except at peak winter flows. There is also a deteriorating low weir composed of cobbles and concrete on the downstream side of the plunge pool, forming an additional potential barrier to upstream movement for all but 2-3 weeks of peak winter flow. A 157-mm cutthroat was brought to hand in this plunge pool, and a 170-mm cutthroat was brought to hand in the stream some 150 feet below this plunge pool in 2004.

A second culvert barrier to fish passage is located 1500 feet farther upstream from the first, under Willow Creek Lane.

Fish presence

Two adult cutthroat trout were brought to hand below the first barrier culvert in June 2004. Between the first and second barriers the WFC survey team found three-spine sticklebacks and fathead minnows but no salmonids. No fish were observed or brought to hand above the second barrier.

Despite frequent visits to the Meadow Brook Lane plunge pool and stream below during winter and spring 2008-2009, no fish were observed. This was presumably due to the impoundment and consequent reduction in winter stream flow described below under Diversions.

Diversions

At least two small domestic water diversions were observed in the stream channel above the intersections of LaPorte and Killebrew Lake Roads. Their impact on instream flow is probably negligible on account of a downstream impoundment: a pond, just above the junction of the east and west branches of the stream. As noted above, the county road diverts wetland outflow from the stream to residential ponds near Bayhead Marina.

During the course of this study, an instream pond just above Killebrew Road was enlarged, impounding significantly more flow from the west branch of the stream than we previously had observed. No fish were seen downstream afterwards by our research team or by the owner of the lowest reach of the stream. The impoundment and consequent loss of stream flow was duly reported to county officials but no action was taken.

Hydrographs (Appendix) show that in the rainy season following the enlargement of this pond, the west branch contributed very little to stream flows below the confluence of the west and east branches of this stream. The influence of other dug ponds on stream flow is evident in the brief steep peak of the downstream (Meadow Brook) hydrograph in winter: flood-like peak season overflows, followed by near-zero spring and summer flow conditions. Barely a trickle is visible at the Meadow Brook plunge poolfor 8-9 months of the year.

Stream flows are also impeded by a small dug pond and failed county road culvert near the juncture of Killebrew and LaPorte Roads. Much of the area around this culvert is inundated in mid-winter.

Land use

Most of the Bayhead stream flows through unmanaged deep woody ravines, but is surrounded by scattered homes and fields.

Toxic sources

This watershed is rural-residential with some subsistence and market gardening. The principal potential sources of contamination are county roads, private driveways and motor vehicles, homes, gardens, and on-site septic systems. Dumping of household trash into the LaPorte Road segment of the stream appears to have been ongoing for decades—large quantities of glass, batteries, and machine parts among other items were observed in this reach wherever the top of the ravine met the county road.

Pool conditions

In 2007, there was no appreciable flow by August 22, and no glide downstream to the sea from the plunge pool at Meadow Brook Lane. The pool remained relatively well oxygenated (85.3 percent at 13.9^{o}C), but we observed neither fish nor invertebrates in the pool. On September 6, oxygen had fallen to 71.8 percent at 12.6^{o}C, and the pool was very turbid with a large submerged mat of algae. No fish were seen, but a few Gammarid amphipods were noted. There was still a trickle of water through the culvert.

The Meadow Brook plunge pool is shallow (less than 2 feet), warm and anoxic in spring and summer as soon as rains cease and upstream ponds no longer overflow. Pond enlargement just above Killebrew Lake Road in 2007 has exacerbated this condition. In spring 2008 algal growth turned the plunge pool opaque green, and this continued until the autumn rains.

Discussion

Bayhead is (for the islands) a mid-sized watershed with more than enough shaded stream riffles and pools, and sufficient water to support native coastal cutthroat runs. But more than 90 percent of the stream habitat is inaccessible at present, and residential pond building has reached the point that winter flood conditions, and low to negligible summer flows, are no longer hospitable to salmonids.

Bayhead supported spawning-size cutthroat trout in 2004, but no longer does, due (it appears) to pond construction in the west branch. This is a significant loss that should be addressed by remedial measures to restore pre-2007 stream flows such as lowering the pond dam or regulating summer pond outflows; installing a culvert under LaPorte Road to restore inputs from the alder-sedge wetland to the main stream channel; and replacing the culvert under Killebrew Lake Road to ensure that all the area north of the road drains into the main stream channel.

We also recommend replacing the perched, over-length culvert under Meadow Brook Lane with a shorter, bottomless one, and replacing the concrete-and-cobble weir at the lower end of the plunge pool with boulders and large woody debris to foster a natural, self-sustaining pool without impeding fish passage.

Cutthroat trout (likely sea-run) from Bayhead in 2004: a run lost in 2007 due to impoundment of flows by ponds.

Cascade Creek – Mountain Lake

Orcas Island

Sources

The stream that meets salt water at Buck Mountain, Orcas, rises from Twin Lakes, Mountain Lake, and the extensive Cold Springs wetlands on Mount Constitution. Several smaller wetlands and streams drain into Cascade Creek between the southern boundary of Moran State Park, where there is a major diversion, and Olga Tank.

Mountain Lake is a natural basin, but its level was recently raised several feet by a concrete dam; drowned trees are still visible in up 4-6 feet of water at the north end of the lake near the input from Twin Lakes. Outflows from Mountain Lake are regulated by the Washington Department of Ecology to maintain supplies for Rosario Resort (via Cascade Lake) and the Olga Water Association (at Olga Tank).

A large expanse of wetlands immediately north of Olga, easily visible from the Olga Café, originally drained east into Cascade Creek. The county road has re-directed it directly into Buck Bay less than 25 feet south of the point where Point Lawrence Road crosses Cascade Creek near its mouth. Lost flows are only approximately 1-2 cfs during winter, however, and negligible in summer.

Large cut stumps (many with springboard notches) attest to logging of the stream banks beginning in the 1880s. Most of the contemporary firs are only 50-60 years of age and still overtaking the alders that established in the ravine during the last round of clear-cutting. The substrate is relatively coarse (coarse sand, gravel, pebbles) for most reaches between Moran State Park and salt water, with numerous sand bars and gravel benches as well as side-channels and cut-banks indicative of periodic extreme water conditions. Just above Kahboo Hill Road at "Cascade Gardens" the ravine widens, however, where there once was a braided wetland, as indicated by sandy-muddy substrates.

A major flood event—we estimate 125 cfs at its peak—occurred in January 2009 as a result of an unusual accumulation of snow in December that melted rapidly in warm rains. Hundreds of tons of gravel were pushed downstream of Cascade Gardens, ending in a large plug about 200 feet above Point Lawrence Road, and causing the lowest reach of the stream to shift 25-50 feet to the west. Spawning gravels at Olga Tank and Kahboo Hill Road disappeared completely, leaving only bare bedrock and cobbles. The impact of this event, and subsequent very late spring thaw on cutthroat is not yet known. No redds had yet been observed in mid-April.

Barriers

There are several significant natural barriers to fish passage in Cascade Creek, as well as anthropogenic ones. As far as we have been able to determine by observing fish movements (mainly with underwater videography), all of these barriers permit a limited degree of downstream movement of juvenile cutthroat, but no upstream movement.

Barriers to fish passage divide the Cascade system into at least six distinct fish habitat zones: (1) from Twin Lakes to Mountain Lake dam; (2) from the south boundary of Moran State Park to the ponds constructed in 2002-2004 as part of "Cascade Gardens"; (3) from the wetlands on the south side of "Cascade Gardens" to Olga Tank where a high concrete dam blocks upstream fish passage; (4) from Olga Tank to the very high waterfall where Cascade Creek flows east under Olga Road; (5) from the high waterfall to a series of lower falls and cascades that end in a large plunge pool about 500 feet upstream from Buck Bay; (6) from the large plunge pool roughly 500 feet downstream through culverts under Point Lawrence Road to tide water in Buck Bay. Obviously only the last of these reaches can support sea-run fish. Nonetheless we believe that upstream resident cutthroat populations can (and probably do) contribute genes to all populations downstream from them: one-way gene flow by which the fish in Twin Lakes-Mountain Lake remain genetically isolated while influencing the development of five downstream populations.

Point Lawrence Road (a county arterial road) crosses Cascade Creek on the edge of Buck Bay over a causeway of shot rock, punctured by a 28-inch culvert and similarly sized overflow culvert that flows on severe winter floods. The county added more shot rock to the causeway in 2007 to stabilize the road, but the winter 2007-2008 and 2008-2009 floods breached the road 75 feet east of the causeway, compromising its integrity. With recorded recent winter flows of 35 to more than 100 cfs, the existing culvert is not only inadequate to protect the causeway and road, but a hydrological barrier to fish when they try to enter from seaward.

Fish presence

Salmonids were observed and brought to hand in all six reaches of Cascade Creek described above, including all age classes of coastal cutthroat and brook trout, introduced at Cascade Gardens in 2002-2004. Brook trout outnumbered coastal cutthroat in all of our collections by electrofishing and hand-nets with the Wild Fish Conservancy.

WDFW began planting hundreds of thousands of cutthroat fry in Mountain Lake in 2006, one year after the Wild Fish Conservancy's initial documentation of cutthroat in the stream below.[4] At least some of the introduced fish have probably drifted downstream and exchanged genes with the coastal cutthroat already established there. Our laboratory was unable to find genetic evidence of multiple cutthroat populations in a sample of 16 cutthroat collected in Mountain Lake and Cascade Creek in 2008. This is consistent with extensive hybridization of recently introduced and native cutthroat.

As early as the 1950s, and again within the last decade, chum and coho have been planted in the sea-accessible reach of Cascade Creek. Mature salmon returned for several years, but there has been no evidence of natural spawning. Although Boessow (WDFW) brought juvenile Chinook to hand in the sea-accessible reach of Cascade Creek in 2008, it is likely that these fish originated elsewhere and were exploring the estuary for prey. No redds were confidently identified in the sea-accessible reach of Cascade in 2008 or 2009, although numerous redds were located farther upstream, between Olga Tank and Kahboo Hill Road by the same survey.

A large out-migration of young-of-the-year cutthroat was observed and filmed on August 30, 2007. Fish were seen both above and below each barrier; very large numbers

[4] WFDW had been planting cutthroat, kokanee and rainbow trout in Cascade Lake since 1999, but they should not have been able to enter the Mountain Lake-Cascade Creek system through the sluice that diverts some Cascade Creek water to Cascade Lake to maintain summer lake levels.

were seen in the large plunge pool and just seaward of the culvert under Point Lawrence Road. What may have been the tail end of a comparable out-migration was observed and filmed on September 14, 2008.

Diversions

Mountain Lake is a regulated drinking water reservoir; the control is a very large concrete overflow dam that raised the natural level of the lake by more than four feet and prevents any upstream passage of fish to the lake. Lake outflow is managed by the State Department of Ecology.

A second diversion is located just below the point where Cascade Creek crosses Olga Road near the southern boundary of Moran State Park. It transfers Cascade Creek water to Cascade Lake, to maintain "head" for small hydro operations at Rosario Resort. At times this diversion can be significant; the shunt leaks, furthermore, so that water is diverted even when the diversion ditch is supposed to be closed. In 2007 local residents reported a large number of salmonids stranded in the diversion ditch when the shunt was closed.

Land use

The lowest 6,000 feet of Cascade Creek is undeveloped except for two privately owned wooden bridges, the concrete dam at Olga Tank, and the culvert that conveys the stream under Olga Road. This portion of the stream has four landowners, including the Olga Water Association, all of whom express interest in maintaining existing woodland conditions.

A different situation has developed between Kahboo Hill Road and the southern boundary of Moran State Park, an area where Cascade Creek historically slowed down, spread out, and threaded its way through broad level wetlands before returning to a very narrow, deep ravine on its way to Buck Bay. Over the past decade, developers cleared large parts of the wetlands, dug ponds, built low dams and modified the stream channel. At least one purchaser has gone to pains to reverse some of the modifications, but there continue to be issues with open treeless ponds and straight ditch-like channels lacking in gravels, shade, or large woody debris. Nonetheless as described above, salmonids have persisted in this highly modified reach of Cascade Creek.

The Cascade system is prone to flash floods. In the winter of 2007-2008, State gauges recorded a December surge from 30 to 95 cfs in a matter of hours. A surge of at least 100 cfs in January 2009 plugged the channel 300 feet above the tidal prism with a massive gravel dam, forcing the stream to shift its course 50 feet eastward in places. It is unlikely that salmonids, particularly juveniles, can resist such severe flows, which may be a result in part of logging, clearing and home construction in the lower Cascade Creek valley, far uphill from the actual stream ravine. Greater storage capacity and off-channel refuge habitat in lower Cascade Creek may be necessary to buffer salmonids from effects of population growth in the portion of the watershed that extends outside the State Park.

Toxic sources

The headwaters of Cascade Creek are located entirely within Moran State Park, where they are exposed to wastewater from campsites and park facilities, presumed to be mainly cleaning products. Our 2008 study found pesticides and surfactants in Mountain Lake at modest levels, probably augmented by airborne deposition: as the highest point in San Juan County, Mount Constitution also receives the greatest precipitation and thus the greatest share of airborne pollution.

Cascade Creek passes through landscaped residential grounds for only a relatively small distance near the park boundary, potentially exposing it to home, lawn and garden chemicals. Much of the remainder of the stream course, while undeveloped, is parallel to a county arterial road and receives road runoff.

A pre-1950 trash dump was observed in the ravine near the large plunge pool. The current landowner has been removing bottles, car parts and other trash for proper disposal. There is also a slide of broken concrete and construction trash in the ravine a short distance north of Olga Tank; it does not appear to include toxic materials.

Pool conditions

Regulated outflow from Mountain Lake has maintained summer instream flows of 0.25 cfs or greater, which is sufficient to maintain pools and at least shallow glides in the undeveloped, well-shaded portion of Cascade Creek.

Several pools were monitored just above the sea-accessible reach and above Olga Tank in 2007-2008. Continuous, albeit diminished flows kept temperatures moderate and dissolved oxygen levels high compared with the isolated summer pools in other watersheds included in this study.

A small dug pond in the Cascade Gardens reach could pose a barrier to summer movements of salmonids. Shallow and relatively still, ponds grow warm in summer, and with significant aquatic vegetation, have greater biological oxygen demand than natural stream pools or glides. We observed (and brought to hand) numerous juvenile cutthroat and brook trout in the stream channel just above this pond in early summer, and saw evidence of fish activity in the pond itself. We did not have an opportunity to monitor pond conditions over a longer term, however.

Discussion

With two major diversions (Cascade Lake-Rosario, and Olga Tank), maintaining adequate instream flow is a concern for summer survival of native fish. At the same time the Cascade system must be protected from severe flooding, which can be exacerbated by the management of the Mountain Lake dam. Recent acquisition of a portion of the flow by the Washington Water Trust has addressed the first of these concerns. Construction of some off-channel reservoir capacity and surge channels would address the second. There is a relatively broad, level wetland corridor around the stream between Moran State Park and Kahboo Hill Road that would be appropriate for flood management works, if riparian landowners agree.

Following the severe January 2008 flash flood in this watershed we observed little salmonid activity or redds below Kahboo Hill Road. Most fish activity appeared to have shifted upstream, in the slower reaches of the streams where more gravels remained. The only structural concern in this portion of the stream would be the Cascade Gardens pond. Increasing shade around the pond will help maintain conditions for summer fish passage and use (moderate temperatures and sufficient dissolved oxygen).

With the exception of the concrete dam at Olga Tank, the barriers between Moran State Park and the sea are natural ledges of bedrock. Numerous log jams were observed, however, which may also pose barriers to fish passage and can be a result of logging and clearing practices. At least one riparian landowner had selectively removed windfall and snags from parts of the stream on his property to break up some jams. A good balance of woody debris and unimpeded fish passage will require active management in this stream corridor.

Large numbers of adult sea-run cutthroat can be seen in fall in the plunge pool beneath the downstream-most series of waterfalls on Cascade Creek, attempting to continue upstream. When flows are strong, producing a continuous sheet of water over the falls, some fish may be able to ascend. Improving fish passage over this natural (albeit historically modified) barrier is a possibility for strengthening the sea-run component of the Cascade cutthroat population and would add approximately 1,500 feet of shaded riffles and pools to their habitat. This could be achieved relatively simply by building two or three stone "steps" that salmonids could use to ascend the waterfall in shallower leaps.

The rapid growth and spread of the brook trout population in less than a decade is arguably the most serious threat to cutthroat in the Cascade watershed at this time. Brook trout can be very aggressive in competition with cutthroat for nesting sites and prey. The possibility of selectively removing brook trout as a part of fish monitoring by seining and electrofishing should be considered. Complete eradication of brook trout from the stream is not feasible, however.

Crow Valley – Turtleback

Sources

The stream that enters West Sound just east of the hamlet of Westsound has two branches. The main (west) branch rises in wetlands at the north end of Crow Valley and runs south down the middle of the valley, drawing on runoff from Turtleback Mountain. A second (east) branch rises in a shallower and narrower valley that rises on the northern slopes of Mount Woolard, and flows southwesterly and westerly to join the main branch approximately 3000 feet above the tidal prism. An instream pond regulates the flow from this branch into the main branch, and many ponds on the shoulders of both branches that affect the flow regime in the sea-accessible lowest reach of this stream.

The Crow Valley watershed extends as far north as Crow Valley School Museum, above which the valley drains to Fowler's Pond (a recently modified wetland) and thence into East Sound.

The width and substrate of the lowest stream reach suggest that peak winter flows have not declined significantly over the last century, whereas summer flows have almost certainly fallen significantly as a result of upstream impoundments. There was no visible flow in this stream from early June through mid-November 2008.

Barriers

A concrete causeway (Deer Harbor Road) restricts the small embayment of less than one acre in extent at the mouth of this stream by about 75 percent. The embayment has a rocky to gravelly floor covered with several feet of very fine silt, and is surrounded by a thick ashy pre-Contact shell midden. A lifelong resident had fished and collected oysters in the embayment prior to construction of the causeway, when the bottom was gravel and shell. Despite the tidal restriction, salinity in the embayment can be as low as 5 ppt when the stream is flowing, as we observed in March 2004.

The northeast quarter of this estuary is heavily armored with riprap and a concrete bulkhead that continues along the east bank for about 100 feet upstream. The west bank is also armored with riprap for about 50 feet above the embayment.

A 4-foot high natural waterfall composed of bedrock and large loose rocks blocks the embayment at its upstream end. It appears to be passable on high tides, at least when there is significant stream flow, such as we observed from December to February in 2008 at 5-12 cfs. Above this point, there are only shallow 1-2 foot bedrock ledges confronting upstream migrants for another 1200 feet, ending in several higher bedrock ledges forming an effective one-way barrier to fish passage.

Approximately 3600 feet above these waterfalls, the main branch flows through a concrete box culvert under Nordstrom Lane; it is 3 feet wide and flush with the substrate, hence unlikely to pose a significant barrier to fish passage.

The pond at Old Trout Inn on Orcas Road, and the road itself, bar fish migrations farther upstream in the east branch, and restrict the movement of water downstream from

Mount Woolard. Farther upstream, the east branch flows through several small road and driveway culverts that might pose access problems if fish were present.

Fish presence

Seining within the small estuary in 2004-2005 was unproductive. Electrofishing just above the tidal prism yielded one juvenile chum (0+ age class); however, we learned subsequently that Fidelis, a women's service club in Westsound, had planted chum fry in the stream prior to our survey. No salmonids have subsequently been observed by video or pedestrian observations in the largely intact lowest 1200 feet of the stream.

In 2007 we video-monitored three large summer stream pools approximately 500 feet above the tidal prism. Sticklebacks were initially observed in all three pools: at least 16 fish in the largest and deepest pool on July 25, and 23 fish on August 9. Gammarid amphipods were abundant in all pools.

On August 24, 26 sticklebacks were seen in this pool, foraging on the surface and substrate, although the level of dissolved oxygen had fallen considerable (29.5 percent at 14.5^{o}C). Several sticklebacks were also seen in three other nearby stream pools this day. A few sticklebacks were still visible in this pool on September 6, when oxygen levels had fallen to 23.4 percent at 13.8^{o}C. These fish subsequently disappeared. Lack of adequate summer flow to maintain oxygen levels is presumably a factor in the absence of cutthroat and other salmonids.

Diversions

While the lowest 1200 feet of this stream are relatively intact—shaded with good gravel riffles and deep pools, with rapids produced by shallow rock ledges that should not pose barriers to salmonids—the remainder of this stream has been modified significantly by agriculture. A straight ditch has replaced the original meander, and there are a number of farm ponds on the shoulders of the channel, intercepting drainage from the Turtleback.

Input from the east branch is blocked by a undersized, failing culvert under Orcas Road and a pond at Old Trout Inn on the west side of the road. Above this restriction, the east branch continues for nearly 5,000 feet in a narrow corridor of trees and shrubs before disappearing into hayfields (most of which are vernal pools) and dug ponds.

The hydrograph for this stream reflects the influence of numerous ponds. Stream flows increase relatively late but very rapidly in fall or early winter, when all ponds have filled and finally overflow (a tipping-point phenomenon). In late spring or early summer, flows drop suddenly to zero. Water that would have percolated gradually out of wetlands or beaver ponds all summer is efficiently contained by at least some of the upstream dug ponds. Winter flows may be reduced somewhat by networks of ponds but not as much as the duration and depth of the summer drought, when fish are most in need of water.

Reduced flows have no doubt contributed to low circulation and silt accumulation in the small estuary as well.

Land use

More than half of this watershed is cleared for pastures, hayfields, and residential lawns and gardens. It is the largest contiguous cleared area on Orcas Island, although it is relatively thinly populated: nearly all is zoned Agricultural Resource, with a minimum of 10 or 20-acre building lots. Significant portions of the cleared area are under easement to the San Juan Preservation Trust, which helps protect the watershed from further build-out but does not necessarily protect flows or facilitate the restoration of the stream channel.

Toxic sources

We did not identify any significant potential point sources of contamination along the main branch of this stream. Two household trash piles (mainly bottles and cans, also some car batteries) were found in the ravine within 500 feet of the tidal prism. Non-point pollution is a greater threat to this system, with much of the watershed cleared, farmed, or landscaped for residences. Pesticides and surfactants were detected in the lowest reach of the stream in 2008, at levels close to the mean for developed watersheds in the county. A potential issue is reduced photolytic degradation of toxics, due to the large number of dug ponds in this watershed.

Pool conditions

Stream pools in the relatively intact seaward reach were completely isolated in the summer of 2008, and despite an alder-fir-cedar forest canopy that kept temperatures close to levels observed in pools with cutthroat in other watersheds, dissolved oxygen fell well below levels that even sticklebacks could survive (as described above).

The little estuary itself may be problematic. Originally deeper with a substrate of hard-packed shells and gravel, according to a longtime resident, it is now soft and muddy, with high turbidity and little aquatic vegetation. We confirmed the change in substrate by coring on low tides. Turbid, muddy, hypoxic waters may deter salmonids from exploring the estuary and the stream above it.

Discussion

Despite a substantial water catchment that includes much of Turtleback Mountain, the Crow Valley watershed has been dissected by ditches, inadequate culverts, and ponds to the extent that it lacks flow for several months each year—too long for pools to remain habitable by fish. No large impounded wetland or artificial reservoir exists that could be regulated to augment summer flows. While winter conditions are excellent for salmonids in the sea-accessible reach of the stream—strong but non-destructive flows, broad riffles, plentiful woody debris—there is little likelihood of juvenile survival in summer without a source of at least 0.25 cfs to this reach.

Doe Bay – Mount Pickett

Sources

Surface runoff from the east slopes of Mount Pickett in Moran State Park collects in wetlands and ponds along the west shoulder of the Doe Bay stream ravine, entering the stream through several small tributaries and numerous seeps. Significant winter flows of up to 5 cfs can be found where the largest tributaries meet to cross Point Lawrence Road approximately 3,800 feet upstream.

Barriers

This stream discharges into Doe Bay over a waterfall that poses a barrier even on the highest tides of the year, when it is still almost 10 feet above sea level. Above it, the stream runs briefly through a narrow slot in the bedrock to a second waterfall. Together, these natural features are complete barriers to upstream migration; however, it is not clear whether they restrict downstream migration to the sea.

Above the waterfalls, there is approximately 200 feet of stream channel with good conditions for salmonids—shaded gravelly riffles and pools—ending in a five-foot deep plunge pool created by a perched culvert under Point Lawrence Road. Above the culvert, the stream channel is alternately sandy, gravelly and clay with good shade and no barriers other than woody debris jams for another roughly 3,400 feet, where it encounters another perched road-culvert plunge pool associated with Point Lawrence Road. Neither perched culvert is high enough to pose a significant barrier to fish passage. In winter, water levels are within inches of the culvert edge. In summer, however, the upper plunge pool is dry, and there are only isolated pools between the upper and lower plunge pools.

There is a single driveway over the stream, a short distance downstream from the convergence of tributaries under Point Lawrence Road; culverts are large and flush with the stream sediment, posing no barrier to flow or to fish.

Fish presence

Cutthroat were brought to hand in both plunge pools, and at least two large adult cutthroat in spawning colors were videotaped in the larger, lower plunge pool in summer and fall 2007 and 2008. Efforts to locate other pools with summer residents in 2008 were unsuccessful. The entire population may retreat to the lower plunge pool, or abandon the stream for the sea, each summer.

Cutthroat in this stream, if not the descendants of plantings, represent an unusual post-glacial relic population isolated by the isostatic rebound of Orcas Island relative to sea level more than 4,000 years ago.

Diversions

There are no significant diversions in this watershed.

Land use

Most of the watershed consists of scattered homes and fields with little active use of land for livestock or other agricultural activities. There is a small cluster of residences approximately halfway between the upper and lower plunge pools but it is perched on the top of the ravine and probably has no appreciable impact on the stream.

The lowest reach—from the larger plunge pool to the waterfalls—is a part of Doe Bay Resort. The resort has avoided any disturbance of the stream channel. A bath house is located between the two waterfalls.

Toxic sources

No dumps or effluents were observed in this watershed. Septic leakage from local homes and the resort is possible of course and soapy water from the bath house should be managed carefully to avoid discharge into the stream or the bay. The resort management is conscious of the need to protect the stream, its water quality and its fish.

Pool conditions

A small trickle of water continues to flow through the large, lower plunge pool for most of all of the dry season, maintaining reasonably cool, oxygenated conditions that are somewhat extreme for salmonids—but from our observations apparently compatible with the survival of island cutthroat. In 2007, dissolved oxygen fell just below 40 percent with no evidence of mortality, compared with 25 percent in monitored Crow Valley pools.

As noted above, the upper plunge pool is completely de-watered in summer, and a search of other small natural pools found no fish. A natural stream pool we monitored in 2008-2009 approximately halfway between the upper and lower plunge pools maintained a trickle of water in summer but like others we investigated in this reach, was too shallow to avoid excessive warming and hypoxia.

Discussion

From the perspective of genetic diversity, it would be highly desirable to preserve and enlarge the Doe Bay cutthroat population; but it is difficult to identify realistic ways of improving the existing habitat significantly. Restoring access from the sea would be a major undertaking, and would not overcome the underlying limiting factor in this stream: inadequate summer flows to maintain habitability except in a single large plunge pool. If summer habitat is not improved, the Doe Bay population will continue to be very small.

One practical option would be to replace the existing large Point Lawrence Road culvert at Doe Bay Resort with a larger bottomless culvert or broad arch; and to enlarge the plunge pool under and above the road by deepening some of the channel immediately upstream. This would combine several small pools with the large plunge pool, providing a larger contiguous habitat for over-summering cutthroat that would be a little shallower, better shaded over some of its area, and thus make better use of available water.

The principal structural issue is this watershed appears to be the lack of sufficient summer reservoirs. Winter flows are significant and have been even greater in the past—as witnessed by the breadth and depth of the ravine through which the stream passes from the upper to lower plunge pools. Summer flows may always have been weak, however. One possibility would be to build several low weirs in the feet of channel above the lower plunge pool, and add gravels to this relatively level, sandy reach, to enhance its spawning potential in winter and the number and size of summer pools. In any event it is critical to ensure no further modifications of upstream wetlands that could reduce summer flows in the channel between the upper and lower plunge pools.

Pickett Springs Creek – Mount Pickett

Sources

This stream appears to rise from two distinct sources. The main source is runoff from the south-facing foothills of Mount Pickett, which collects in wetlands and artificial ponds perched on the hillside above Point Lawrence Road near Studio 420, and in winter cascades down to the road and passes under it through a culvert. There are also springs at the head of the narrow valley through which the stream flows, but their total contribution is proportionally very small.

Barriers

Logjams form each winter blocking the outflow of this stream through the beach, at least partially and in some years almost completely. Beach sands and gravels also drift considerably from year to year, sometimes plugging the stream outflow until a significant precipitation event blows out a new channel.

Barely 150 feet from the beach, a driveway crosses the stream channel on fill with a perched culvert. This feature creates a shallow pond where the next 300 feet of stream channel would have been. A second driveway on fill crosses the pond approximately 180 feet upstream of the first. Not far above this second driveway is a second instream pond, with a wooden weir that blocks fish passage in or out of the pond.

Some distance above the second pond, the stream passes through a large concrete box culvert under Point Lawrence Road, perched somewhat but probably not a barrier in itself. Above it, however, the channel disappears into a marshy area. Several more weirs and small driveway culverts were observed farther upstream.

Fish presence

According to Joanne Johnston, jacks were taken in this bay during her childhood (1940s), and Chinook have been observed trying to enter the stream. Cutthroat were once planted in the stream but were washed out by a storm flood and never returned. This may also be one of the streams that Fred Leatherwood recalled being stocked with coho fry in the 1950s by Orcas sportsmen. More recently, Sandy Taylor maintained a small egg box in the sea-accessible reach of Cascade Creek, and observed a few years of chum and coho returns to this miniature hatchery. It was still operating as late as 2005 barely a kilometer distant from the mouth of Pickett Springs Creek.

WFC electrofishing brought a single juvenile coho to hand in the stream channel between the first barrier (first driveway bridge) and the beach. Most of this small reach is tidally influenced, a tiny estuary. It is possible that juvenile salmon occasionally wander into the estuary in search of prey, perhaps soon after their departure from Cascade Creek. Our efforts in subsequent years to bring other salmon to hand, or to videotape them in the channel, were unsuccessful. Occupants of the two homes within close sight of the stream and beach did not observe fish in the stream, or leapers.

Land use

The beach and low bluffs at the outlet of Pickett Springs Creek have been popular for a very long time: shell midden covers much of the area, albeit most of it disturbed by landscaping in years past. Excavations conducted in 2007 to evaluate geological stability for a driveway bridge found evidence that the original stream channel and most of the salt marsh surrounding it had been filled.

Homes, gardens, and small fields dominate the watershed nearly to its headwaters, interrupted by patches of alders and shrubs.

Diversions

We observed numerous impoundments of this stream but no significant diversions or withdrawals.

Toxic sources

Small-scale farming and raising livestock may be sources of elevated nutrients in this stream. Soils are shallow and saturated for a large part of the year, so septic leakage could also be an issue. No significant dumping or chemical use was evident.

Pool conditions

The only existing summer refuges in this stream are ponds. We did not find fish in the lowest ponds; at least one of the upstream ponds had been stocked with minnows with poor results. Instream flow in summer is negligible, and accordingly ponds tend to become very warm, and potentially hypoxic due to high biological oxygen demand from decaying vegetation.

Discussion

The focus of restoration discussions thus far has been creating a winter spawning channel for coho and/or chum. In 2005, People for Puget Sound developed a conceptual design for recreating a tidal slough and salt marsh from the beach to the second driveway above the beach, incorporating the entire area of the existing lowest pond. Maintaining ingress over the beach is a threshold consideration. Winter storms shift logs and gravels on the beach annually. A small jetty or boulder array would seem necessary to keep the mouth of this stream free of debris; otherwise annual clearing will be required and could be even more costly and disruptive.

Existing ponds could be shaded better, and regulated to maintain modest summer flows to enhance conditions for the re-introduction of fish such as coastal cutthroat. Sea-run stocks could re-colonize this stream, or be re-introduced, only after re-configuring at least the two large in-line ponds between the sea and Point Lawrence Road. Both could be rebuilt to include a continuous channel and some off-channel wetland habitat. Water flows from farther upstream would be the main limiting factor.

Skull Creek – Turtleback

Sources

This stream originally drained a string of large depressional wetlands beginning just below Orcas Knob (the head of the Turtleback turtle). All have been dug or drained. The lowest wetland, just to the north of Deer Harbor Road, is an artificial residential lake maintained by an earth dam with an offset overflow to the stream channel.

Excavation, damming and flooding of a large peat bog near the headwaters of the Deer Harbor (Fish Trap Creek) watershed created a second, larger artificial lake on the same landowner's property. The overflow culvert on this reservoir diverts water from the Deer Harbor watershed into the headwaters of the Skull Creek watershed. Measurements made in winter 2007-2008 indicated that this had reduced Fish Trap Creek flows by about half, and increased Skull Creek flows to the stage that the owner of the seaward reach had complained of flood damage and significant redistribution of gravels.

Barriers

A waterfall flowing over a bedrock ledge limits entry to the stream; we concluded that it is probably passable on high tides when the leap would be only about three feet. A second barrier is the Deer Harbor Road culvert, narrow and perched in road fill more than 8 feet over the streambed, which becomes a horizontal jet of water in winter and is dry in summer. On the upstream side of Deer Harbor Road, a series of 4-6 foot bedrock ledges, and a clay chute, restrict access to the lower, older artificial lake. Fish do appear to make it downstream from this lake, but return passage under Deer Harbor Road and up the falls and chute is almost certainly impossible.

Fish presence

Rainbow trout were brought to hand by WFC crews in the seaward reach of Skull Creek below Deer Harbor Road. They were presumed to originate in the artificial lake on the upstream side of the road, which has been stocked and continues to support rainbows.

Diversions

As described above, current flows have been augmented by a significant diversion from the Deer Harbor watershed. The original artificial lake on the stream has negligible summer seepage, resulting in a dry stream bed from midsummer until the fall rains.

Land use

The Skull Creek watershed is divided between two properties. The seaward reach is residential, with little clearing and a meandering shaded stream channel. The upstream is mainly agricultural—hayfields bordered by wood lots, with horses and other livestock, and no remaining natural water features. Most of the water available in this watershed is impounded in two artificial lakes on the upstream property.

Toxic sources

An artisanal sawmill, livestock operations, and periodic earthmoving with heavy equipment are the only significant potential influences on water quality we observed. It is likely limited to nutrient issues, mainly around the lower lake, and motor oils and fuels used in heavy machinery and vehicles. The lower lake appears eutrophic: a combination of livestock inputs, dense aquatic detritus and heavy use by Canada geese results in high biological oxygen demand.

Pool conditions

Conditions in the artificial lakes were not investigated systematically. The stream below Deer Harbor Road has no summer flow and is too level and sandy for pools to last.

Discussion

Habitat structure from the county road to the sea is good, and could support a run of steelhead derived from the lake population, or attract colonization by wild coho, chum or trout. Water delivery to this reach must be regulated, however, to avoid winter floods and maintain at least 0.1 cfs in summer for pools. This could easily be accomplished by reversing the recent diversion from the Deer Harbor watershed and by installing a control structure on the lower artificial lake to draw its level down in summer and fall. Using the lake for a summer reservoir will necessitate addressing nutrient issues, but this is also not technically challenging. Shading vegetation that limits algal growth and goose access to open water, livestock management, and some water movement in summer, may suffice.

West Beach (Bonnie Brook) – Turtleback

Sources

This stream rises from a string of small wetlands and ponds on the northeast slope of the Turtleback, and from a number of lower lying wetlands and ponds along its course.

Barriers

Two main potential barriers were identified. A driveway with two small, perched culverts impounds the stream barely 50 feet above salt water, forming a long shallow and relatively static pond at the bottom of the historical stream ravine. It appears that the low end of the pond was also dug for road fill when it was established it the 1950s. There can be downstream passage through the culverts, and possibly limited upstream movement as well. Low oxygen conditions and turbidity in the pond may actually pose more of a fish barrier than the perched culverts.

A short distance above the pond just described, the stream passes through a large corrugated steel culvert under West Beach Road. The culvert is perched 1-2 feet during winter, which is not necessarily a barrier; it is also rusting out, and the rock fill around it has begun to loosen and collapse. In summer, it separates two pools, a long shallow one on the upstream side, and a deep plunge pool on the downstream side.

There is a short reach of rapids and rock ledges farther upstream, which should not impede fish passage in winter when flows are high.

Fish presence

Local fly fishermen recall taking cutthroat in this stream until the 1970s. Several adult cutthroat and one adult steelhead (confirmed by Restriction Fragment Length Polymorphism analysis of DNA extracted from fin clip tissue) were brought to hand in the large plunge pool at West Beach Road during the course of this study. Up to ten juvenile cutthroat have been observed in the same plunge pool by underwater video; juveniles use this pool consistently in summer (Appendix I). Juvenile cutthroat were also occasionally observed in pools and glides for 100 feet below this plunge pool, and in the shallow pools just above it on the upstream side of West Beach Road.

Comment [JG1]: What is RFLP?

Adult and juvenile sticklebacks were frequently observed in the large plunge pool, in the stream channel below it, and in the pond near the mouth of this stream. The plunge pool also had several non-native pumpkinseeds sharing it in 2007-2008.

Diversions

There are several small dug ponds in the source wetlands of this system. Summer flows represent leakage and seepage from ponds, and would be jeopardized by any efforts to seal ponds more effectively.

Land use

The upper half of this watershed consists of old farm fields, little used at present except for hay. The lower half—below the rapids—is residential, and a number of small houses are perched on the edge of the stream ravine. The property at the stream mouth is an artisanal pottery. Most of the lower half is densely wooded where not built.

West Beach Resort does not drain appreciably towards this watershed across West Beach Road, but the road itself is culverted directly into the stream at several points, most notably at the large plunge pool where juvenile cutthroat summer.

Toxic sources

Small amounts of trash such as tires, car parts and remains of older buildings have been dumped throughout the ravine. Toxic metals and wood preservatives are potentially associated with these materials. Potteries are sources of toxic metals used in glazes so the disposal of chemical waste on that property could be a concern. The most serious issue is the county road, however, since it focuses runoff directly into the most critical habitat on this stream.

Pool conditions

Although some flow persists year-round, glides disappeared by August 9 in 2007, and even earlier in 2008, leaving pools isolated for several months. Minimum flows were 0.1-0.2 cfs during the period of isolation. Oxygen levels remained relatively high—more than 60 percent—in the large plunge pool, while they fell to half that level in the "pottery pond" near the stream mouth. The pond is relatively static, not fully shaded, and choked with decaying vegetation: conditions that result in high biological oxygen demand (BOD) and rapid draw-down of any oxygen input from continued summer stream flows. On the contrary, winter floods flush the large plunge pool of all but the heaviest woody debris—and the pool is shallow enough (about three feet) in summer to retain modest circulation with only a small throughput of fresh water. Cutthroat, sticklebacks, and pumpkinseeds were actively feeding in the plunge pool during our summer-fall video observations; but only sticklebacks were ever observed in the pond.

Discussion

A growing number of upstream ponds has gradually reduced summer flows in the West Beach system to the edge of survival conditions for cutthroat and steelhead; and the temperature and oxygen conditions in the "pottery pond" prevent its use by salmonids as summer habitat. This historical recreational fishery is at the edge of extinction. Culverts draining the "pottery pond" can be replaced by a larger passage that facilitates upstream migration, and either restores the pond to a stream channel, or at least increases summer flow through the pond to improve habitat conditions (lower temperatures, more oxygen). Removing some of the decaying vegetation in the pond is also advisable, to reduce BOD.

Regulating the discharge of upstream ponds would help restore historical summer flows. Increasing flows from July to October by just 0.2 cfs would connect many stream pools that are currently isolated during this period. No further impoundment or diversion of water is compatible with the survival of West Beach salmonids, in any case.

The West Beach Road crossing at Enchanted Forest Road is problematic. A large amount of rock was used to create a roadbed across the stream, and it is now shifting and threatening to crush the culvert. Removing it without destroying the existing plunge pool will be a technical challenge. Fish will need to be moved and probably conserved *ex situ* during construction. A bottomless culvert or arch would improve fish passage but lead to loss of the existing pool. Placement of large woody debris and rocks in the channel must be considered, to help new sustainable pools form. Trash removal should be considered, as part of any work in the streambed.

Rebuilding this county road crossing should also address road runoff. Vegetated ditches and swales in the county right-of-way on the north side of Enchanted Forest Road would allow for some bioremediation of runoff. There is also space for an enhanced and enlarged wetland (possibly with off-channel habitat for fish) on the upstream side of the existing road crossing.

Garrison Creek – Mitchell Hill

Sources

The Garrison watershed is surprisingly complex for its size. The main perennial flow, historical and present, descends from wetlands atop Mitchell Hill that also appear to feed Briggs Lake, the drinking water reservoir for Roche Harbor. There is a considerably smaller secondary natural source in lower-elevation wetlands due south of the States Inn, which drain through a corridor of willows and cottonwoods on the west side of the States Inn property. A large artificial pond on the east side of the watershed, and smaller one on the west side of the watershed also feed the stream when they overflow in the winter and spring. We observed the stream running year-round through the States Inn property, but disappearing—infiltrating and/or evaporating—in the large wetland immediately north of the Inn's property, such that there was no flow at all for five to six months in the stream channel at Blazing Tree Road.

Barriers

The tidal prism extends nearly 200 feet above (to the south of) Yacht Haven Road passing through two large culverts that appear to pose no barriers to fish passage. Several large metal culverts connect the estuarine reach and the lower stream channel with a large in-line pond at Krystal Acres and the long ditch above Blazing Tree Road; all of them are relatively flush with the substrate or sunk slightly, and should not pose obstacles. For the distance from the tidal prism to the upper (south) end of the long ditch, the limiting factor for connectivity is stream flow rather than physical barriers.

The large wetland complex between the long ditch and the States Inn property is a potential barrier at most or all times of year: there are no well defined channels, and what standing water can be found in winter and spring is choked with vegetation dominated by reed canary grass. Water is shallow and slow moving. And with a thick layer of detritus, biological oxygen demand (BOD) is likely to be high and the dissolved oxygen available for fish correspondingly low.

At the upper (south) edge of the wetland, where it meets the States Inn property, several very small culverts, often plugged with leaves and other debris, limit fish passage into the upper stream channel that winds through the States Inn and across West Valley Road towards Mitchell Hill. Not much farther upstream, there are three small, perched culverts under the States Inn driveway that almost certainly restrict upstream fish passage without necessarily affecting downstream movement of fish. A few hundred feet farther, the stream crosses under the county road through a partly collapsed, partly gravel-filled 2.4-foot culvert that we believe is passable at present, but could deteriorate into a partial or complete barrier within 5-10 years.

A short distance upstream from the county road there is a high concrete weir that is a complete barrier to upstream fish migration—although it is plausible that fish could survive a downstream plunge, as we have observed at a barrier of comparable height on Cascade Creek. It was unclear what function this structure had served—no pipes or other fixtures could be seen—and it is plainly abandoned and deteriorating.

Other than occasional large root wads in the streambed, we observed no partial or complete barriers to fish passage above the concrete weir.

Fish presence

Cutthroat juveniles and adults were brought to hand and videotaped on the States' Inn property, both above and below the Inn's perched driveway culverts. Two adults and several juveniles were videotaped in the little plunge pool below the driveway culverts in December 2008. Redds were observed just above the culverts in 2009 and 2010. Otters were observed fishing in this reach in April 2010.

Cutthroat juveniles were also repeatedly observed and brought to hand above the concrete weir, upstream from the States Inn; and in the long ditch, downstream from the large wetland that bisects the Garrison watershed. Several large adults were videotaped in the pond below Blazing Tree Road, and one adult mort was collected from the stream channel below that pond. According to the current owners, the pond was popular with fly fisherman for many years.

It is unclear how many relatively distinct populations of cutthroat may inhabit this stream. Downstream movement is difficult at places but not impossible, making one-way gene flow likely. Our genotyping of 11 juveniles and adults brought to hand at the States Inn and Troutbeck Farm properties, both above and below the concrete weir, and perched driveway culverts, found no differences with respect to the microsatellite marker set that we used. A larger sample may reveal finer scale variations attributable to partial barriers, but from the evidence gained thus far, it would appear that the cutthroat population south of the horse ranch is relatively homogeneous, but distinct from all other San Juan County cutthroat specimens that we have genotyped.

The owner of the large pond just east of the stream channel reports "trout" as well as introduced bass, and during the writing of this report WFC was able to confirm bass in the channel draining this pond to the large wetland and stream. This may be an emerging concern, and should be addressed before the connections between partly isolated reaches of this stream are restored.

Diversions

A large part of the mid-stream was ditched, drained and leveled in the past. There is now a broad, braided wetland (blue shading) into which the stream channel disappears (dashed blue line). The wetland drains into a straight ditch to Blazing Tree Road, which dries out completely by mid-summer and remains dry until the first substantial fall rains. Evaporation and perhaps infiltration in this wetland is sufficient in summer to disconnect the fish-bearing upstream and downstream reaches of the watershed.

The large dug pond or lake on the east side of the wetland, at the horse farm, has a simple overflow weir, and contributes a significant quantity of water to the wetland in the winter and spring, but none in summer and early fall when it could be used to offset water losses from wetland evaporation, and maintain flows in the big ditch.

The large instream "alpaca" pond was dug before the current owners purchased the land 12 years ago, dredged the pond back down to 10 feet, and removed encroaching vegetation. They have also set the inflow and outflow culverts to facilitate movement of water and fish, and the pond does help ensure summer flows in the sea-accessible lowest reach of the stream.

Land use

The Garrison watershed is predominantly agricultural with a cattle ranch, a mixed livestock operation at States Inn, a horse-raising operation near the large wetland, and the alpaca ranch along its sea-accessible reach. A few homes are also located between farms.

The perennial source is largely protected, either as part of the recent Mitchell Hill addition to San Juan Island National Historical Park, or as part of the reservoir for Roche Harbor. Artificial reservoirs in this watershed are located on working farms, but are used for recreation rather than farm purposes.

Toxic sources

Farming in this valley is largely non-chemical and the main water quality concern is nutrient loading by livestock: high ammonia reserves, and eutrophication of ponds that serve as water sources for the stream. Weekly measurements made in 2010 found spikes in ammonia throughout the watershed associated with livestock movements; and rapidly declining spring oxygen levels in the stream at Blazing Tree Road, presumably as a result of high biological oxygen demand (BOD) in the wetland and big ditch, both choked with decaying reed canary grass and other vegetation.

Pool conditions

Pools and glides persist through summer above the big wetland, maintaining good conditions for salmonids wherever there is shading vegetation. Below Blazing Tree Road the “alpaca pond” functions as a large pool; but it does get quite warm at the surface over the summer, and we observed adult cutthroat resting during the day in the deepest parts of the pond, presumably to stay cool. The stream channel from the alpaca pond to the tidal prism alternates between gravels and clay, and is essentially all glide with an inch or two of water in summer. Summer flows maintain adequate oxygen in this reach, and where it is shaded by riparian vegetation, it is good salmonid habitat year-round.

Discussion

Although the Garrison system hosts a relatively healthy small cutthroat population that arguably ranks second only to Cascade, and is not threatened by further development or impoundments, a number of measures can be taken to improve habitat conditions.

It is useful to consider this watershed as three functional units: the relatively intact stream channel from Mitchell Hill to the downstream boundary of the States Inn property where the stream disappears into the big wetland; the wetland and ditch, down to Blazing Tree Road; and the sea-accessible reach, from Blazing Tree Road to the tidal prism near Yacht Haven Road.

There are three unnecessary barriers in the Mitchell Hill-States Inn reach: the high concrete weir a short distance above the county road, which could simply be removed; an inappropriately small culvert under the county road, which could be replaced with a large bottomless culvert—action that should be taken within the next few years, as this culvert is failing; and three small perched culverts under the States Inn driveway, which could be replaced by a single culvert or arch perched just a foot or above the bottom of the existing plunge pool in order to preserve it. A pair of steel culverts at the point where the stream crosses from the States Inn property to the horse farm should also be replaced. It tends to plug up with debris in winter, blocking fish passage.

Adding to the existing riparian vegetation along the stream corridor as it meanders through the States Inn would help ensure adequate shade as well as enhanced buffering of nutrients from livestock. Increasing total diversity, and choosing plant species carefully, is more important than simply increasing buffer width.

Moving to the central portion of the watershed, there are plans already underway to build a new stream channel through the wetland to restore connectivity. Maintaining a channel of this size as salmonid habitat—especially if some off-channel wetland habitats are to remain here—will require additional water in summer. The large stocked pond at the horse farm is a potential source. Modifying the existing weir to lower the pond a bit more in summer will be simple. Preventing bass from leaving the lake and colonizing the rebuilt channel is essential.

With regard to the sea-accessible reach, the main goal should be to increase shade around the "alpaca pond" and those parts of the stream corridor that remain exposed. The landowners have been planting trees along the corridor, and a greater variety of shrubs as well as trees would enhance shade as well as nutrient buffering. Additional large woody debris in the sandy and gravelly parts of the streambed can help create and maintain pools for juvenile salmonids.

Appendix I – Summary of video observations

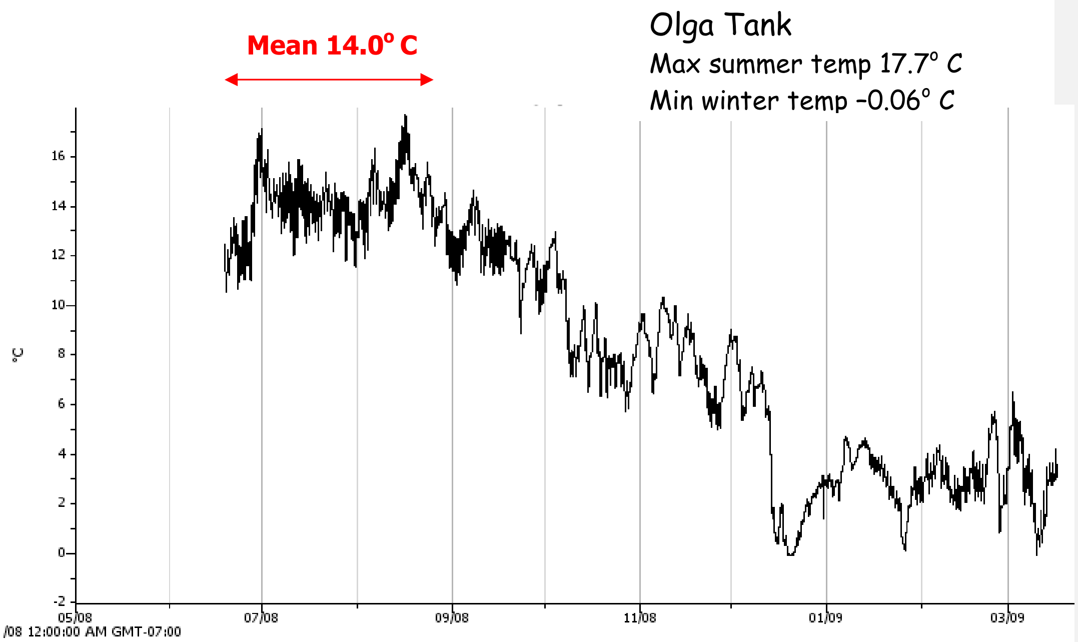
Stream – site		Date	Cutthroat			Other fish	Activity
			Number	Minutes	Ages		
West Beach	Plunge pool	3-Aug-07	3	6	0+		Benthic feeding
Doe Bay	Plunge pool	9-Aug-07					
West Beach	Plunge pool	9-Aug-07	3	13	0+	1S	Surface feeding
Doe Bay	Plunge pool	16-Aug-07	2	6	2+		Surface feeding
West Beach	Plunge pool	16-Aug-07	2	10	0+	2S 2P	Benthic feeding
Garrison	Alpaca pond	17-Aug-07	3	3	1+2+		Patrolling
Doe Bay	Plunge pool	22-Aug-07	2		2+		Surface feeding
Crow Valley	Long pool	24-Aug-07				4S	Benthic feeding
Crow Valley	Large pool	24-Aug-07				26S	Benthic feeding
West Beach	Plunge pool	24-Aug-07	2	23	0+	1S	Benthic feeding, patrolling
Cascade	Estuary	31-Aug-07	12	90	0+2+	20Sm	Surface feeding
Cascade	Olga tank	31-Aug-07	5	31	0+		Surface feeding, agonistic
Cascade	Footbridge	31-Aug-07	3	17	0+1+		Benthic feeding, agonistic
West Beach	Plunge pool	6-Sep-07	3	47	0+1+	4S 4P	Benthic feeding, agonistic
Doe Bay	Plunge pool	11-Sep-07	1	11	2+		Resting, surface feeding
Cascade	Lowest pool	11-Sep-07					
Cascade	Olga tank	11-Sep-07					
West Beach	Plunge pool	14-Sep-07	2	26	0+	1S 1P	Patrolling, feeding, resting
West Beach	Pottery pond	14-Sep-07				3S 1P	Benthic feeding, resting
Garrison	Alpaca pond	26-Sep-07	1	2	2+		Benthic feeding, resting
West Beach	Plunge pool	28-Sep-07	2	3	0+	3S 2P	Benthic feeding, patrolling
Doe Bay	Plunge pool	28-Sep-07					Surface feeding
West Beach	Plunge pool	12-Oct-07	2	3	0+	1S 1P	Patrolling, Benthic feeding
Doe Bay	Plunge pool	24-Oct-07	1	3	2+		Patrolling
West Beach	Long pool	1-Nov-07	3	8	0+	3S	Benthic feeding, resting
Doe Bay	Plunge pool	5-Nov-07					
West Beach	Plunge pool	13-Nov-07	2	14	0+		Benthic feeding, resting
West Beach	Plunge pool	16-Nov-07	2	24	0+	3S 5P	Benthic feeding, patrolling
Cascade	Plunge pool	20-Nov-07	13	45	0+2+		Surface feeding, agonistic
Garrison	Inn riffles	18-Dec-07	3	14	0+		Surface feeding
West Beach	Plunge pool	26-Feb-08					
Cascade	Plunge pool	26-Feb-08	1		2+		
Garrison	Inn riffles	11-Mar-08	8	8	0+2+		Patrolling
Garrison	Driveway pool	18-Nov-08	4	19	0+1+2+		Patrolling

Number of cutthroat is minimum number of fish. Other fish = S(tickleback), Sm(elt), P(umpkinseed)

Appendix II.1

Cascade Creek Pool Temperatures

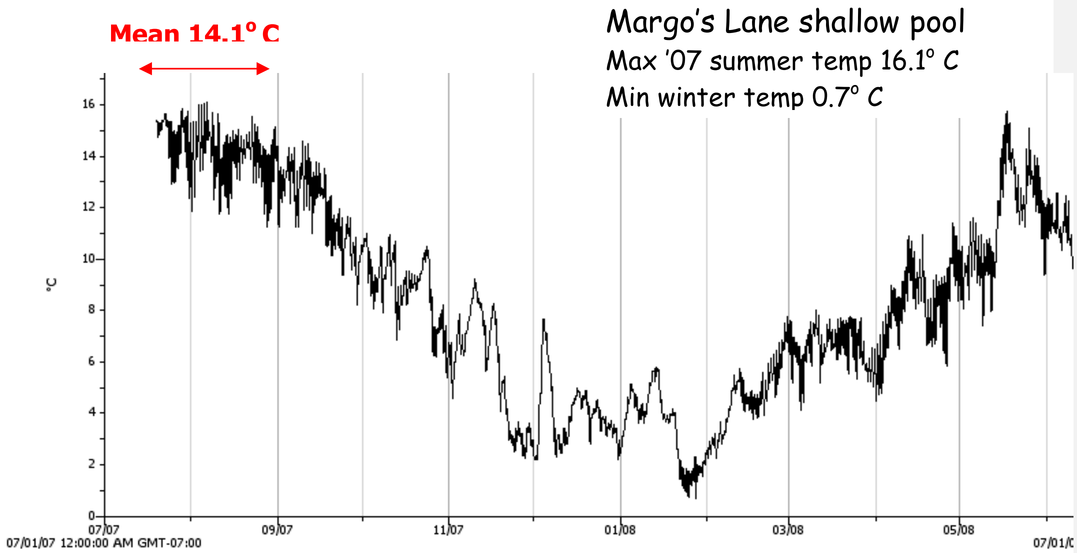
Summer 2008-Winter 2009

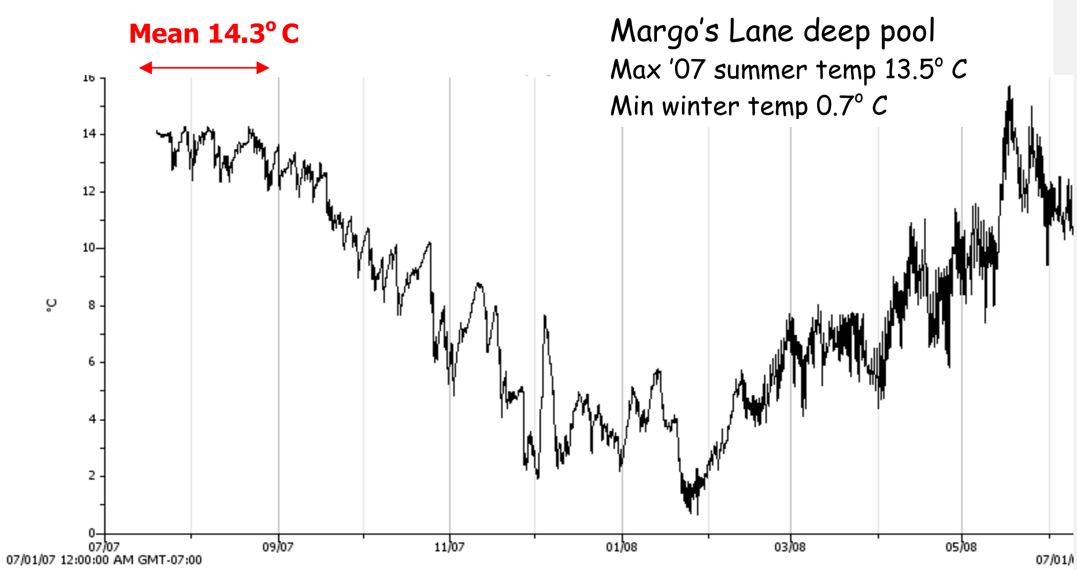


Appendix II.2

Crow Valley Pool Temperatures

Summer 2007 – Spring 2008

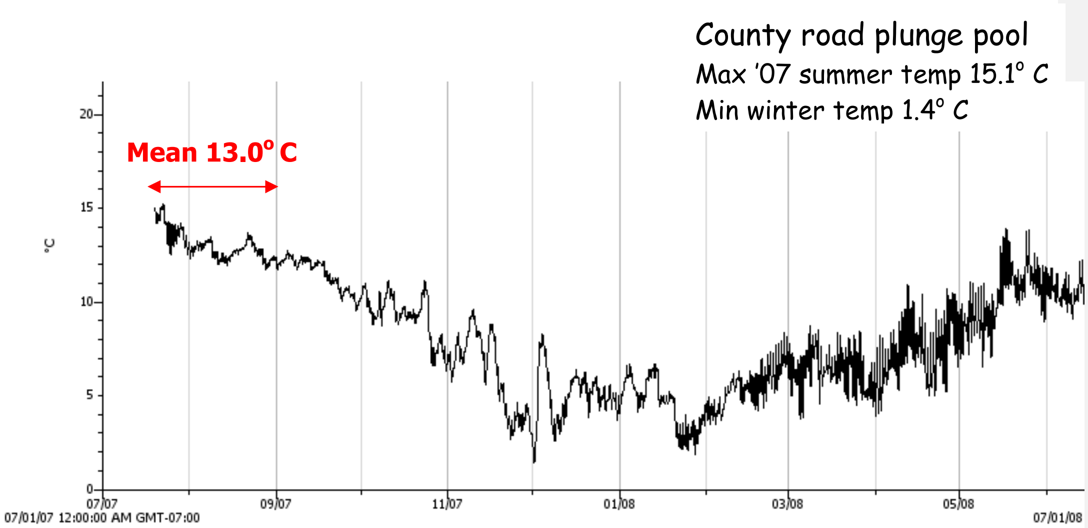


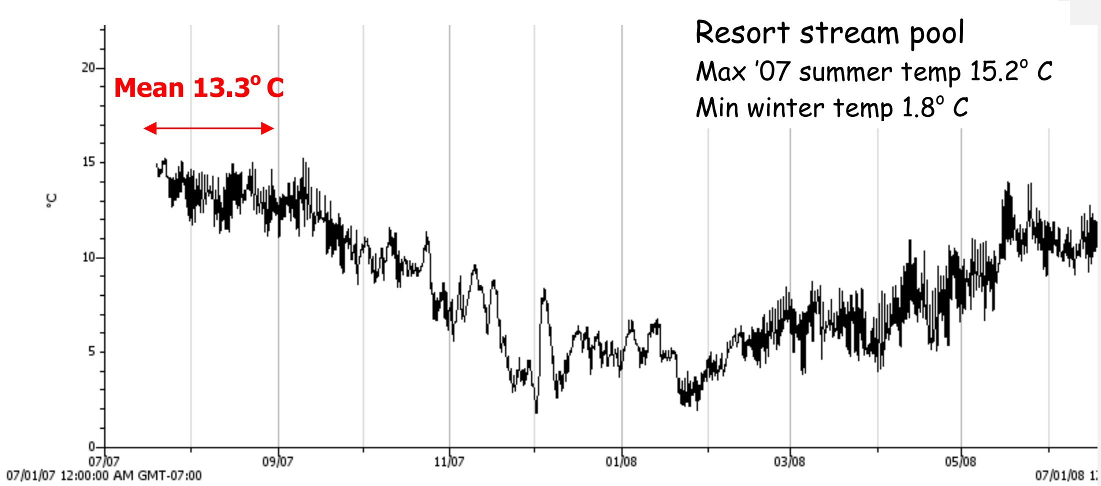


Appendix II.3

Doe Bay Pool Temperatures

Summer 2007 – Spring 2008





Appendix II.4

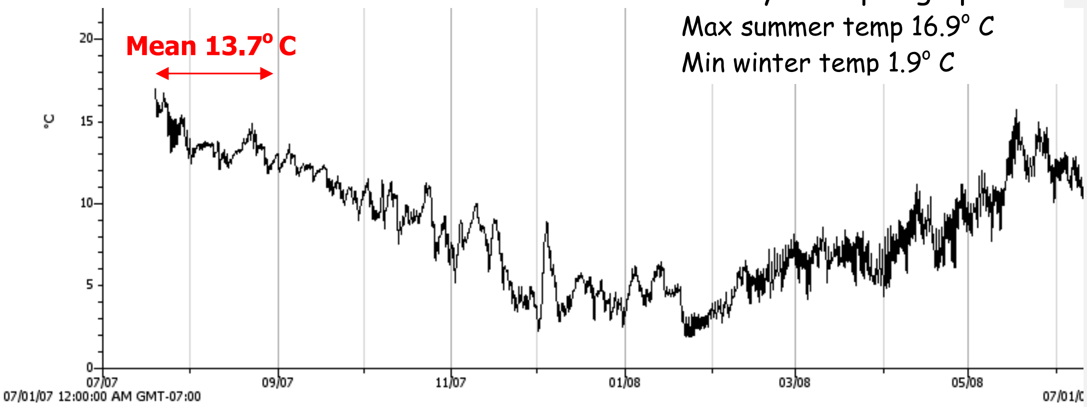
West Beach (Bonnie Brook) Pool Temperatures

Summer 2007 – Spring 2008

County road plunge pool

Max summer temp 16.9° C

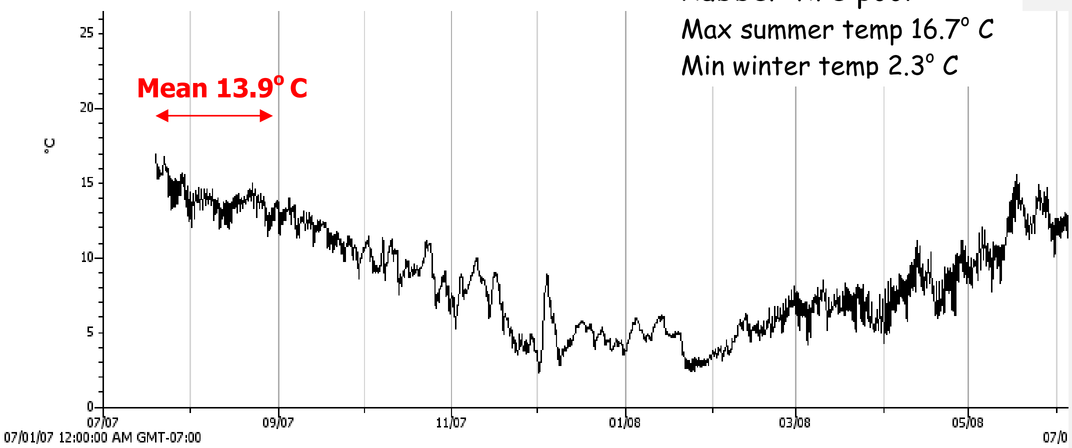
Min winter temp 1.9° C



Rubber tire pool

Max summer temp 16.7° C

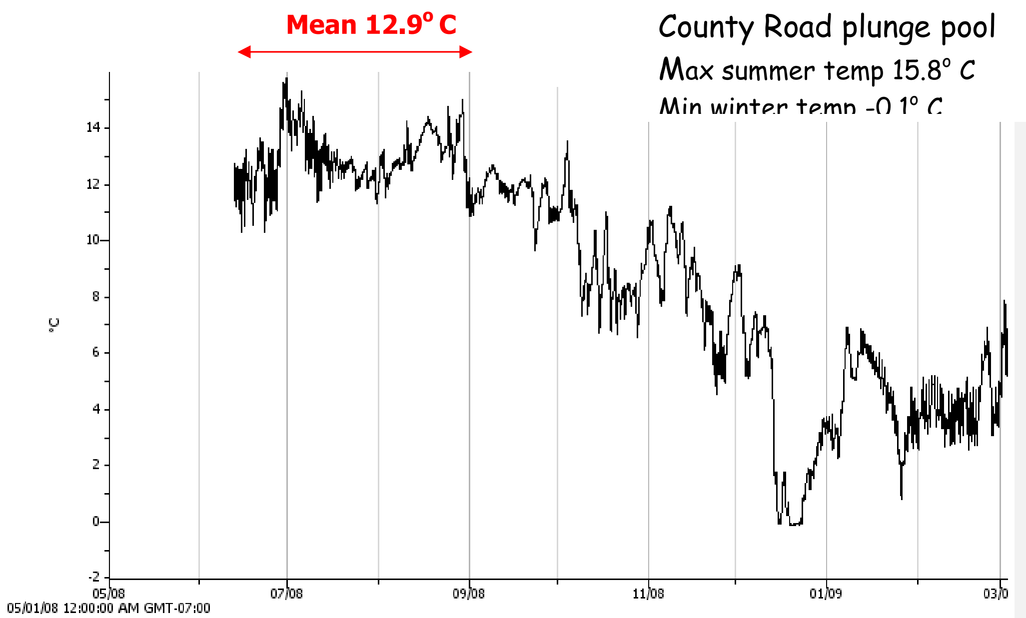
Min winter temp 2.3° C

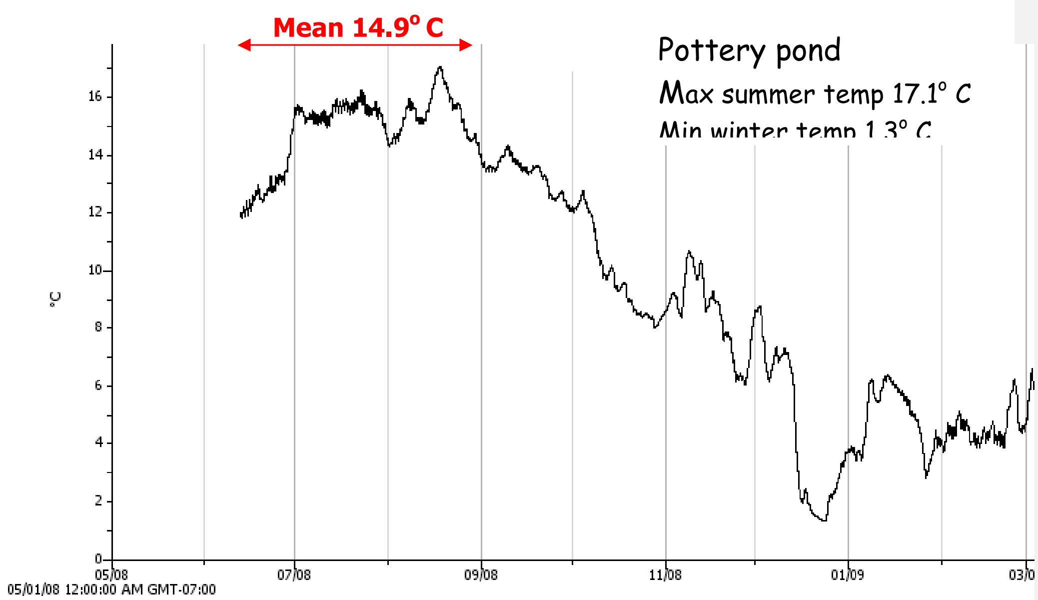


Appendix II.5

West Beach (Bonnie Brook) Pool Temperatures

Summer 2008 – Winter 2009





Appendix II.6

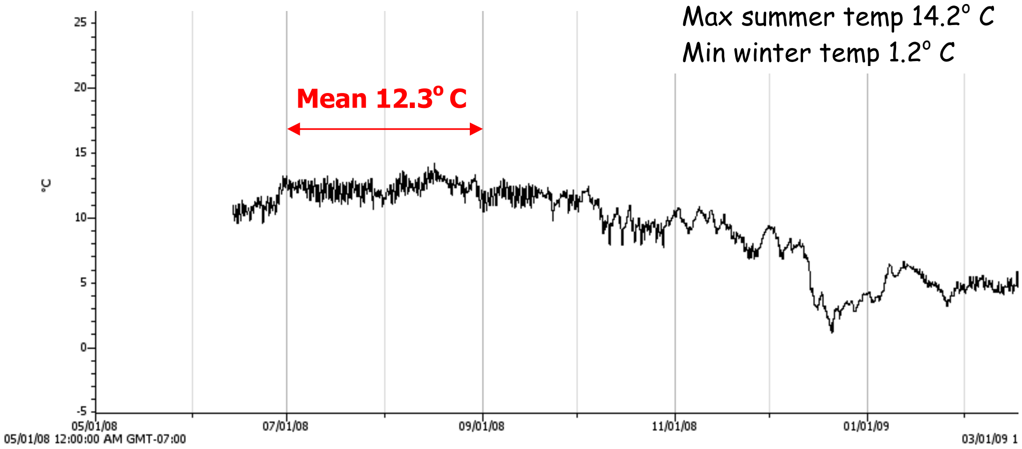
Garrison Creek Pool Temperatures

Summer 2008 – Winter 2009

Troutbeck Farm

Max summer temp 14.2° C

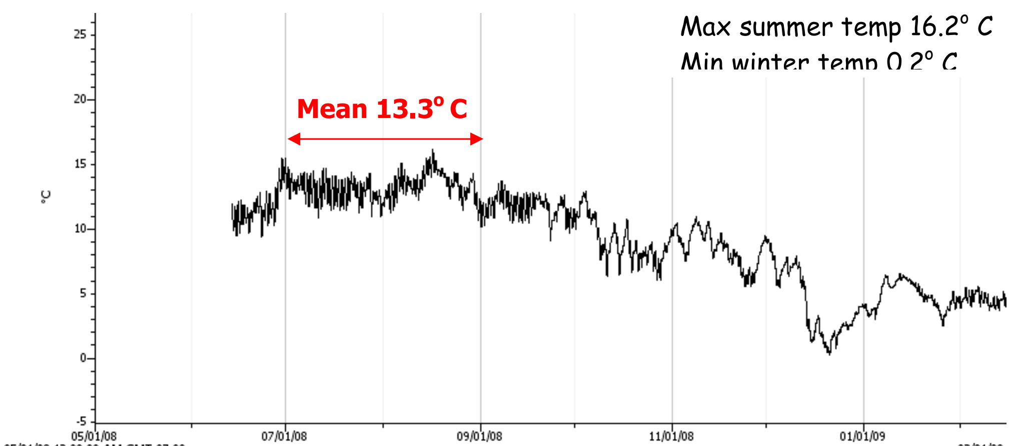
Min winter temp 1.2° C



States Inn

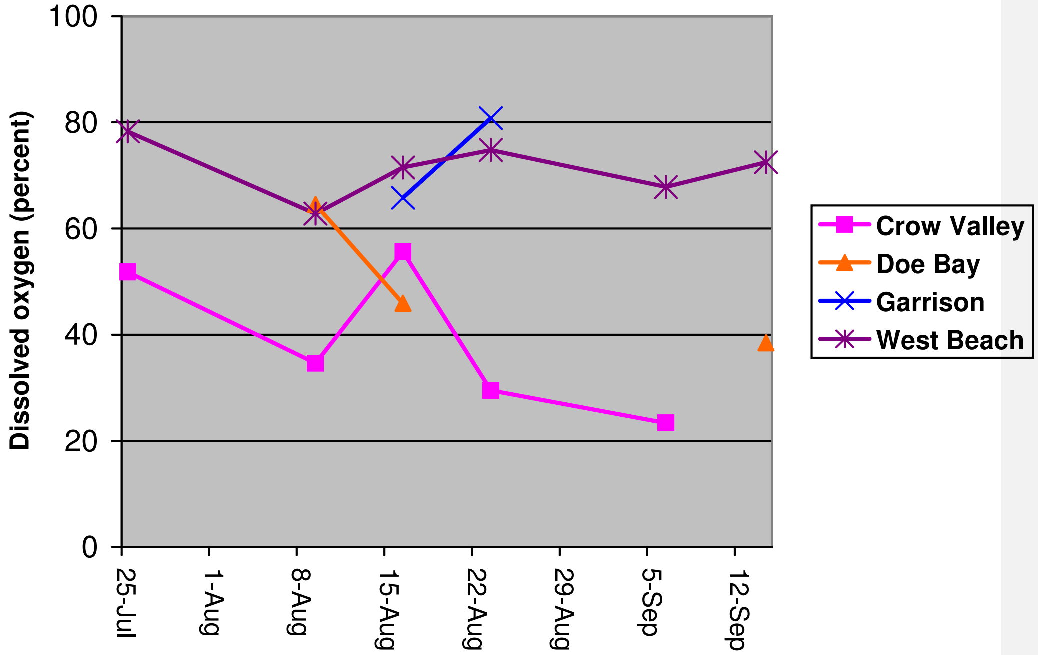
Max summer temp 16.2° C

Min winter temp 0.2° C

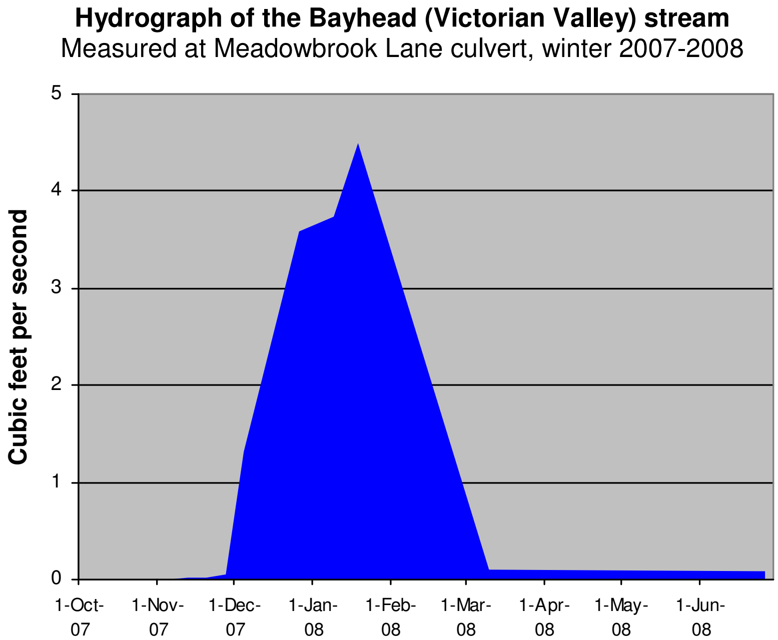


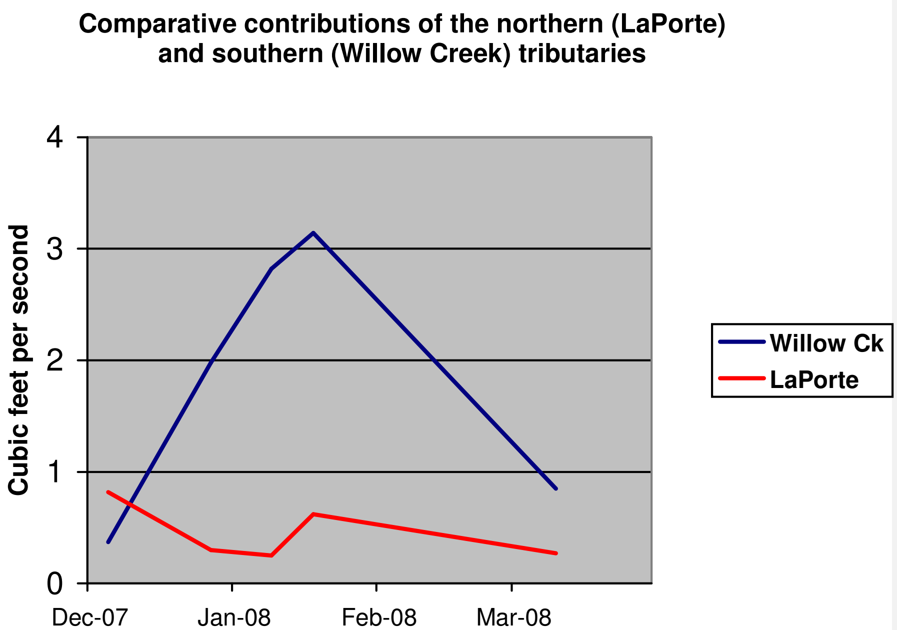
Appendix II.7

Pool Dissolved Oxygen Conditions (2007)



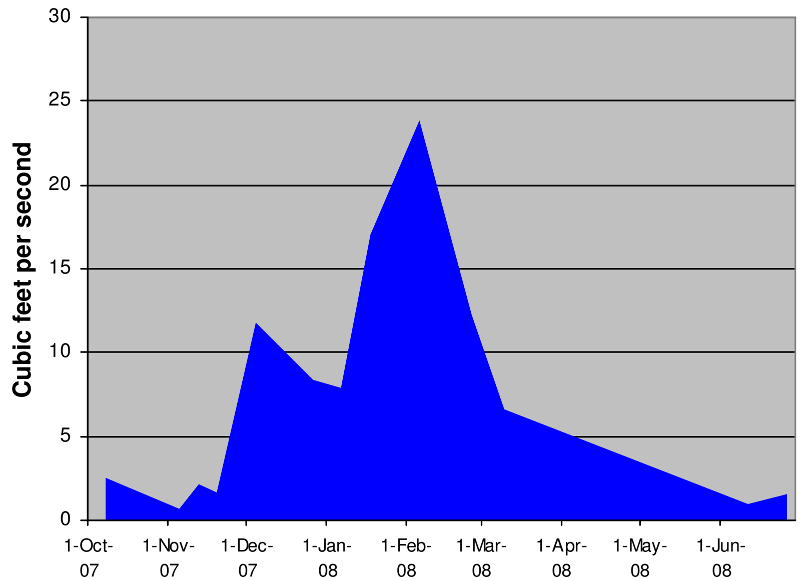
Appendix III.1



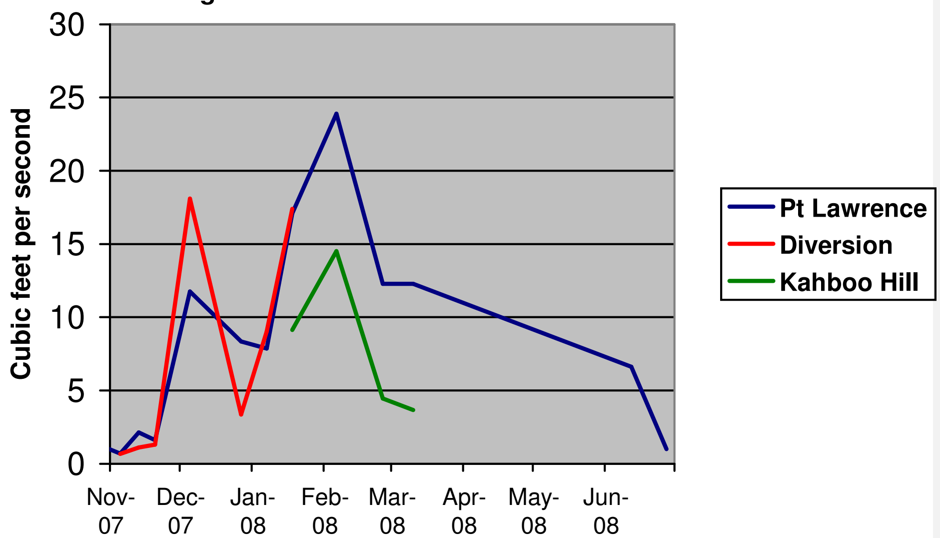


Appendix III.2

Hydrograph of Cascade Creek
Measured at Pt. Lawrence Road, winter 2007-2008

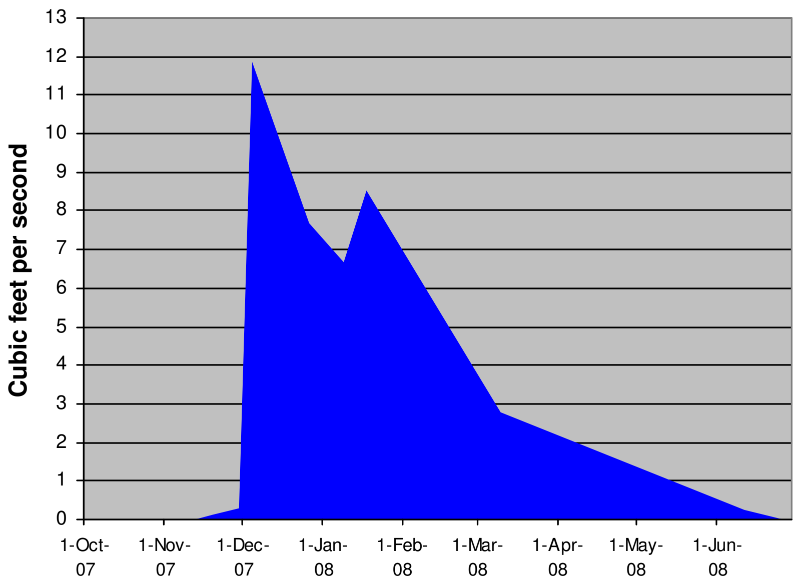


Comparison of Cascade Creek above the Cascade Lake diversion with discharge at Kahboo Hill Road and Pt. Lawrence Road

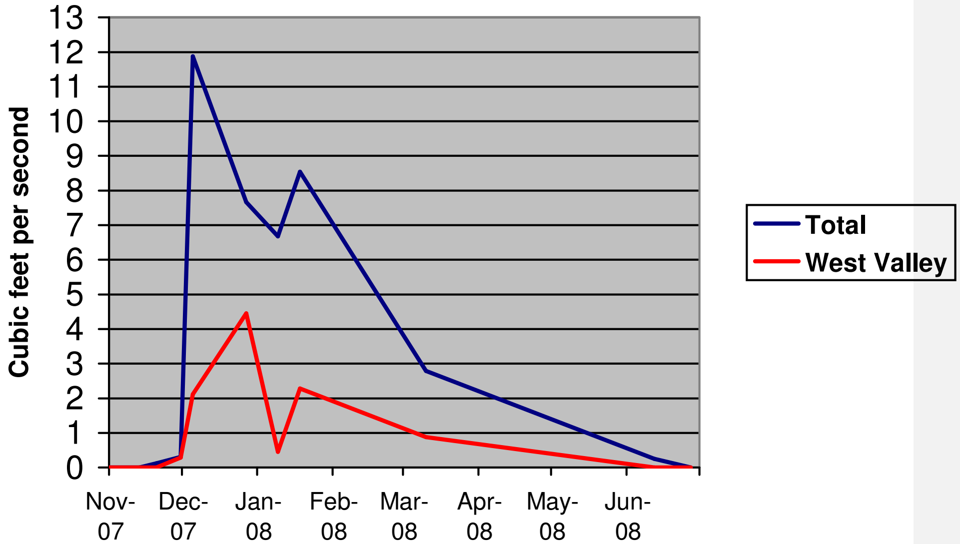


Appendix III.3

Hydrograph of Crow Valley Creek
Measured at Margo's Lane, winter 2007-2008

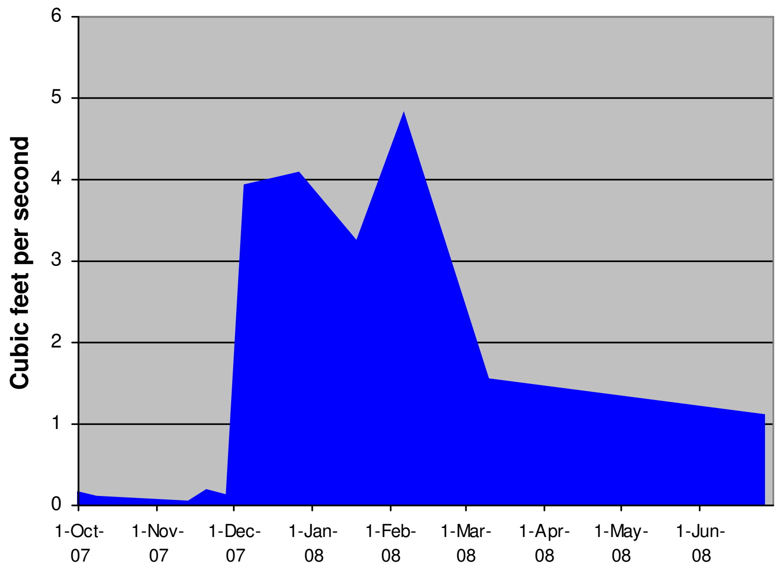


Contribution of west valley wetlands to
stream flows measured at Obstruction Pass Road

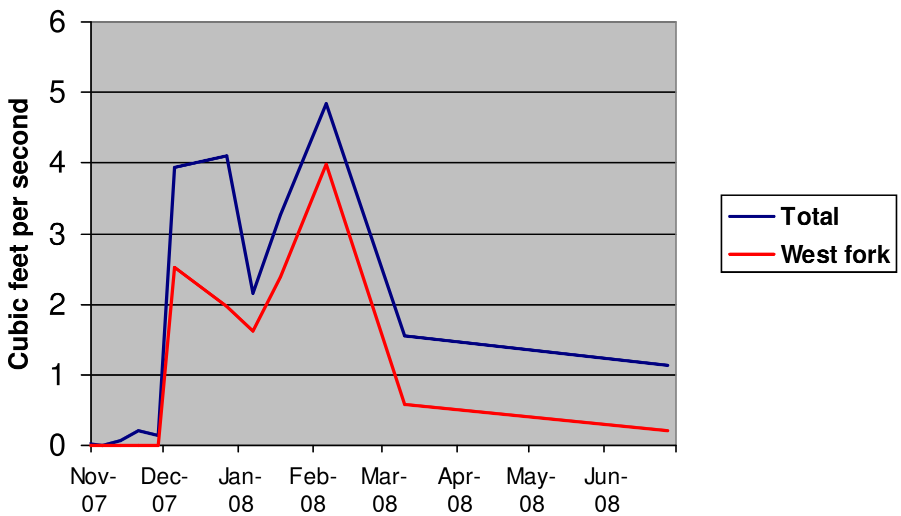


Appendix III.4

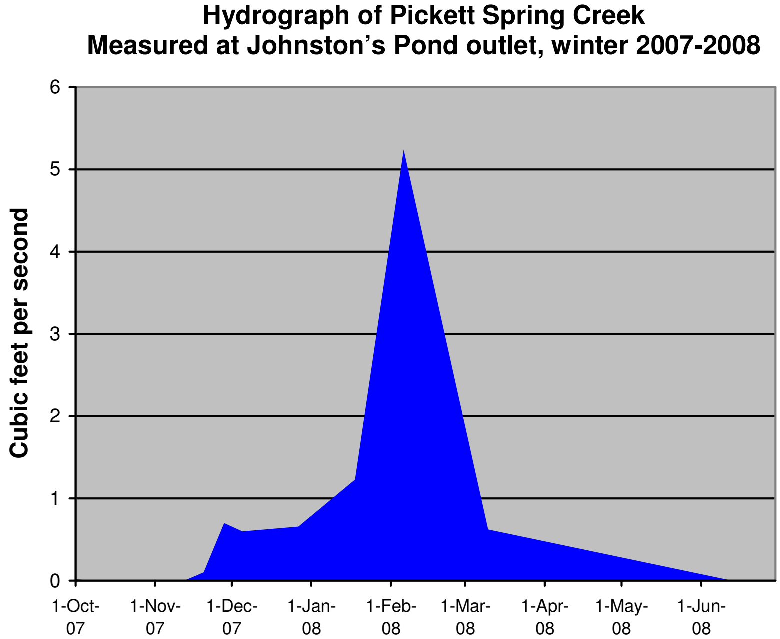
Hydrograph of the Doe Bay stream
Measured at Doe Bay Resort, winter 2007-2008

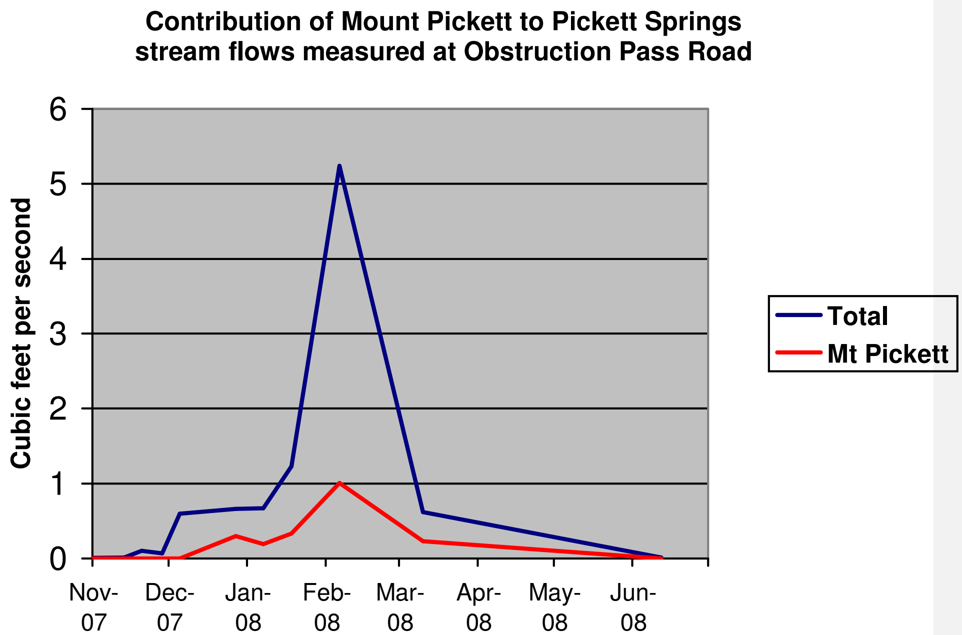


Contribution of the northwest tributary to total Doe Bay downstream discharge



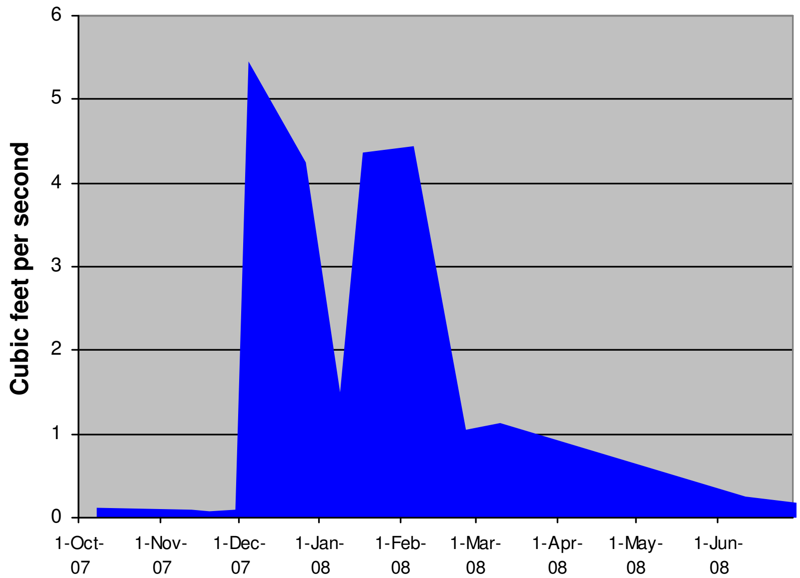
Appendix III.5



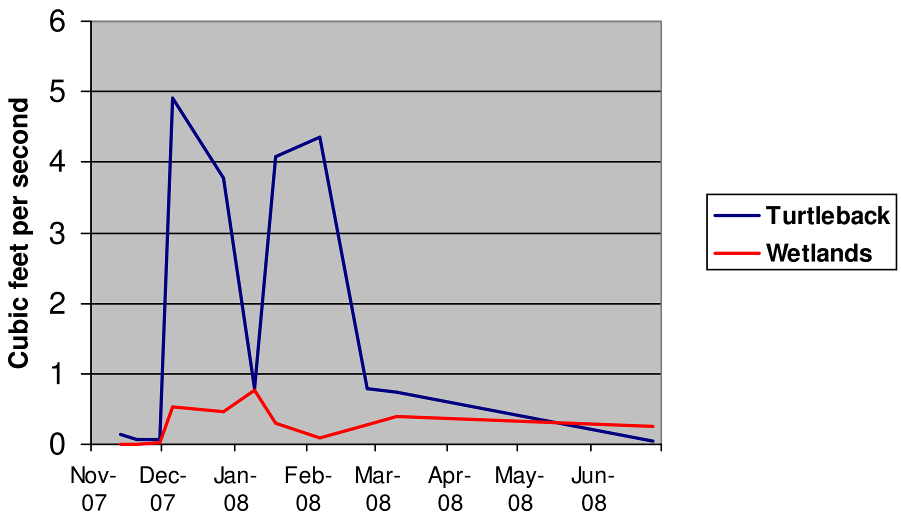


Appendix III.6

Hydrograph of the West Beach (Bonnie Brook) stream
Measured at West Beach Road culvert, winter 2007-2008

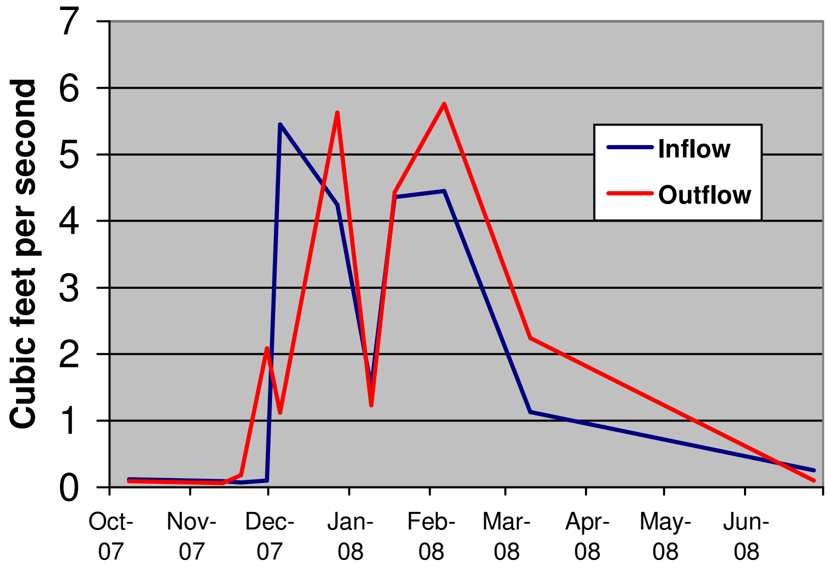


Comparative contributions of the Turtleback and low-elevation wetlands

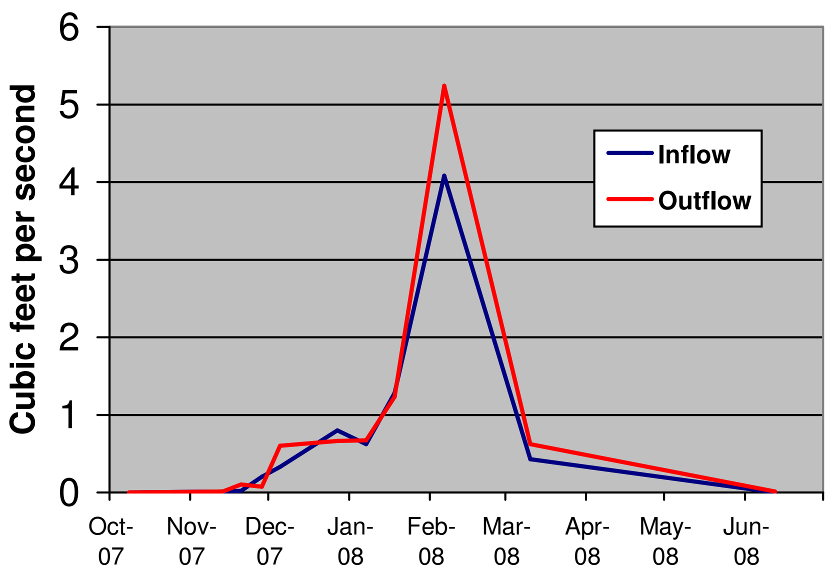


Appendix III.8

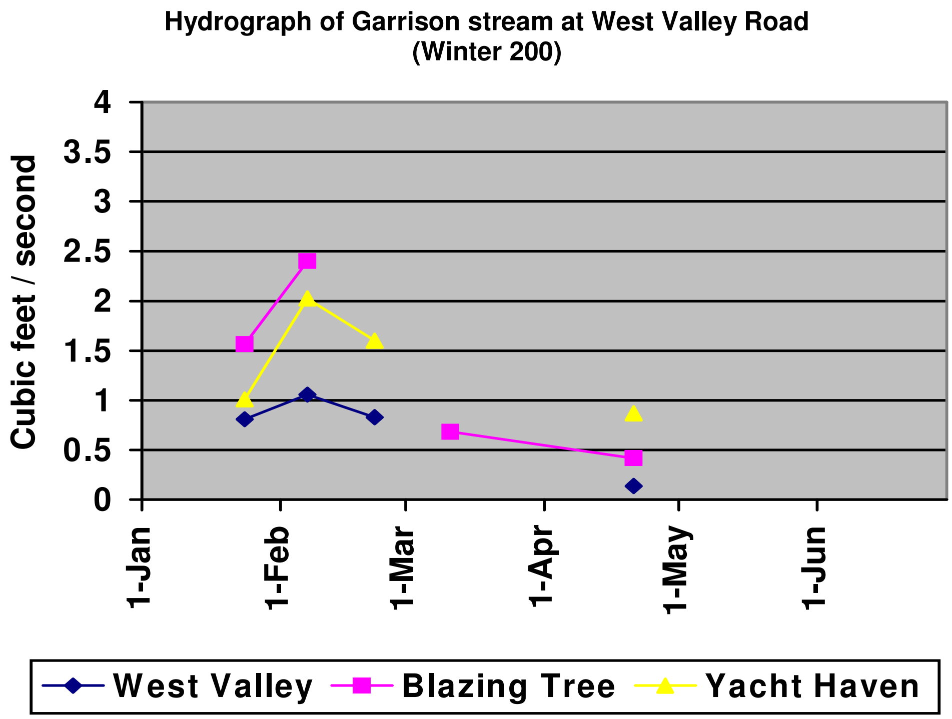
Comparison of Pottery Pond inflows and outflows
Measured at West Valley Road and at beach



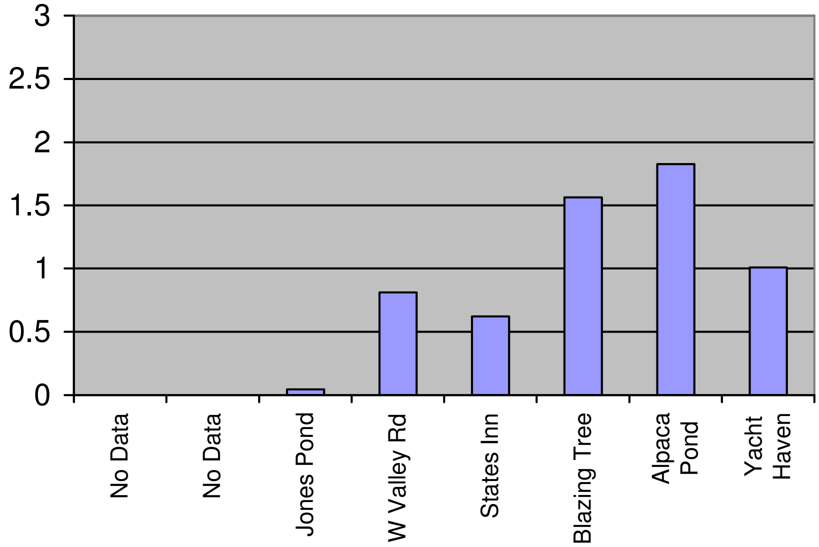
Comparison of Johnston-Eisner ponds inflows and outflows
Measured at Obstruction Pass Road and Johnston's Pond outlet



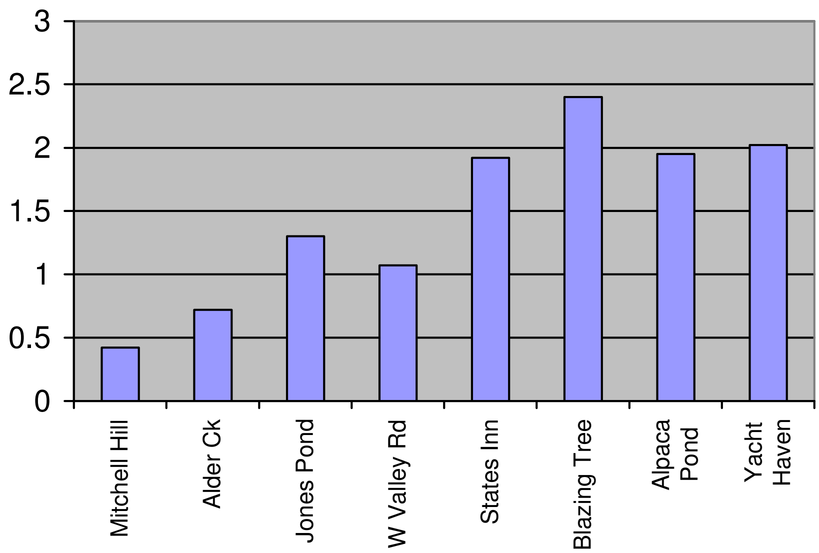
Appendix III.8



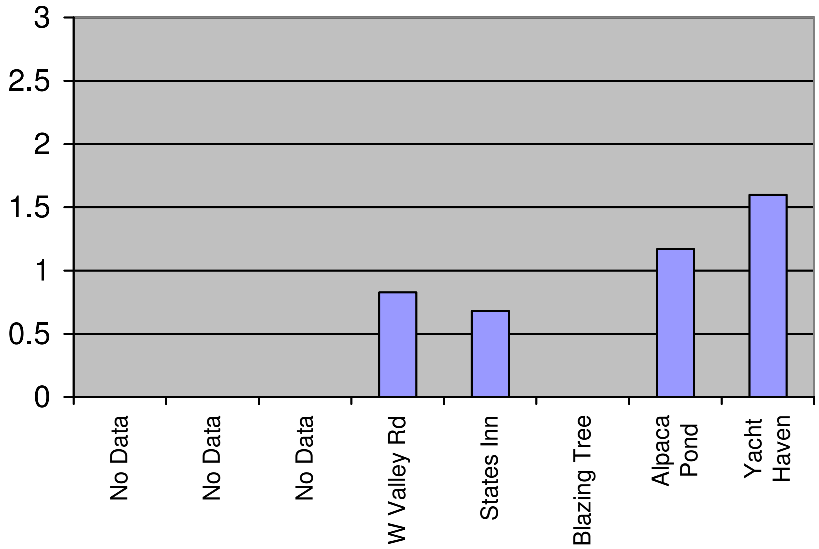
Appendix III.9
Garrison Creek flow-stage profile
24 January 2008



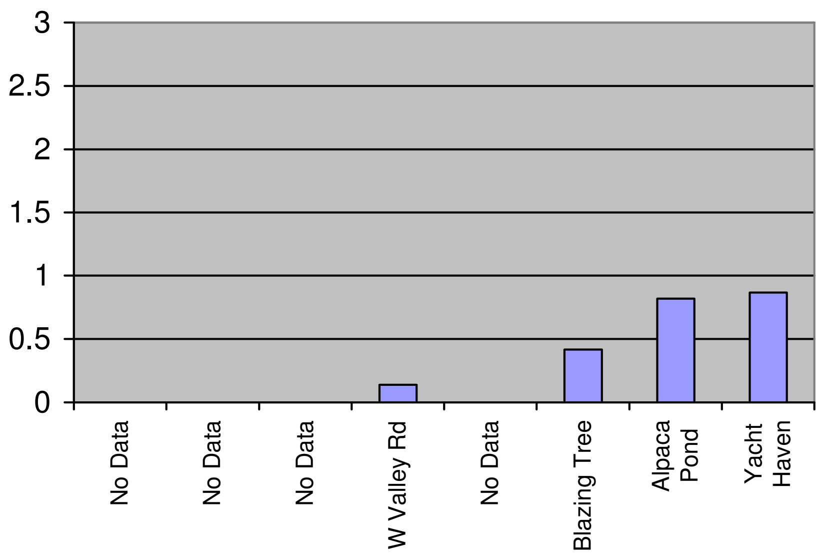
Garrison Creek flow-stage profile
7 February 2008



Garrison Creek flow-stage profile
22 February 2008



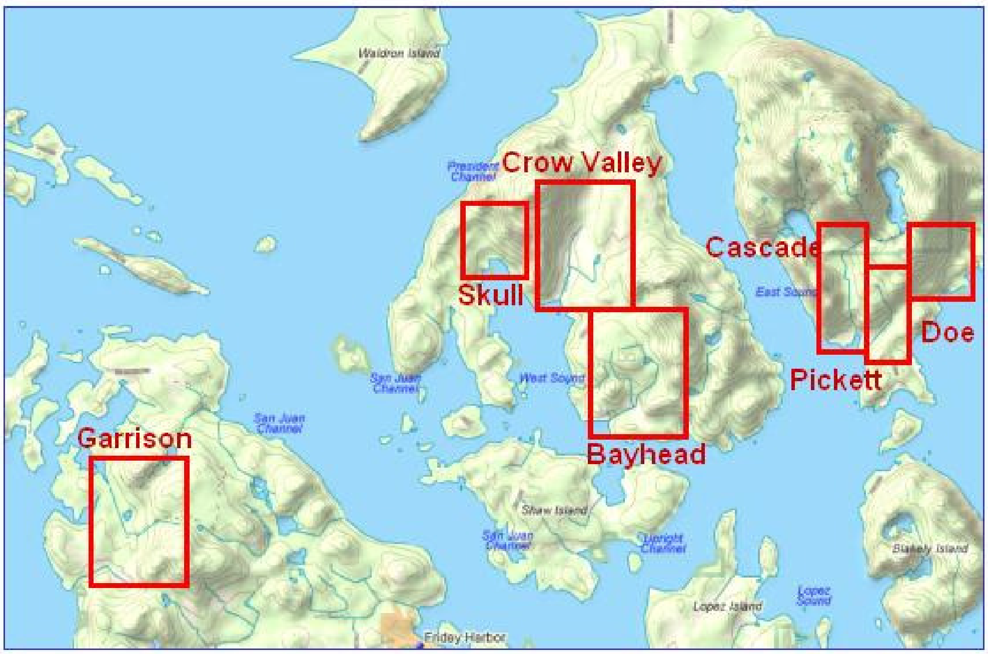
Garrison Creek flow-stage profile
21 April 2008



Appendix IV.1

Structural diagrams

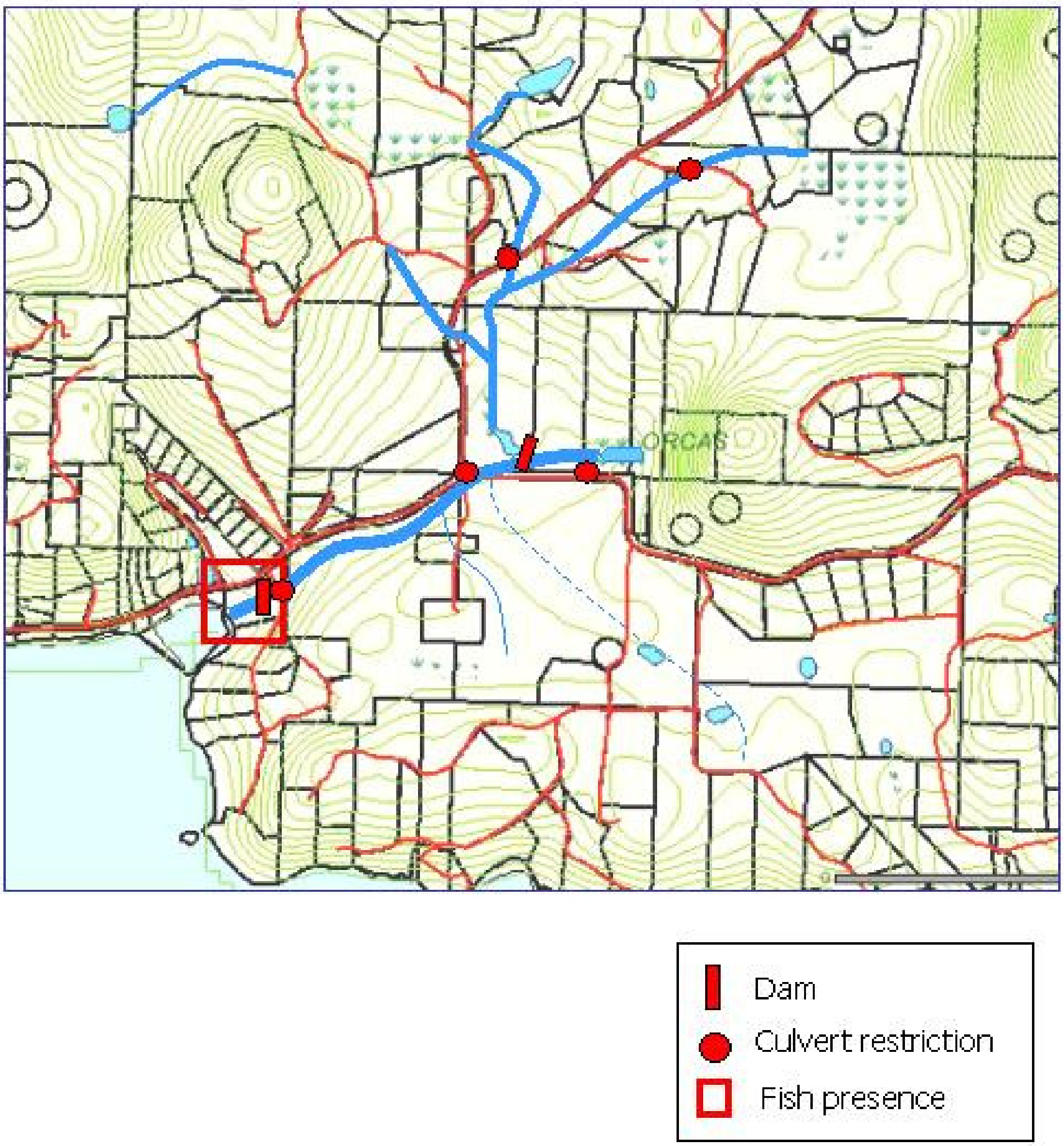
Locations of target watersheds



Appendix IV.2

Bayhead-Victorian, Orcas

Structural diagram

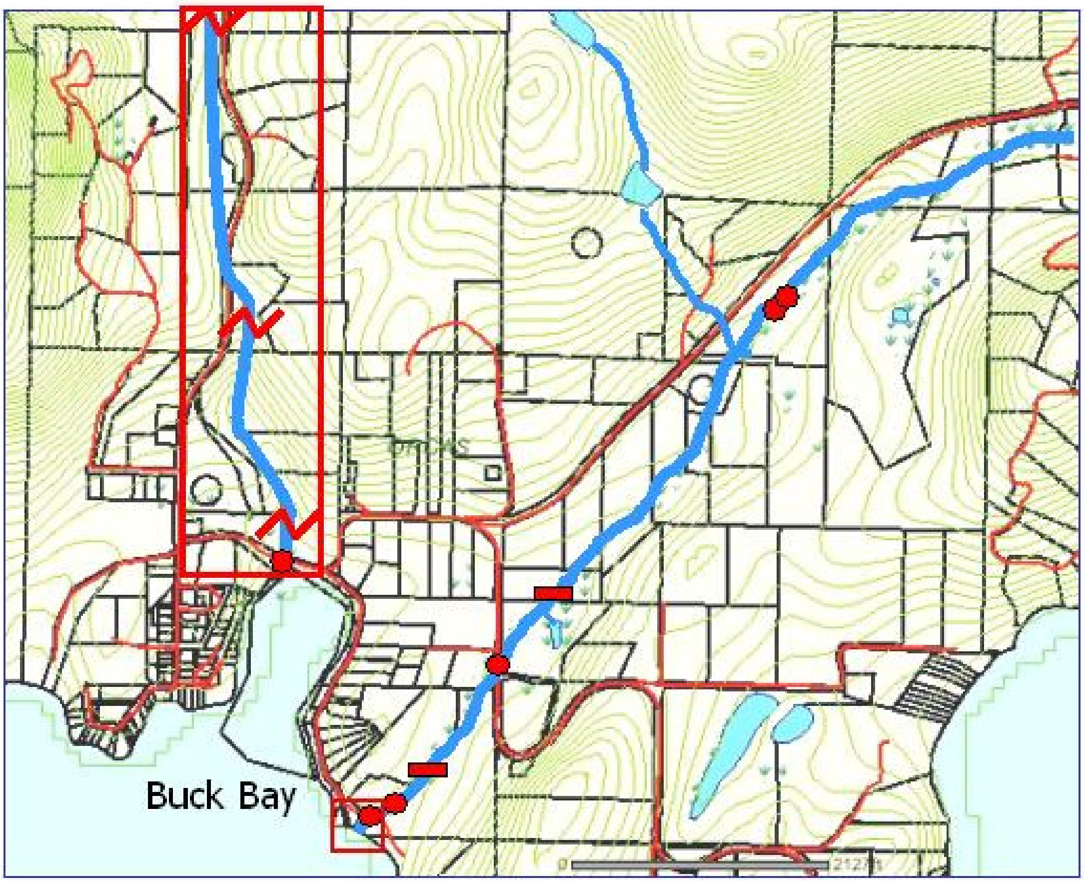


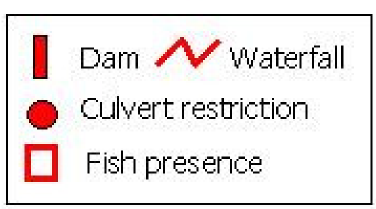
Appendix IV.3
Cascade Creek, Orcas
Structural diagram

Appendix IV.4

Cascade and Pickett, Orcas

Structural diagram





Appendix IV.5

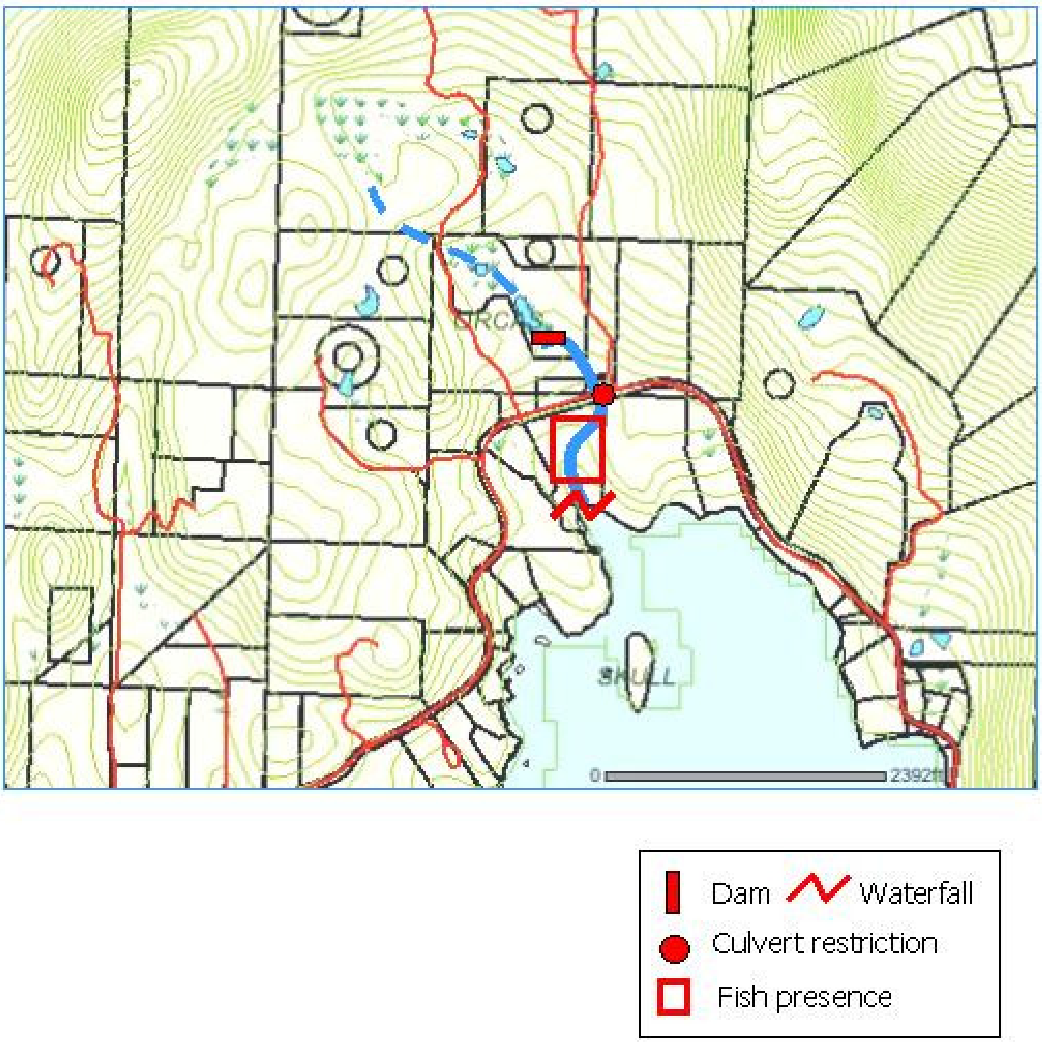
Doe Bay, Orcas

Structural diagram

Appendix IV.6

Skull Creek, Orcas

Structural diagram



Appendix IV.7

West Beach, Orcas

Structural diagram

Appendix IV.8

Garrison, San Juan
Structural diagram