Appendix 1. Program Reviews

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2-Page Fact Sheets

A. Samish Basin: Keeping Shellfish Beds Open

B. King County Habitat Restoration: Re-establishing Native Forests

C. Nisqually Delta: Restoring Ecosystem Function for Salmon

Narrative Summaries

A. Samish Basin: Keeping Shellfish Beds Open

B. King County Habitat Restoration: Re-establishing Native Forests

C. Nisqually Delta: Restoring Ecosystem Function for Salmon

DRAFT: 10.06.14

Protecting and restoring Puget Sound

Effective Action

Samish Basin:

Keeping shellfish beds open by reducing fecal coliform bacteria

A look at successes and lessons learned

In the Samish River watershed, bacteria often reach levels so high that local shellfish are not safe to eat and the water is not clean enough to allow swimming. Shellfish harvest in the Samish Bay is worth about $3 million each year, but high levels of bacteria in the water regularly reduce harvest from 4,000 acres of shellfish beds. To improve the situation more than 20 government, business and nonprofit organizations have come together as part of the Clean Samish Initiative with the goal of identifying and eliminating sources of bacteria.

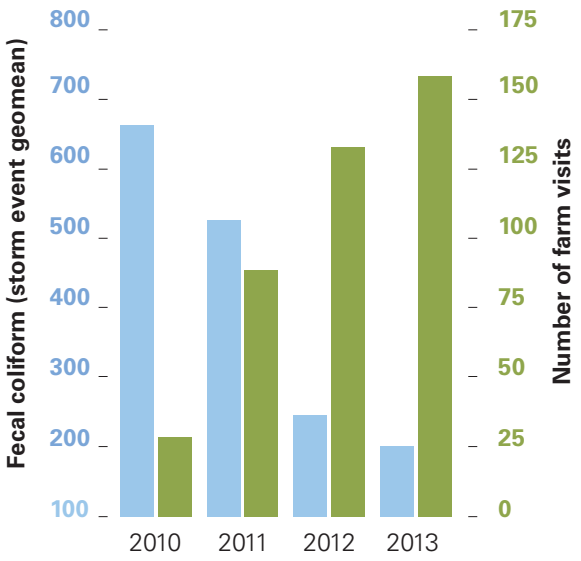
What worked

- **Working closely with other agencies to cooperate and coordinate actions.**
- **Working with farmers to reduce manure that can run into streams during storms.**
- **Applying manure as fertilizer during dry periods only.**
- **Fencing to keep livestock away from streams.**
- **Inspecting on-site sewage systems regularly.**
- **Volunteer sampling to help open shellfish beds sooner after storms.**

Since 2010, fecal contamination has dropped by 80% at the sampling site closest to the shellfish beds.

In 2010, 80% of shellfish bed closures were confirmed; in 2013 confirmed closures dropped to 50%.

Fecal bacteria declined as farm visits increased



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More information is available at: www.psp.wa.gov/effectiveaction.php

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An overview of actions taken to reduce fecal coliform and protect shellfish beds in the Samish Basin watershed from January 2010 to July 2014

Program	Action	Results	Challenges
Pollution ID and Correction $1,700,000	• 6,330 parcels evaluated • 53 farm plans implemented	• Pollution caused by fecal coliform bacteria decreased annually at most sites • Shellfish beds were closed fewer days • Cleaner water • 100 best management practices implemented	• Levels of fecal coliform bacteria still exceed state standards at many sites • Shellfish beds are still closing • Livestock move between inspections
On-site Septic System Assessment Program $2,800,000	• 4,253 septic systems assessed • 500 people took septic system classes (Skagit County)	• 95% passed • 3% needed repairs • 2% failed	• Owners need help with expensive repairs • Continued inspections necessary
Natural Resources Stewardship Program $472,000	• Farms with livestock inspected • 22,905 linear ft of fencing installed to keep manure out of streams	• 30 acres of habitat upgraded	• Extreme weather events can overwhelm normally acceptable BMP's
Regulatory $174,000	• Enforcement actions taken on a few parcels	• Overall compliance increased • 4 out of 6 parcels in violation improved	• Regulatory enforcement is sometimes necessary when voluntary actions are not sufficient

Insights from Samish Basin

- **Small changes add up to large reductions in fecal contamination.**
- **Conversations with individual land owners work best for improving manure management.**
- **Regulatory actions are needed in some instances, but are best used sparingly.**
- **Continued follow-up and site inspections are necessary even after problem sites have been identified and addressed.**

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updated 10.06.14

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Effective Action

Habitat Restoration: King County

Re-establishing native forests on restoration sites

A look at successes and lessons learned

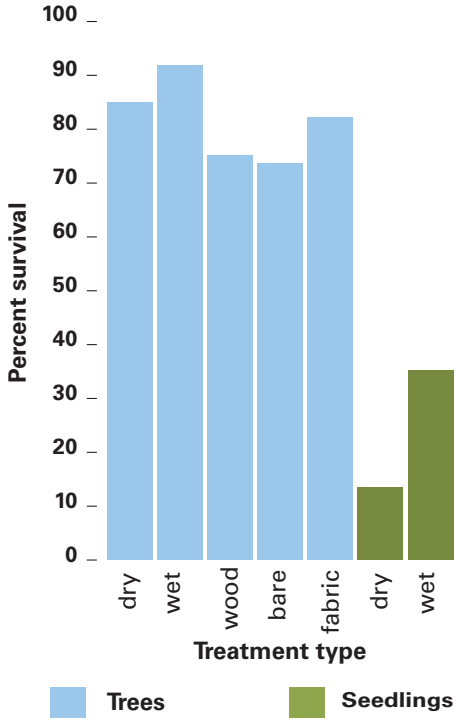
Forest cover has decreased dramatically in the Puget Sound Basin, which has lead to poorer water quality in streams and rivers. Trees beside streams are particularly important because they provide habitat for wildlife, keep streams cool for fish, provide food for stream insects and travel corridors for wildlife. This is why many habitat restoration projects involve planting trees. Watering and mulching help the young plants survive; however, both methods are expensive and may not be needed.

What worked

- **Most cottonwood and alder trees survived the first summer (89-100% survival).**
- **Without watering, trees survived just as well.**
- **Without mulching, trees survived just as well.**
- **Money spent on watering and mulching was better spent planting more trees or replacing trees that died.**
- **Avoiding mulch improved the chances that other plants would return on their own from seeds.**

Irrigation and mulching increase cost by 30-50% but do not improve survival.

Watering and mulching do not significantly improve plant survival



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An overview of plant survival and the affects of mulching and watering.

Action	Outcome	Challenges	Cost per tree	Cost per acre
Plant tree	Year 2 survival rates were 84% for 6-foot cottonwood; mixed tree species had 89% survival		$9.50	$16,500
Water trees	No improvement in survival	Watering is expensive, 10% of cost for cottonwood	$1.00	$1,700
Wood mulch	No improvement in survival, but does reduce invasive species	Wood mulch may attract voles that damage plants; mulch prevents establishment of desirable plants	$1.80	$3,200
Fabric mulch	No improvement in survival	Expensive to install, remove, and dispose of material	$4.09	$7,100
Natural growth from seeds	13% survival for cottonwood	No information about survival after first year		
Water seedlings	22% improvement in survival			

Insights from King County habitat restoration:

- **Don't assume that watering is needed.**
- **Replacing lost trees was cheaper than watering them.**
- **Wood mulch can prevent natural reseeding of trees, and may attract voles.**
- **Buy healthy plants, and handle them carefully before planting.**

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Protecting and restoring Puget Sound

Effective Action

Habitat Restoration: Nisqually Delta

Creating natural habitat for salmon and other wildlife

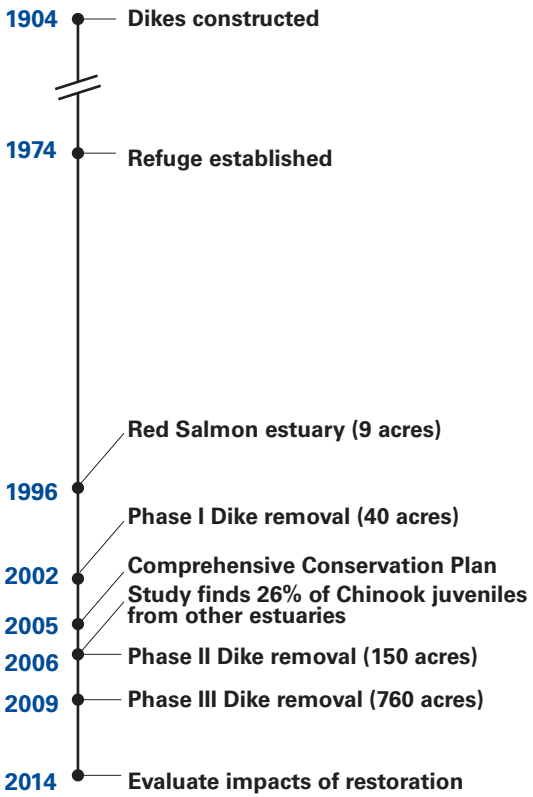
A look at successes and lessons learned

The Nisqually Delta is the largest tidal estuary restoration project in the Pacific Northwest. For a century, tidal flow to the estuary was prevented by dikes. Restoration began in 1996 and progressed from small projects to a combination of projects that directly impact nearly 1,000 acres, and have the potential to produce large-scale changes to the entire delta ecosystem. In 2008, 760 acres of estuary habitat was restored and is now used by salmon, waterfowl, invertebrates and other native wildlife.

What worked

- **Removing dikes increased estuarine habitat by 42%.**
- **Juvenile salmon occupied new habitat and began feeding immediately.**
- **Construction reconnected historic channels to tidal flow.**
- **New wetland habitat attracted migratory and resident birds.**
- **Native plants provide better forage for wildlife reduced invasive grass.**

Salmon were found feeding in new habitat and tidal channels immediately.



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An overview of habitat restoration, protection and enhancement to resotre the Nisqually Delta.

Habitat	Actions	Results	Challenges
Estuary $10,000,000	• 5 miles of dike removed • Tidal flow restored to 760 acres • 21 miles of historic channels restored	• Estuary habitat increased by 42% • Juvenile salmon use the new habitat to find preferred prey • Juveniles spend more time in the estuary growing • Many native species of fish, birds, and inverte-brates use new habitat	• Water temperature in restored channels may be too high for salmon • Juveniles density and growth rates do not yet match natural habitat • Not enough sediment is captured to build habitat
Riparian $1,700,000	• 30 acres protected • 4.4 miles of salmon habitat protected • 2.5 miles of channel flow restored • 6 acres of riparian buffer created with 50,000 cubic yards of fill	• Elimination of invasive reed canary grass • 50% of plants survived after 5 years	• Spread of plants slow, 80% of unplanted areas are still bare
Wetlands, riparians, and grassland (behind new dike) $3,000,000	• 246 acres of freshwater ponds enhanced • 68 acres of diverse habitat protected • 21 miles of historic channels restored	• New plantings provide preferred food for waterfowl in 50% of area	• Habitat is not establishing as planned because the land area is low and sediment is not accumulating fast enough • Diverse habitats are not connecting as expected
All habitats $6,000,000	• Hydrodynamic model to test restoration scenarios • Measure fish presence, feeding and growth	• Channel modification increased sediment retention and tidal flow	• Natural development of habitat takes time

Insights from Nisqually Delta restoration

- **Native species start using newly created habitat immediately.**
- **Habitat formation depends on a source of sediment and the channel structure to retain it.**
- **Successful restoration depends on good science to understand how the ecosystem responds.**
- **Start small with restoration, early success builds support for larger scale restoration efforts.**

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SAMISH BASIN: KEEPING SHELLFISH BEDS OPEN

The Samish Bay Watershed contains approximately 140 square miles of land covered in lowland farms, fields, and timber in a largely rural community. Samish Bay contains both commercial and recreational shellfish harvesting areas. The shellfish harvest in Samish Bay is worth approximately $3 million a year in sales alone. Since 2011, 52 shellfish harvesting area closures have been implemented due to high levels of fecal coliform bacteria, an indicator of fecal pollution from warm-blooded animals that could be associated with pathogens.

In 2008, large values of fecal contamination discovered after storms intensified management responses by local agencies to reduce sources of fecal bacteria. Tremendous effort from local government entities has since been initiated to address the status of Samish Bay, identify the causes of fecal contamination, and improve water quality to support viable, long-term aquaculture. The Clean Samish Initiative was developed to implement and monitor the Total Maximum Daily Load (TMDL) which was established by the Department of Ecology in 2007. In 2011, about 4,000 acres of the Samish Bay shellfish growing area were downgraded due to high bacteria levels in the Samish River. Subsequently, Skagit County and a number of federal and state agencies and organizations have developed a concerted effort to identify fecal contamination sources, restore water quality, and improve community outreach.

Watershed activities in the area that may contribute to fecal loading in the Samish River and Bay include residential sewage and septic systems, beef and dairy cattle farms, crop land, and non-commercial agriculture. Sources of fecal contamination in the watershed include failing on-site sewage systems, manure application, livestock, non-point source run-off, inadequate stream buffers, pet waste, and wildlife. The Clean Samish Initiative, in conjunction with an EPA funded Pollution Identification and Correction (PIC) program was organized to coordinate actions to reduce fecal coliform and keep shellfish beds open.

We have a serious pollution problem in the Samish watershed that continues to threaten our livelihood, recreation, shellfish beds and quality of life. We have had a good program in place, but we welcome the extra help and added manpower to address this issue.

– Ron Wesen, Skagit County Commissioner

GOAL

- Upgrade the status of shellfish beds in Samish Bay from "Conditionally Approved" to "Approved", eliminating the need for shellfish bed closures due to fecal coliform bacteria.

The current classification of Samish Bay requires a precautionary closure of shellfish harvesting when flow in the Samish River rises above certain criteria because the risk of fecal contamination in the runoff is too high. The closure is considered "confirmed" if subsequent laboratory analysis of water samples confirm that the fecal coliform loading rate exceeds the number established by the Department of Health for protection of the Samish Bay. Loading rates are related to the state water quality criteria for fecal coliform. Closures are temporary until subsequent laboratory results can confirm that fecal coliform bacteria are within state allowed levels.

In order to upgrade Samish Bay shellfish beds, closures need to be limited to no more than one closure during the critical period for high bacterial loading which is from March–June during high precipitation events. Samish Basin recently failed a four-month Department of Health water quality evaluation in the third week of 2014.

ACTIONS

Several actions were taken to reduce fecal bacteria in Samish Basin that included identifying sources, working with landowners, and correcting problems (Table 1).

DESIGNATE SAMISH BASIN AS A MARINE RECOVERY AREA (MRA)

The entire Samish Basin was designated as an MRA to address on-site sewage system contamination and ensure systems are compliant with state law (RCW 70.118A.040). Most of the Samish Watershed was already declared an MRA in 2007, and work was currently in place assuring septic systems were inspected. The 2007 MRAs included the sub-basins for Colony Creek, Thomas Creek, the Upper Samish (including Friday Creek), the Lower Samish and Samish Island. Two additional MRAs were added in 2012 (Upper NE Samish and Willard Creek) to encompass all the waters in the Samish River Watershed.

ESTABLISH CLEAN SAMISH INITIATIVE

In 2009 the Department of Ecology facilitated the collaboration of over 20 local, federal, state, and non-governmental stakeholder organizations to develop a work plan to reduce fecal contamination by implementing education and outreach, sampling water quality, referring landowners to resource agencies for pollution abatement, and enforcing water quality and land use regulations. This initiative leveraged EPA funding to implement clean-up actions.

POLLUTION IDENTIFICATION AND CORRECTION (PIC) PROGRAM

The PIC program works with stakeholders and community members to assess properties, provide resources to landowners to make repairs, and monitor water quality to detect problems and areas to focus contact with landowners. Parcels were evaluated with drive-by surveys and aerial imagery in agricultural areas. Skagit County Public Works and WA Department of Ecology staff followed up with farm visits and site inspections if an initial evaluation indicated a potential source of bacterial contamination. Skagit County Public Health inspected septic systems. Skagit County Planning and

Development Services followed up with violations and enforcement actions related to the Critical Areas Ordinance. In a few cases, the Department of Ecology worked with local agencies to support enforcement of pollution regulations. The Skagit Conservation District provided farm plans to landowners for manure storage, drainage solutions (e.g., roof gutters), and agricultural best management practices (BMPs).

- As of 2014, 100% of 6,330 parcels were evaluated; of these, 100% of 5,450 non-timber parcels have been assessed. All parcels that need to be inspected have been. PIC inspectors provided free technical assistance to guide property owners through the process of correcting identified pollution sources, such as failing on-site septic systems, pet waste, livestock and agricultural animal manure, failing sewer infrastructure, and correcting illicit discharges to storm water and storm water conveyances.
- For septic systems, 47% of the inspections are currently up-to-date; these numbers change daily as property owners update their inspections. Gravity systems are required to be inspected every three years. All other types of systems are to be inspected annually.
- As of March 2013, only 3% of the 4,253 on-site septic systems that were inspected needed repairs, another 2% were failing and needed further repair or replacement.
- Provided assistance in the implementation of 100 structural BMP's.
- The Conservation District provided farm planning and technical assistance to 53 landowners, 174 farm visits, and completed farm plans for 53 landowners with recommendations for best management practices to minimize fecal contamination.
- A total of 22,905 linear feet of fencing, approximately 14,000 native riparian plants, 91 pieces of large woody debris for bank stability and increased channel complexity, and a bridge were installed; and 30 acres of riparian habitat were improved (Table 3).

Table 1. Program, actions, outcomes, challenges and total cost to reduce fecal coliform and protect shellfish beds in the Samish Basin watershed. Program costs for Samish Basin were calculated for 1/1/2010 – 7/31/2014, a period of 4.5 years.

Program	Actions	Results	Challenges	Total Cost
Pollution ID and Correction	- 6,330 parcels evaluated - 53 farm plans implemented - Used molecular source tracking to identify fecal sources	- Pollution caused by fecal coliform bacteria decreased annually at most sites - Shellfish beds were closed fewer days - Water is cleaner - 100 best management practices implemented -	- Levels of fecal coliform bacteria still exceed state standards at many sites - Shellfish beds are still closing - Livestock move between inspections - Difficult to interpret molecular source tracking data	$1,700,000
On-site Septic Systems	- 4,253 septic systems assessed - 500 people took septic system classes (Skagit County)	- 95% passed - 3% needed repairs - 2% failed	- Owners need help with expensive repairs - Continued inspections necessary	$2,806,000
Natural Resources Stewardship Program	- Farms with livestock inspected - 22,905 linear ft of fencing installed to keep manure out of streams	- 30 acres of habitat upgraded - 17 landowners enrolled in program	- Fencing keeps cows out of streams, but manure stills runs into streams during extreme rainfall events	$472,000
Regulatory and Enforcement	- Enforcement actions taken on a few parcels - Worked with individuals to increase compliance	- Overall compliance increased - 4 out of 6 parcels in violation improved	- Regulatory enforcement is sometimes necessary when voluntary actions are not sufficient	$174,000

Table 2. Recovery and management actions in the Samish watershed through 2013 (Skagit County Public Works Natural Resources).

Action	Results
Assess 6,330 parcels (5,450 are non-timber)	100% have been assessed
Inspect 4,253 On-site sewage (OSS) systems	47% of inspections are currently up-to-date
Evaluate OSS failures (2013)	2% need repair/replacement
Follow up with site inspections	150 site-visits
Develop Conservation District farm plans	53 implemented
Implement Best Management Practices (BMPs)	100 implemented
Install pet waste stations	16 locations
Install portable toilets	12 installed

Table 3. Recovery and management actions of the Natural Resources Stewardship Program in the Samish Basin watershed through 2013.

Action	Results
Implement Projects	17
Number of land owners enrolled in NSRP	17 participants
Fence livestock out of streams	22,905 linear feet installed
Improve natural habitat	91 pieces of large woody debris installed
Livestock crossings	1 installed
Improve riparian buffer habitat	20,000 linear feet
Enhance natural habitat	30 acres improved
Restore native vegetation	14,000 plants installed

Table 4. Farm visits, farm plans, and parcels evaluated by year.

Year	Farm Visits	Farm Plans Produced	Parcels Evaluated (n =5450)
2009	17	22	22
2010	28	23	30
2011	61	17	462
2012	45	10	2351
2013	23	3	1642
Total	**174**	**75**	**4507**

COMMUNITY EDUCTION & OUTREACH

The Skagit Conservation District led implementation of a landowner outreach program that provided educational forums and materials to livestock owners to gain support for agricultural best management practices.

Protocols were developed to provide inspection information, work plans, and establish agency contacts for landowners. Communication tools were aimed to clarify landowner obligations, expectations and outcomes of inspections, and explained the regulations aimed at protecting the watershed from fecal contamination.

Community outreach regarding fencing and best land management practices was implemented under Skagit Conservation District and County Natural Resources Stewardship programs to help prevent livestock from entering or contaminating local streams and tributaries that flow to the Samish River.

- Septic system maintenance classes hosted by Skagit County had approximately 500 participants County-wide. Samish Bay watershed residents were not counted separately, however most septic system class participants are spurred to take the class because of outreach efforts. The majority of participants were likely from the Samish Watershed.
- The Clean Samish News publication distributed to over 6,000 watershed residents.
- Educational displays hosted at a variety of educational events.
- One-on-one support provided to the Friday Creek Habitat Stewards and numerous community residents.

REGULATORY COMPLIANCE

Increased involvement from partnering agencies worked to increase compliance with water quality laws. Enforcement actions, including warnings, orders and penalties were taken to ensure compliance. Actions taken to identify priority parcels included:

- Inspect all parcels to evaluate fecal coliform loading contribution into Samish Basin consistent with state law (RCW 70.118A.040), identify high priority areas to focus clean-up efforts, and explore options to reduce bacterial contamination.
- Skagit County: expedited the property inspection efforts in the Basin.
- Department of Agriculture: increased site visits of small acreage and animal operations, and continued inspection of seven dairies in the Samish Basin.
- Department of Ecology: expanded inspection capacity to properties that create, store, or apply manure.
- Regulatory enforcement action was taken on a few non-compliant parcels.

MICROBIAL SOURCE TRACKING

Water samples were collected and the fecal contamination was evaluated to determine the source. Two molecular source tracking studies, one by the EPA and one by Oregon State University, were completed to identify sources of fecal contaminants in Samish Bay. Molecular markers were used to determine whether the sources could be traced to humans, ruminants, horses, gulls, or dogs. Results showed the highest rate of appearance for ruminant and avian sources, but data interpretation was hampered by poor blind-sample performance and lack of correlation between microbial marker counts and fecal coliform counts.

OUTCOMES

- When the Clean Samish Initiative began, over 80% of river rises resulted in confirmed shellfish bed closures due to high levels of fecal bacteria. By the end of the 2013, that percentage dropped to approximately 50%. During the first half of 2014, the percentage was 47%.
- Since 2010, fecal contamination during storms, when fecal coliform loads are the highest, has steadily declined for all sites. At the most downstream site, Samish River at Thomas Road, fecal coliform has decreased by >80% (Figure 1).
- The percentage of times that fecal coliform values have exceeded state water quality standards has declined significantly across all sites since 2006 (Figure 2).
- The commitment of local government and executive committee members increased watershed resident participation in clean-up efforts.
- The number of landowners participating in voluntary programs has steadily increased.
- Results from molecular source tracking study indicated ruminant, avian, and human sources of contamination. The OSU study suggested ruminants were the leading source, followed closely by avian sources. However, the quantification of markers did not correspond well with fecal coliform counts from the same samples, and some blind quality control samples were not accurately identified. MST results served as a general indicator of fecal coliform sources and education tool, but the science is not developed to the point where accurate results can be determined from individual samples.
- As a result of regulatory actions, 4 out of 6 landowners complied with legal requirements.

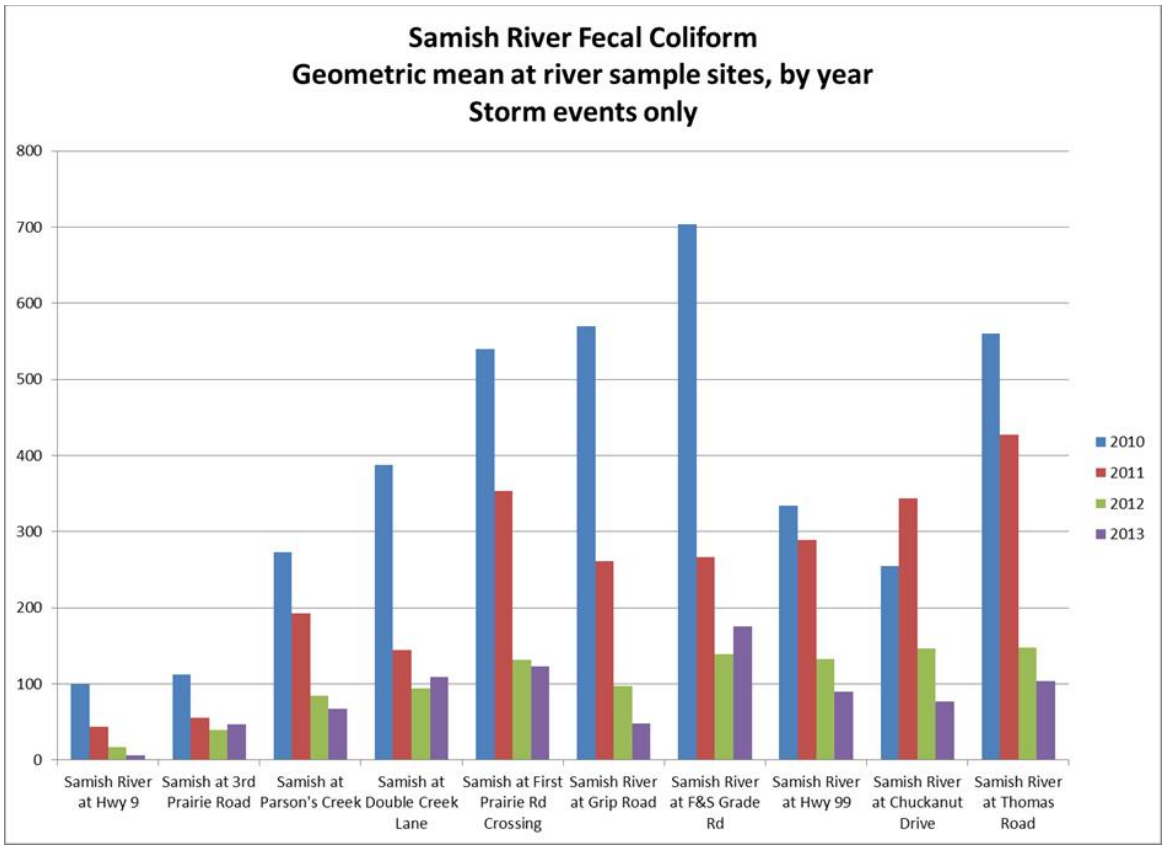

Figure 1. Fecal coliform bacteria declined at every site from 2010 to 2013. Shown are geomean values of fecal bacteria measured after storm events when pollution is highest. For each site, bacteria are shown for each year.

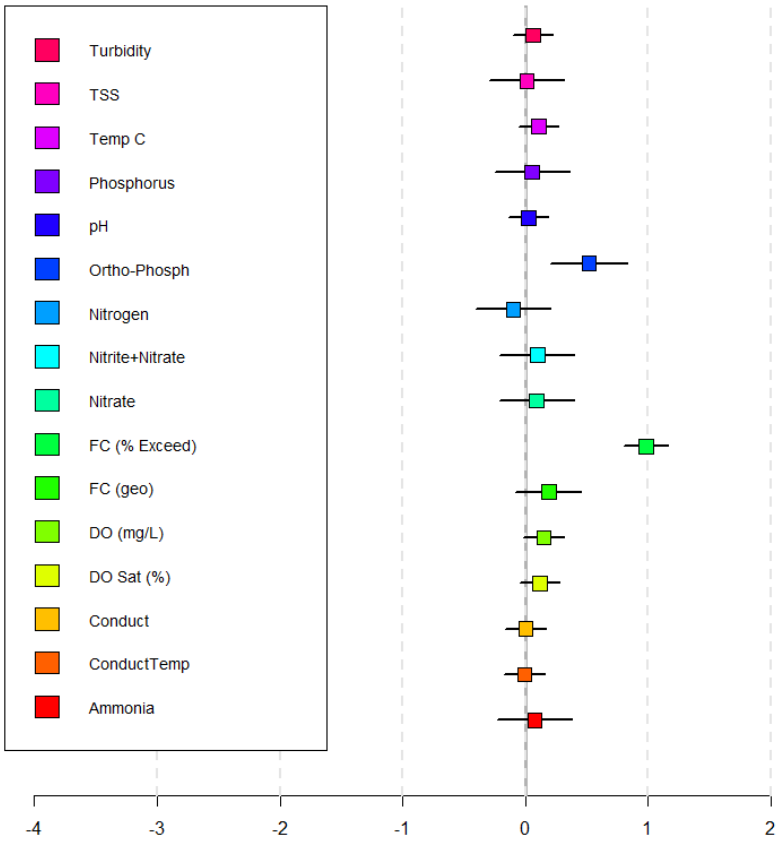

Figure 2. Change statistics for water quality measures. Values greater than zero indicate an improvement in condition (i.e., a decline in fecal coliform exceedences). Values less than zero indicate a decline in water quality measure. Box values represent Cohen's d, which summarizes change over time at 11 sites in the Samish watershed from 2006 to 2012; whiskers represent the 90% confidence interval. (See Appendix 1 this document for a description of meta-analysis methods.) Exceedances for fecal coliform and otho-phosphate levels improved over time, indicated by the positive values for Cohen's d. FC = fecal coliform (geo = geomean; % exceed = fecal coliform samples that exceed state criteria); TSS = total suspended solids; Temp C = temperature (C◦); DO = dissolved oxygen; Conduct = conductivity; ConductTemp = specific conductance (C◦).

CHALLENGES

- Fecal coliform exceedances at monitoring sites are significantly decreasing, yet levels of fecal coliform bacteria still exceed state water quality standards at many sites.
- Shellfish beds in Samish Bay are still subject to frequent closures, especially during high rainfall.
- Livestock tend to move between inspections.
- Continued inspections are necessary for septic systems and farm parcels.
- Fencing livestock out of the stream does not prevent manure from contaminating the stream during the highest rainfall events.
- Regulatory enforcement is sometimes necessary when voluntary compliance does not resolve the problem.
- Molecular source tracking results vary from testing laboratories and are difficult to interpret in terms of which sources are the largest contributors to fecal contamination.

COSTS

Program costs for Samish Basin were calculated for 1/1/2010 – 7/31/2014 a period of 4.5 years. Costs are from Skagit County Public Works, Planning and Development Services, and Public Health and Community Services. Funding was a mix of state and federal grants and match from the County.

Program	Total Cost	% of Total
On-site Septic Systems	$ 2,805,876.00	40%
Natural Resources Stewardship Program	$ 471,773.00	7%
Pollution ID and Correction	$ 1,700,000.00	24%
Clean Water Law	$ 174,208.00	2.5%
Clean Water Partners	$ 1,113,394.00	16%
Administration	$ 715,724.69	10%
Pet Waste Stations & Port-A-Potties	$ 8,750.00	0.1%
Grand Total To Date	**$ 6,989,725.69**	**100%**
Total County Expenditures in Samish Basin	$1,992,486.04	28.5%
State and Federal Grants	$ 4,997,239.65	71.5%

INSIGHTS FROM SAMISH BASIN

- One-on-one communication with landowners is key to compliance, small changes at the parcel scale add up to large reductions in fecal contamination.
- Fecal contamination increases dramatically after storm events suggesting that surface water run-off moves manure from farms and fields into streams.
- High soil moisture may cause septic systems to inadequately treat effluent.
- Waterfowl are most likely not a major source of contamination during the critical late spring period because they migrate away from the Samish watershed before fecal coliform counts and loadings peak during the late spring.
- Skagit Stream Team (a volunteer group) provided critical data that elucidated the relationship between high precipitation events, freshwater quality, and the quality of marine receiving waters. Their work also helped open shellfish beds faster when storm events happened outside normal business hours.
- Fencing out livestock from streams and tributaries keeps the livestock out of the watershed, but fecal contamination can still occur due to the proximity of the animal waste to water, especially during the most intense rain events.
- Manure spreading during the wet season increases the chance of fecal contamination due to run-off and because the ground is saturated.

- Regulatory actions are needed in some instances, but are best used sparingly. When regulatory actions are used, they are best coordinated with all regulatory agencies participating in the larger clean-up effort to avoid loss of trust within the community.
- Fixed monitoring sites are useful in tracking progress and if enough are monitored, they can be used to characterize the overall condition of the watershed.
- Now that all parcels have been inspected, the rate of discovery of new problems has slowed down. Recovery efforts can now focus on known problems and repairs.

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HABITAT RESTORATION: RE-ESTABLISHING NATIVE FORESTS

ROLE OF NATIVE VEGETATION

Vegetated buffers along streams help filter pollutants, stabilize stream banks, and prevent erosion. Riparian vegetation also provides shade, woody debris and leaf litter deposition, all of which benefit salmonids and benthic insects. Human activity is responsible for the decline of riparian areas in the Northwest, specifically in highly urbanized areas of Puget Sound. Most riparian habitat throughout the region has been altered and/or fragmented by human activities over the past century.

The re-establishment of native vegetation within riparian buffers is an important component of most ecological restoration in the Puget Sound region. Native vegetation is planted to improve habitat in various river restoration, mitigation or enhancement projects, particularly in areas of soil disturbance and where invasive species need to be excluded. Common goals are to stabilize streambanks, provide diversity in plant structure and species, and provide shade and to establish a long-term supply of large wood. A wide variety of planting and maintenance methods can be used to re-establish a functioning riparian area.

To restore riparian habitat, plants are often maintained using weed control and irrigation to promote high survival and dense cover, which are often stipulated as conditions in environmental permits. However, plant maintenance is expensive and may be unnecessary when site conditions are favorable and plants are healthy and well-adapted to site conditions. Though plant survival is routinely monitored, factors that affect survival are rarely verified. Current knowledge of what maintenance activities – irrigation, mulching, invasive control – are required to meet habitat restoration goals is based primarily on best professional judgment and anecdotes, rather than scientific evidence.

Cost is often one of the primary factors constraining the feasibility and scope of restoration projects. More reliable, evidence-based guidance is needed to help define what level of site preparation and 'establishment care' is warranted to meet project objectives or regulatory permit conditions. Here, we summarize recent plant maintenance experiments aimed at testing the effectiveness of commonly-implemented plant maintenance practices. The purpose of this summary is to assist in planning and budgeting restoration projects within Puget Sound. This is a work-in-progress, however, because these studies are ongoing and need to be replicated at multiple sites and over many years to represent a wider range of conditions and circumstances.

ACTIONS

Evidence-based experiments using systematic, balanced designs with experimental controls were used as a basis for native forest re-establishment guidelines for floodplains of large rivers and upland areas adjacent to streams and rivers. Controlled experiments were conducted over 1-3

years to systematically test individual maintenance treatments in restoration projects at four rivers in King County (Lower Boise Creek, Green River, Cedar River, and Snoqualmie River). These experiments were set up to begin to evaluate the cost-effectiveness of various maintenance techniques.

Multiple experiments were performed to investigate the effect of typical maintenance regimes – hand irrigation and mulching (woven plastic sheeting squares (1 yd^2) or 6" hog-fuel, wood, mulch), on the survival of plantings, and in some cases on the survival of naturally-recruited seedlings. Experiments in the Green River sites focused on black cottonwood *(Populus trichocarpa balsamifera) poles* (i.e., large stakes, approximately 6-8' tall poles, 3-5" in diameter) and at one site also included potted one-gallon red alder (*Alnus rubra*) (summarized in Table 1). The experiment on Lower Boise Creek focused on multiple deciduous and coniferous tree and shrub species, in aggregate. The Snoqualmie River experiment focused on naturally–recruited cottonwood seedlings. Watering was performed by hand with a hose and pump with water drawn from a tanker truck or from the river. Irrigation regimes varied by location. All sites were exposed to natural precipitation. Each study occurred over 1 – 3 years and the most recent data are summarized, three of these experiments are ongoing (e.g., Pautzke SE, Lower Boise Creek, Snoqualmie River).

Table 1. Summary of experiments to test various maintenance actions on plant survival or seedling recruitment. All experiments performed by King County over 1-3 years; three are ongoing.

			Treatment tested		
Planting type	Initial Condition	Project Name	Irrigated vs. Not irrigated	Fabric mulch vs. Wood mulch vs. No mulch	Irrigated wood mulch vs. Irrigated no mulch
6-8' Cottonwood poles (3-5" dia.) with fabric	Former agricultural site, dominated by blackberry	Pautzke N	X		
6' Cottonwood poles (3-5" dia.)	Former rural residential area	Rainbow Bend	X		
	Former agricultural site, dominated by blackberry	Pautzke SE		X	
1-gal. Potted Red alder	Former agricultural site, dominated by blackberry	Pautzke SE		X	
1-gal. and bare root trees (aggregated) with wood mulch	Bare river spoils	Lower Boise	X		
Shrubs (aggregated) with wood mulch	Bare river spoils	Lower Boise	X		
Natural recruitment	Bare river spoils	McElhoe-Pearson	X		
	Bare river spoils	Lower Boise			X

OUTCOMES

Average tree survival by maintenance treatment are summarized in Table 2. Studies showed irrigation did not improve overall tree survival of cottonwood poles or potted alder, although

frequent, shallow irrigation of bare, disturbed soils was shown to significantly increase establishment and survival of naturally-recruited cottonwood seedlings (Snoqualmie River). Similarly, mulching (wood or fabric) had shown no increase in tree survival (Pautzke SE). Mulching was shown to provide weed and herbaceous species control, but delayed natural recruitment of red alder, at least temporarily (Lower Boise Creek). These studies compliment other maintenance studies performed in the Willamette river basin, which showed that species selection and placement of appropriate nursery stock in combination with effective herbaceous control (i.e., ring spraying with herbicide around plantings) reduces competition and the need for irrigation (Guillozet et al. 2014).

Table 2. Average tree survival by maintenance treatment. Gray cells indicate that treatment was not performed for plant type. Survival for irrigation experiments were reported for Year 1 or 2 as shown.

		Year 2	Year 2	Year 2	Year 1	Year 2
Planting type	**Treatment**	**Cedar River Rainbow Bend**	**Green River Pautzke N**	**Pautzke SE**	**Snoqualmie McElhoe**	**Lower Boise**
6-8' Cottonwood poles (3-5" dia.) with fabric	Irrigation		93%			
	Control		93%			
6' Cottonwood poles (3-5" dia.) without fabric	Irrigation	91%				
	Control	84%				
	Fabric mulch			81%		
	Wood mulch			75%		
	Control			74%		
1-gal. Potted Red alder	Fabric mulch			46%		
	Wood mulch			18%		
	Control			43%		
Trees (aggregated) without wood mulch	Irrigation				100%	
	Control				89%	
Trees (aggregated) with wood mulch	Irrigation					98%
	Control					92%
Shrubs (aggregated) with wood mulch	Irrigation					85%
	Control					93%

IRRIGATION:

Experiments showed that cottonwood poles planted in full sun and in silty soils without mulch can have average Year 2 survival rates of 84% without irrigation (Rainbow Bend); statistically indistinguishable from trees that had been irrigated (91%). At Pautzke N, Year 2 survival averaged 93% (87-99%) in unirrigated plots; these had been fitted with plastic mulch fabric. At Pautzke SE, Year 2 survival of unwatered cottonwood poles was 74%, but was not different from cottonwood that had been mulched with plastic or wood. Differences in tree vigor seemed to vary more according to plot location, rather than irrigation treatment (at Rainbow Bend) (Latterell and Hartema 2014).

Year 2 tree survival on bare soils remained high (>89%) regardless of irrigation (McElhoe). Even at sites with comparatively shallow soils (Rainbow Bend), tree mortality was unaffected by irrigation in the first year, and no significant effects of Year 1 irrigation were evident after three growing

seasons. In one experiment, the replacement of dead trees was more cost-efficient than site irrigation, though irrigation costs can vary widely among sites (Latterell and Hartema 2014).

MULCHING:

Mulching (wood or fabric) experiments showed no increased survival with cottonwood or alder at Year 2. Similar to irrigation experiments, cottonwood poles planted under sunny, quality soils can have over 74% summer survival at Year 2 without the need for mulching (Pautzke SE). In one case, red alder mortality from vole damage may have been exacerbated by the use of wood mulch though high variability reduced the statistical power of the comparison (Latterell 2014). Studies at Lower Boise Creek confirmed that wood mulching delayed herbaceous cover – as expected – but also reduced natural tree recruitment, at least temporarily.

NATURAL REGENERATION:

Soil moisture is well-established as the limiting factor to cottonwood seedlings survival. Another irrigation experiment tested whether frequent watering of bare, disturbed soils, a common feature of restoration sites involving earth work and re-grading, promoted the natural establishment of cottonwood trees (Snoqualmie River). As expected, watering was shown to increase over-summer survival of naturally-established cottonwood seedlings when compared to unwatered plots (13% survival in dry plots vs. 35% in wet plots). Watered plots may also continue to be wetter throughout the growing season, possibly increasing seed survival. At Lower Boise Creek, wood mulch had a negative, though temporary effect on the natural recruitment of trees when compared to bare plots.

LESSONS LEARNED: PLANT MAINTENANCE

IRRIGATION:

- Don't assume that watering is necessary. Irrigate trees and shrubs as needed, instead of by default. A large proportion of the observed mortality in Year 1 can happen before the first growing season, so be sure to source quality plants, and take good care of them before and during installation.
- On high, sunny sites with good soils, watering is often unnecessary for high survival of 6-8' tall, 3-5" (larger than average) cottonwood poles.
- Soil moisture and sun exposure is imperative to determine how much maintenance is needed. Early monitoring of sites and testing summertime soil moisture regime prior to plantings may help determine watering needs.
- The replacement of lost trees was less costly than irrigation.
- Because mulching inhibits weed growth and retains soil moisture, using mulch rings around plantings can be an alternative to full mulch cover over bare areas.
- In future studies, measure effects of irrigation on plant vigor and on additional species; replicate existing studies at other sites.

MULCH:

- On sunny sites with good soils, wood mulch may be unnecessary for high survival of 6-8' tall, 3-5" (larger than average) cottonwood.
- Wood mulch inhibits establishment of herbaceous and invasive plants; usually a desirable outcome.

- Wood mulch has no lasting effect on herbaceous plant establishment and any inhibitory effect lasts approximately 2 years.
- Wood mulch may attract unwanted pests (voles) and increased alder mortality.
- Wood mulch reduces natural recruitment of red alder, when compared to bare (non-mulched) areas – at least temporarily.
- No difference in red alder survival using fabric mulch compared to bare plots after Year 2.
- When using fabric mulch, project cost analysis should include materials, labor for material installation, removal and disposal.

NATURAL REGENERATION:

- Watering was shown to increase survival of naturally recruited cottonwood seedlings on bare, disturbed soils, where naturally-produced seed is abundant – long-term effects are not yet known; this suggests that irrigation may be an effective tactic for increasing tree densities without additional plantings.
- Consider evaluating the proximity of the restoration project to seed producing cottonwood trees to increase seedling density.
- Because counting seedling densities is difficult and time intensive, counting subsamples of quadrats may help to census cottonwood seedlings.

ALTERNATIVE OPTIONS TO COMMON MAINTENANCE REGIMES INCLUDE:

- Use irrigation on stressed plants only. Monitor sites early in the season to forecast watering needs.
- If moisture retention or herbaceous cover is a concern, using mulch rings (or herbicide) around the plants instead of sheet mulching.
- Fabric mulch is expensive compared to wood mulching, especially when the cost of removal and disposal is included in the budget. Where feasible (e. g., in areas lacking reed canary grass), use wood mulch or wood mulch rings as an alternative.

CHALLENGES

- Permit requirements are often generalized, or reused with little or no change, and not always well-suited to the restoration approach or project objectives.
- The use of experimental controls is essential to improve our understanding of the cost-effectiveness of post-planting maintenance and allows for the quantification of cost benefit for extra maintenance.
- Experiments summarized here do not evaluate if native woody cover is higher in irrigated plots (because the precision of cover estimates is much lower than the precision of survival, which can be determined with almost no sampling error).
- Rodent damage (voles), assumed to be attracted to the wood mulch at one site, appeared to increase mortality of red alder at one site, though high variability between plots made the treatments statistically indistinguishable.
- Obtaining accurate counts of seedlings in natural regeneration studies is a painstaking effort- and probably only feasible in the first growing season.

COST ESTIMATES

Approximate number of trees per acre was based upon the spacing distance between trees in feet "on-center" (o.c.) was calculated using this equation from Latterell (pers. com):

$$\text{Number of stems per acre} = 43{,}560 \text{ square feet in one acre} * (\text{spacing in feet})^{-2}$$

Cost estimates for common tree installation and maintenance actions are summarized in Table 3. Estimated number of trees spaced at 5' o.c. is 1,742 stems per acre.

Table 3. Average cost of common maintenance actions in habitat restoration projects. Costs are based on average cost (plant cost plus installation cost) of black cottonwood (*Populus trichocarpa balsamifera*) poles (6' poles, 3-5" diameter) set at 5' o.c.

	Cost per tree	Itemized cost per acre	Cost per acre including tree	Cost per acre including irrigation and tree
Plant + installation	$ 9.50	$ 16,549		
One year of manual irrigation (3 times)	$ 1.00	$ 1,742	$ 18,291	
Hogfuel (wood) mulch	$ 1.81	$ 3,153	$ 19,702	$ 21,444
Fabric mulch (material, installation, and removal)	$ 4.09	$ 7,125	$ 23,674	$ 25,416

RECOMMENDATIONS:

Additional effectiveness monitoring is needed to assess the efficacy of different maintenance methods for plant survival in restoration projects. To test maintenance actions on plant survival several guidelines for project managers are recommended.

PLANTING RECOMMENDATIONS:

- Develop monitoring and maintenance plans collaboratively with project design teams to better anticipate potential risks and improve the timing of problem detection.
- Use frequent site visits to monitor vegetation competition, moisture stress, and signs of herbivory to implement corrective measures, if necessary, although this may add significant cost to a project.
- Consider waiting a year or two to see how the river responds to levee or revetment removal before planting the site.

EXPERIMENTAL RECOMMENDATIONS:

- A well-planned, long term study with control plots will help test hypotheses and will further the development of evidence-based guidelines for riparian restoration projects.
- Use simple experimental designs. Only test one or possibly two treatments at a time so that one site can host at least 10 replicates of each treatment and each plot can contain at least 30-50 trees (or more). Testing multiple treatments at once makes it difficult to determine what action influenced the planting survival and can quickly complicate experiments.
- Replicate studies at other projects across a range of soil conditions and climates.
- If possible, continue studies for at least 3 years to determine how treatments affect plant survival, keeping in mind that it is difficult to maintain plots where there is high usage by visitors or in dynamic, flood-prone environments.
- Testing the effects of common maintenance treatments (wood mulch, fabric mulch, irrigation) on other native tree species. Some species are more challenging to study because they are typically planted at lower densities, necessitating larger plots and a larger experimental 'footprint'. These factors make it much more challenging to conduct well-replicated, randomized, and controlled field experiments on these species.
- Bareroot plants cost less than potted stock. Assessing the survival and cover differences between woody vegetation installation types, bare root seedlings and container plants, would help determine the best planting strategies for restoration sites.
- Evaluate if native woody cover is significantly higher in irrigated plots as compared to non-irrigated plots.
- Testing methods and duration of weed/invasive removal methods – herbicide, mulching, and manual removal of invasive plants.
- Evaluate how baseline site conditions affect the cost-effectiveness of treatments (e.g., bare or disturbed soil, dill, grass, blackberry thickets, knotweed, reed canarygrass).
- Examine survival of naturally-recruited seedlings on bare ground with/without watering.
- Examine the influence of soil texture on plant survival.
- Compare survival between trees with mulched rings versus no treatment on bare or disturbed sites.

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NISQUALLY DELTA: RESTORING ECOSYSTEM FUNCTION FOR SALMON

The Nisqually Delta Restoration Project, led by the Nisqually National Wildlife Refuge, Ducks Unlimited, the Nisqually Indian Tribe, and the Washington Department of Fish and Wildlife, represents the single largest tidal marsh restoration project in the Pacific Northwest. The river delta is being restored to natural salt marsh and estuary flood plain for salmon and other native fish, migratory waterfowl, resident birds and wildlife, aquatic mammals, and the people who enjoy this remarkable environment (Washington Tribes, 2014).

The Nisqually River is one of the largest tributaries to Puget Sound and forms an ecologically important delta where the sediment from the river is deposited as it joins the Sound. The Nisqually estuary refers to the area where the salt and fresh water mix and provide unique habitat for birds, fish, mammals and insects. For the past 100 years, tidal flow to parts of the Nisqually delta was blocked by agricultural dikes. Lack of saltwater flow resulted in loss of estuary habitat and populations of declining fish and wildlife.

The Nisqually Fall Chinook population is one of 27 stocks in the Puget Sound listed as threatened under the Endangered Species Act. Restoration and preservation of the Nisqually delta ecosystem is the highest priority for Chinook recovery (Lind-Null, 2008a). The Nisqually Delta is the largest tidal marsh restoration project in the Pacific Northwest and represents the most restorable river delta in Puget Sound. The restoration of the Nisqually complex began in 1996, and has progressed from smaller pilot projects to a cumulative restoration of nearly one thousand acres. This restoration is large enough to impact other physical and biological processes across the entire ecosystem.

The Nisqually delta restoration provides critical habitat for Nisqually winter chum and non-salmonid fishes, and provides crucial migration and resting habitat for migratory birds of the Pacific Flyway. The restoration presents a rare opportunity to evaluate the long-term effects of recovery actions on a large estuary. And to inform restoration actions in other estuaries of Puget Sound.

> *"Being involved in a project of this scope and scale for more than a decade has been a once-in-a lifetime project for all of us and it will benefit many fish and wildlife species for years to come."*
>
> *Tom Dwyer, Conservation Director, Ducks Unlimited*

RESTORATION FRAMEWORK

Overall goal: Restore the delta, estuary, and tidal marshes to increase habitat for juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and other wildlife.

Habitat restoration:

Restore estuary habitat and other associated habitat types such as surge plain riparian habitat, freshwater wetlands, riparian forests and grasslands:

- Restore tidal flow to ~762 acres by removing about 5 miles of dike.
- Restore ~ 37 acres of freshwater tidal riparian forest along the lower Nisqually River by shaping the land and planting intensively next to existing surge plain forest.
- Construct new, exterior dike to protect infrastructure at the Wildlife Refuge and create 246 acres freshwater wetlands and grasslands.

Measuring the impact of restoration:

Assess the effectiveness of the Nisqually Delta projects in restoring estuary processes and habitats and increasing habitat for juvenile Chinook salmon and other types of fish (Figure 1).

- Measure river flow, the amount of sediment in the river, and the amount available to build delta habitat.
- Evaluate how freshwater and saltwater mix and circulate in the nearshore around the Nisqually delta.
- Examine and compare the invertebrate community in restored and reference sites to understand how Chinook feed in the delta.
- Measure salmon residence time, growth rates, and number of life history stages present within different habitats.

EXPECTED OUTCOMES

- Restoration of historic channels
- Development of a complex landscape of permanent and seasonal freshwater wetlands, with riparian forest and grassland mixed in
- Vegetation replacing bare ground
- Growth of reproduction of native plants
- Native plants replace invasive species
- Invertebrate communities become more similar to those found in natural sites
- Increase in distribution and abundance of waterfowl
- Broader distribution of Chinook salmon, increased abundance of juveniles, increase in feeding opportunities, increased time in estuary, increased growth, and a greater number of life stages (ages) observed
- Creation of computer models to evaluate alternative scenarios for sediment transport and estuarine mixing

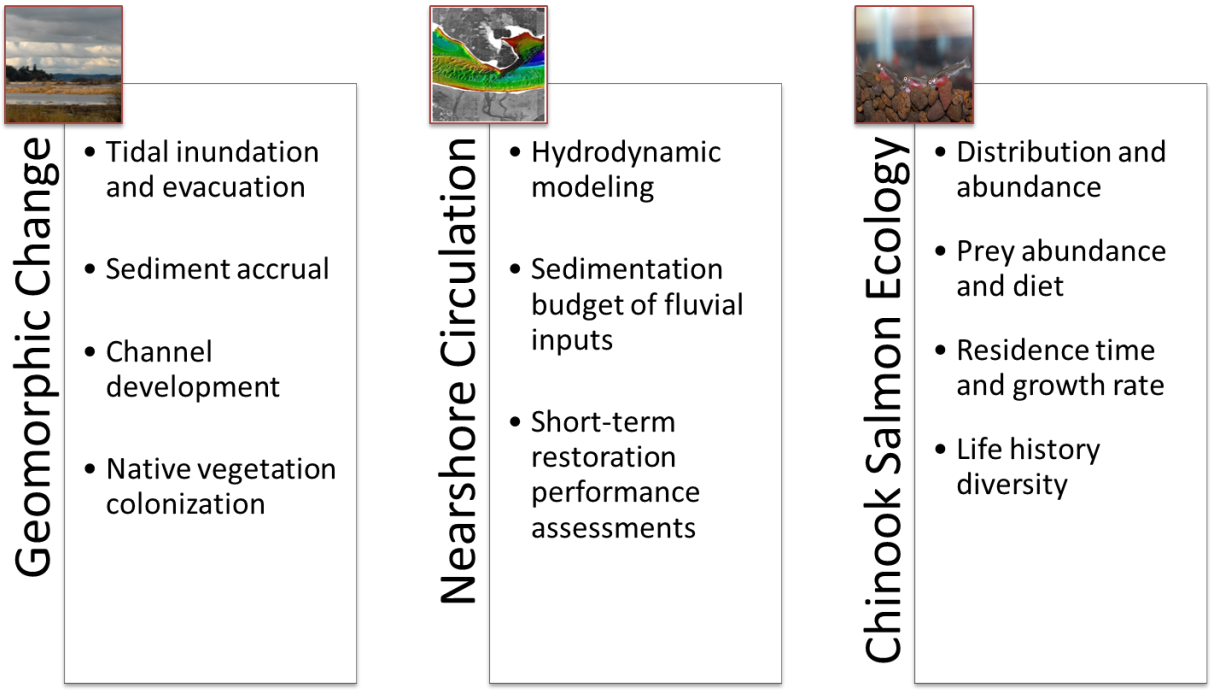

Figure 1. Adaptive management indicators used to assess the impact of restoration actions on the landscape and ecology of the estuary and delta.

ACTIONS

Habitat Restoration

The Nisqually Delta restoration took place in three phases (Figures 2 and 3). From 1996 to 2002, Phase 1 opened ~40 acres of diked land, restoring tidal flow to land that was pasture. In 2006, Phase 2 opened an additional 100 acres of pasture on the east side of the Nisqually River. In 2011, the Brown Farm Dike was removed, allowing large tidal channels to be reconnected to smaller historic channels (Figure 4). Tidal influence was returned to approximately 762 acres by removing approximately 5 miles of dike. Earth moving equipment was used to slope and level the land so that tidal water could flow into the previously diked areas. In this way, the estuary habitat was restored to the delta area.

Upland habitats, away from tidal flow, were also restored. Nearly 50,000 cubic yards of fill was contoured to create land that would support the growth of trees and plants in along the riparian edge of the Nisqually River. Native trees and snags were planted. Rip rap was removed and placed on portions of the exterior dike to protect the area from erosion by the Nisqually River.

A new dike created 246 acres of freshwater wetlands and grasslands and was expected to support natural development of these habitat types.

Adaptive Management

An adaptive management framework was implemented to insure that monitoring data would inform restoration actions as the project evolved. Effectiveness monitoring tools developed included:

- Hydrodynamic model to explore future scenarios;
- Budget of sediment inputs from the river;
- Performance targets;
- Indicators of plant and invertebrate communities; and
- Ecological indicators of Chinook salmon use, growth and life history.

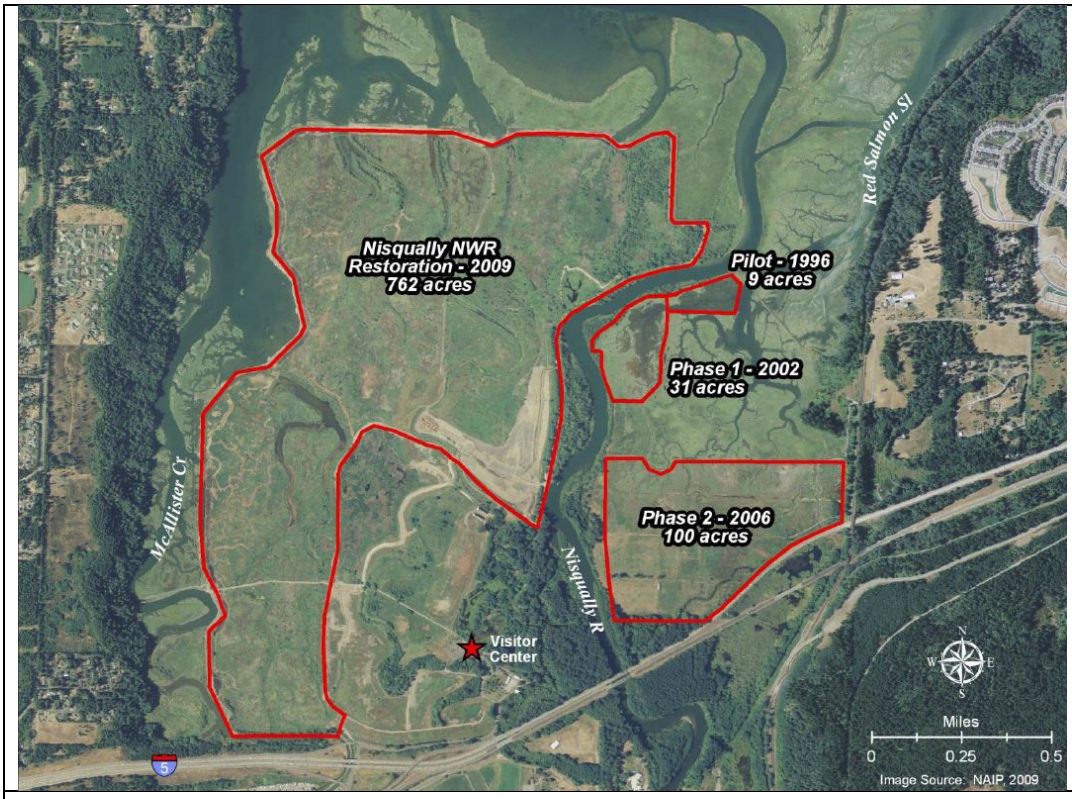

Figure 2. Restoration phases of the Nisqually delta (Ellings, 2010).

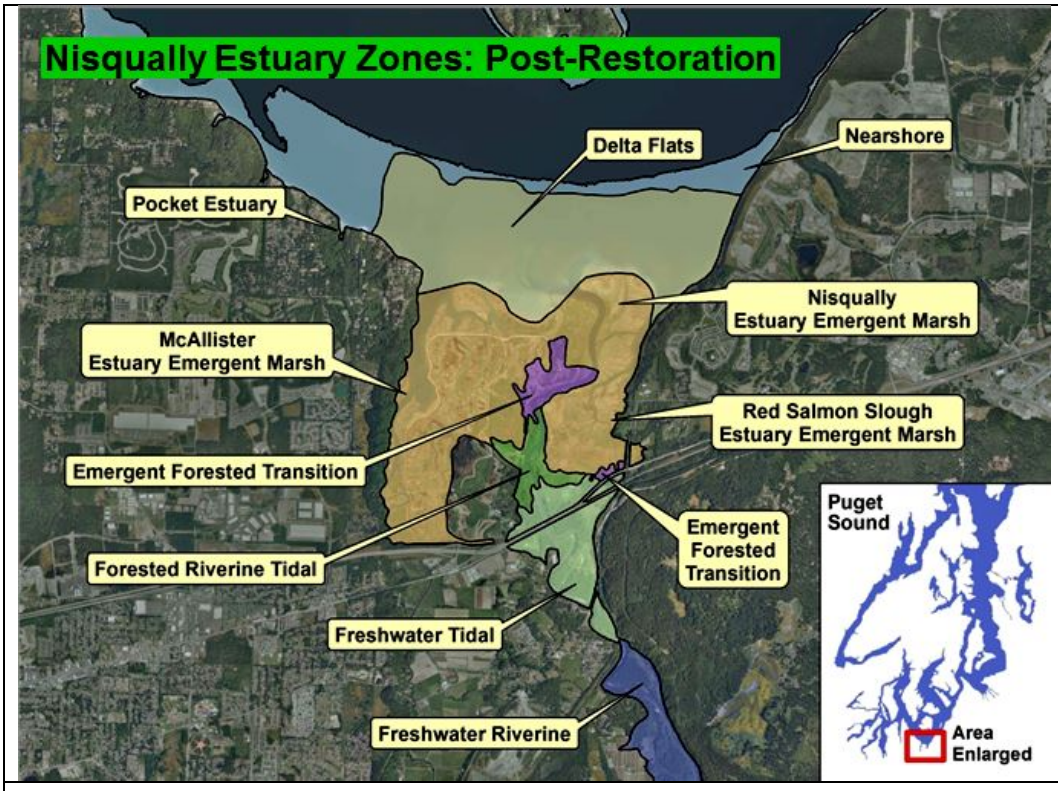

Figure 3. Nisqually Delta after restoration showing the diverse types of habitat found in the estuary and delta. Designated habitat zones are shown (map courtesy of J. Cutler, Nisqually Indian Tribe; Lind-Null et al. 2014).

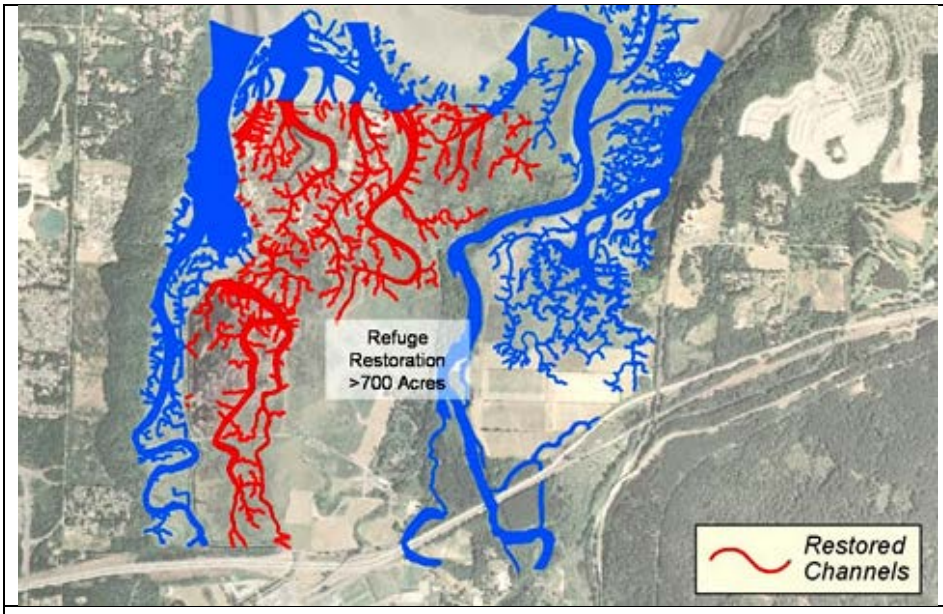

Figure 4. Nisqually Delta restoration of tidal flow and connections to historic channels. Restored channels are indicated by red and existing channels in blue.

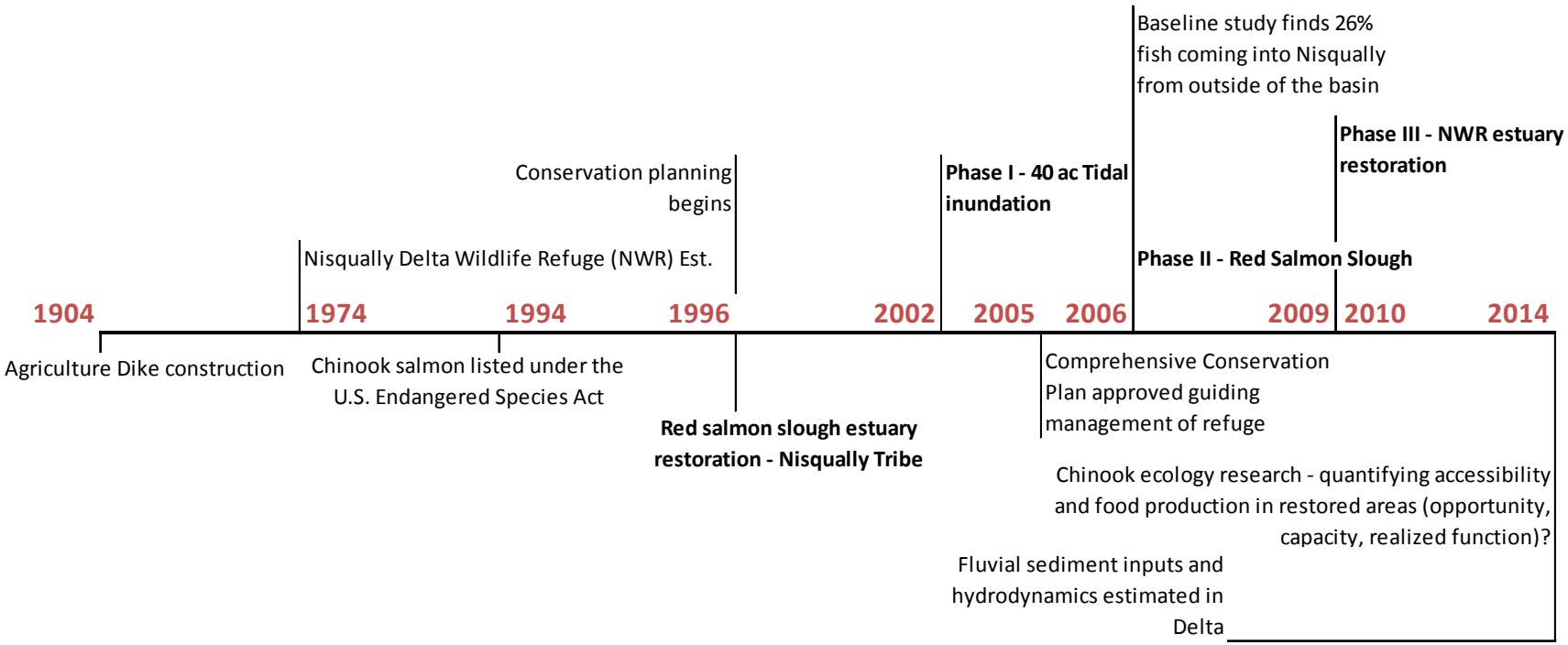

Figure 4. Timeline of Nisqually Delta restoration actions, phases and milestones.

OUTCOMES: DELTA RESTORATION

Habitat development

In estuary areas, wetland habitat increased by 42% as a result of dike removal (David et al. in press). Tidal flow was restored to more than 21.4 miles of historical tidal channels and approximately 2.3 miles of historical floodplain and delta (Woo et al. 2011a).

In the marsh areas, about 50% of the area measured had high-quality vegetation while invasive plants covered about 25% of the area. Channel development increased and channels were more diverse after restoration. Area covered by mudflats and other types of habitat increased, representing an increase in habitat diversity (Woo and Takekawa 2008).

In the riparian area along the edge of the Nisqually River, invasive species (primarily reed canary grass) covered 75% of the area before restoration and covered less than 1% of the same area after (Woo et al. 2011a, b). About half of the native vegetation plantings have survived, and some active colonization has occurred 5 years post planting(Woo et al. 2011a). Survival of plantings and reduction of invasive vegetation is encouraging, but success of plant survival, colonization, and recruitment of plantings is less than expected. Continued monitoring of plant survival, native/non-native species occurrence, and native plant recruitment is still being assessed.

Within the 246 acres of actively managed as freshwater wetlands, the habitat has begun to diversify into a mix of permanent and seasonal freshwater wetlands, with smaller proportions of riparian forest and grassland habitats (see Figure 2). The physical construction on the land and water management successfully created seasonal wetlands.

Sediment transport and hydrologic dynamics

To build and preserve estuary habitat, the delta needs to retain sediment to build the land. Computer models predict how the land, sediment and water from both tides and the river interact to form, erode and create habitat (Breithaupt and Khangaonkar, 1999). More sediment was captured in the upper reaches of the restored channels (Woo and Takekawa 2008).

Hydrodynamic and sediment modeling guide the next round of restoration actions such as carving additional small channels to route and increase sediment from upstream to create more habitat.

OUTCOMES: BIOLOGICAL RESTORATION

Waterfowl and shorebirds habitat

Vegetation in the freshwater wetlands provides the type of food that is good for waterfowl. Both dabbling ducks and shorebirds were seen using the restored areas (Woo et al. 2011a). Migrating ducks also fed and rested in the restored areas.

Salmon and invertebrates

Both Chinook distribution and abundance increased in the restored areas. Chinook juveniles are using restored channels, and the area available for Chinook use has increased. Residence time for juveniles in the estuary has also increased (Lind-Null and Larsen 2010; Lind-Null et al. 2014). Whether the new habitat is good enough to provide the right prey in adequate amounts to support enough growth of Chinook juveniles to survive outside the estuary is not yet known.

Sampling indicates that invertebrates have colonized and continue to be found in the newly restored habitat. Diet composition studies indicate that Chinook are feeding on insects and invertebrates in the restored estuary. Comparisons between restored and reference estuary habitat showed that Chinook diets in the two areas are becoming more similar over time (David et al. in press). Chinook prey consumption and potential growth rates were similar within restored and reference marshes (Lind-Null et al. 2008a; Lind-Null et al. 2008b; Lind-Null and Larsen 2009; Lind-Null et al. 2014). Habitats are expected to evolve over time and become more natural in terms of habitat feature and insects.

CHALLENGES:

Challenges remain for recovery of the Nisqually delta and estuary and continue to be evaluated in an adaptive management framework (Ellings, 2008; Woo and Takekawa, 2008; Woo et al., 2011a, b; David et al., in press).

- Rates of sedimentation were slower than expected; probably because Alder Dam captures sediment from eroding areas upstream and reduces the amount available to build the delta.
- Habitat formation in salt marsh and freshwater wetlands did not happen as quickly as expected due to a slower rate of sediment deposition than was originally expected to occur.
- The development of new habitat into a more diverse pattern has been slower than expected; creation and connection of historic channels in new habitat has been slow.
- Partial dike removal at major channels was not as effective in restoring tidal flow, appropriate levels of salinity, or adequate sediment.
- Ponding due to poor tidal flow resulted in fish kills. Dredging initiated in 2010 helped with poor drainage by creating deeper channels and enhancing tidal flow.
- Restored estuary habitat was warmer (2°C) than in similar habitat in reference sites; higher temperatures in restored estuary habitat may slow Chinook growth; deeper channels and more riparian shade may be needed in restored estuary habitat.
- Native plant colonization is slow; about 80% of areas that were not planted are still bare.
- New invasive plants species have been detected (e.g., spartina) and may threaten native plant survival and colonization.
- Chinook residence within the delta has increased, but Chinook densities are still greater in reference marshes than restored areas.
- Recently observed growth rates of juvenile salmon were lower than growth rates observed before restoration.
- Before restoration, two Chinook life stages were seen in the estuary, fry-migrants and delta-users; after the restoration only delta-users were observed.

COST

Approximately $15 million in completed projects
Source: Puget Sound Partnership 2009; Ellings 2010; Puget Sound Partnership 2012

1. *Restore estuarine habitat: $10 million*
   Cost: $13,000 per acre restored
   - 4.5 miles of dike removed
   - 760 acres restored
   - 21 miles of historic tide channels restored

2. *Protect, restore, and enhance surge plain riparian habitat: $1.7 million*

   Cost: $57,000 per protected acre

   - Approximately 30 acres of floodplain riparian habitat protected
   - 4.4 miles of salmon habitat protected
   - 2.5 miles of surge plain hydrology restored
   - 6 acres of riparian buffers

3. *Protect, restore, and enhance a mosaic of primarily permanent and seasonal freshwater wetlands as well as riparian forests and grasslands within the new exterior dike: $3 million*

   Cost: $12,000 per enhanced acre

   - 246 acres freshwater ponds enhanced
   - 68 acres of wetland, riparian buffer, and riparian forests protected
   - 21.4 miles of historical tidal sloughs and channels restored
   - 0.25 salmon habitat protection

4. *Adaptive management research: $600,000*

   Cost: $167,500 for hydrodynamic and sediment modelling

   - Fluvial sediment inputs
   - Hydrodynamics affecting sediment transport

   Cost: $156,500 for fish distribution and relative abundance research

   Cost: $126,000 for Chinook otolith research to explore functional response

   Cost: $150,000 for assessing Delta capacity and realized function for Chinook

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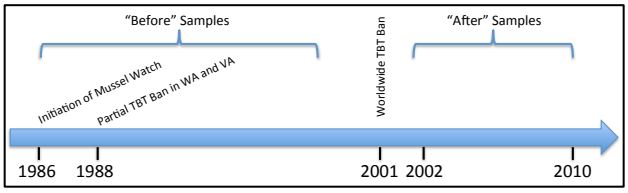
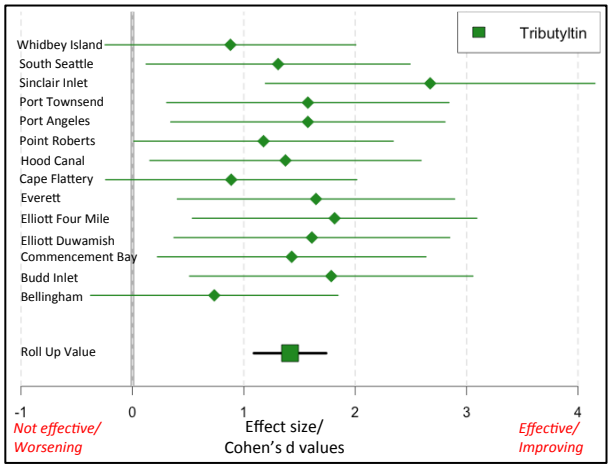
Appendix 2. Meta-Analysis of Puget Sound Monitoring Data

Prepared by

Constance Sullivan, Friday Harbor Laboratories, University of Washington

Leska S. Fore, Puget Sound Partnership





Meta-analysis of Puget Sound Monitoring Data

Constance Sullivan, University of Washington, Puget Sound Institute

Leska Fore, Puget Sound Partnership

EXECUTIVE SUMMARY

Over the past few decades, dozens of restoration projects have been undertaken in Puget Sound. These include actions to restore water quality, populations of various species, and different types of habitat. The main question after all of these actions have been undertaken, combined with the knowledge that more are needed, is whether or not the restoration and associated management actions are having the desired effect. One way in which to quantitatively answer this question is by performing a meta-analysis (i.e., an analysis approach that combines results from different studies).

Applying meta-analysis to questions about the effectiveness of restoration efforts allows us to combine information from a variety of studies related to a particular topic area or throughout a specific region to evaluate the effectiveness of implemented actions. In the current project, we are using a Cohen's *d* statistic to determine the size of an effect of a management action (DeCoster 2009).

Data from six regional studies were used to evaluate ten measures of site condition at 51 regional locations (Figure 1). Studies ranged from water quality measures to habitat condition to concentrations in and effect of contaminants in organisms. A variety of management actions were employed to address the issues. Overall, eight variables show a positive change in site condition following management actions and two showed a negative change. Site conditions following sediment capping shows reduced incidences of DNA adducts, concentrations of fluorinated aromatic compounds (FACs), and risk of liver lesions in English sole. A full ban on tributyltin (TBT) was followed by reduced concentrations in mussels. Implementation of phosphorous TMDLs in lakes was followed by improved conditions in lakes. Source identification and the resulting management actions were followed by reduced levels of fecal coliform bacteria. Site conditions following habitat restoration provide mixed evidence; fish density declined following implementation but the richness of benthic invertebrates and insects increased following implementation. The available data provide no evidence that partial bans on pesticides activities achieve intended changes in site conditions; in fact, conditions appear worse after implementation of these management activities. The results of these meta-analyses support conclusions about the positive effects of some management actions on (some) site conditions:

- Nearshore habitat restoration actions appear to have positive effects on invertebrate communities (i.e., benthic community and insect richness)
- Capping of contaminated sediments appears to have positive effects on marine fish exposed to and effects from toxic contaminants (i.e., contaminant metabolites in bile, DNA harm, and liver disease)

- TMDL implementations appear to have positive effects on phosphorous levels in lakes
- Source identification and control actions appear to have a positive effect on the levels of fecal coliform bacteria found in freshwater and marine areas
- Implementation of a full ban on pesticides appears to have a positive effect on levels of the pesticide in benthic organisms (i.e., concentrations in mussel tissue); however, partial bans do not appear to have a uniformly positive effect on detection frequency in freshwater

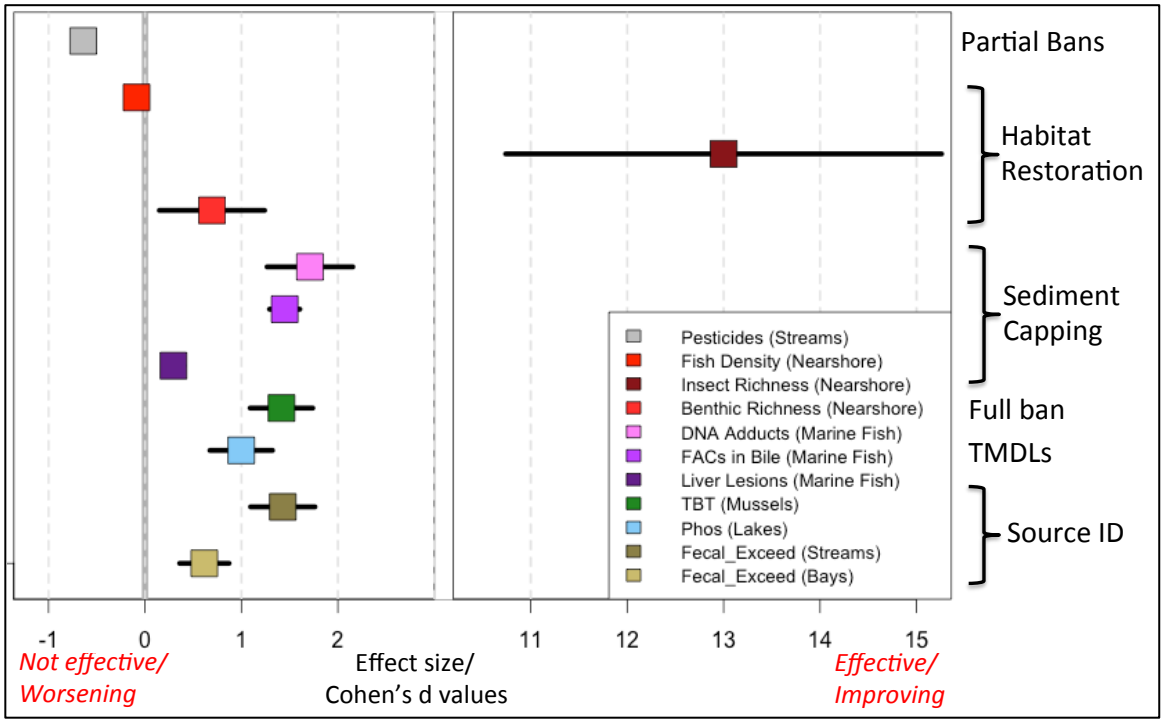


Figure 1: Puget Sound-wide meta-analysis of selected restoration and clean up projects. The legend shows the targeted variable and the medium the variable was measured in. Text to the right of the plot shows the management action used to affect each variable. Each variable is discussed in more detail in the sections below. Abbreviations are as follows: FACs = fluorinated aromatic compounds; TBT = tributyltin; TMDL = total maximum daily load.

INTRODUCTION

Over the past few decades, dozens of restoration projects have been carried out in Puget Sound. The goals of the projects range from improving water quality to restoring habitat to increasing species populations. A frequently asked question is whether or not the management actions designed to improve conditions in Puget Sound are effective. Individual projects have demonstrated their effectiveness, but there has been no regional effort made to develop a process to systematically determine which management actions are the most effective and which variables are the most responsive. We propose the use of meta-analysis as a tool to quantify the size and direction of the effect of a management action and to allow the simultaneous comparison of different variables. Ultimately, this

work will aid in the determination of which management actions are the most successful and will be used to recommend successful actions.

Meta-analysis is the statistical analysis of a large collection of studies for the purpose of integrating the findings (Whiteway et al., 2010; Bowler et al., 2012; DeCoster 2009). Meta-analysis calculates a change statistic to measure difference in a variable before and after an action (Figure 2). The change statistic, or effect size, measures the effectiveness of actions across different projects and variables (Nakagawa and Cuthill 2007). For this work, a Cohen's *d* change statistic (Equation 1) was chosen as the appropriate calculation to determine effect size and direction. Cohen's *d* is easy to interpret and widely used to estimate effect size (Nakagawa and Cuthill 2007; DeCoster 2009). Cohen's *d* is roughly equivalent to a *Z*-score from a normal distribution.

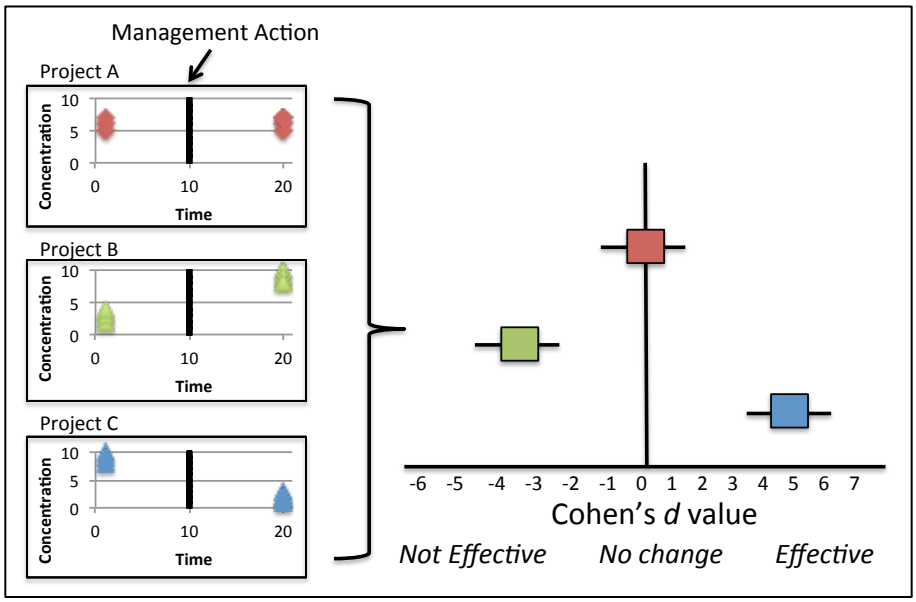


Figure 2: Diagram of the data that is used in calculating a Cohen's *d* value. The Excel graphs (left-hand side of the diagram) represent three different projects. The black line shows the date of the management actions for each project, and the aim of the management actions was to decrease the concentration of each contaminant. The Cohen's *d* value (right-hand side of the graph) is representative of the effect of a management action that utilizes data taken before and after the action. Error bars represent 90% confidence intervals. As the desired outcome from management of a pollutant is typically a decline in the levels of a pollutant, the pollutant in Project B shows an increase due to the management action and was thus not an effective management action. The pollutant in Project A showed no change, and the pollutant in Project C declined over time. Project C's Cohen's *d* value is therefore positive, and indicates an effective management action. Because Cohen's *d* values are unitless, multiple variables from different sites and projects can be represented on the same plot to evaluate the effectiveness of various management actions with ease.

PURPOSE

The purpose of the meta-analysis is to determine which management actions show a positive change and which variables respond the most readily. The intent is to get a high-level overview of what is working and what is not to restore Puget Sound. It relates to the effectiveness monitoring framework in that it provides a unitless value to compare the effectiveness of management actions to restore different endpoints in Puget Sound.

The utility in this method is that it can be used at various levels in Puget Sound:

- The analysis can be performed on a site-by-site basis,
- Different sites within a project that analyze the same variable can be combined into a single value, and
- Different projects that use the same variable collected in the same way can also be combined for a regional-scale value.

An exhaustive search of available projects was not performed; rather, a wide variety of projects were selected so as to provide methods and examples for different types of management actions and datasets. Project variables used in this work include water quality, species population changes resulting from habitat restoration, sublethal effects in organisms, contaminant levels in water, and contaminant levels in organisms. Data are from both freshwater and marine systems.

METHODS

In order to evaluate the effectiveness of restoration and management actions on the recovery or improvement of Puget Sound habitat and water quality, the relationship between the variable of interest and the action to change it needs to be defined. A clear problem statement and management action, with expected results, needs to be documented to form the hypothesis and to understand the desired outcome. Ideally, a dataset will contain monitoring data that was sampled prior to the initiation of a management action ('before' data) and data following the management action ('after' data). The dataset will also contain variables that were collected the same way prior to and following the management action. We define the term "variable" in this study as the parameter that is being measured for change (i.e., species richness, fecal coliform bacteria counts, phosphorous levels, etc.). The interval following the management action should be sufficient so as to have allowed time for an effect to occur. The data required for this analysis include a mean, sample size, and standard deviation for both the before and after data.

Steps to the Analysis

Step 1. For each site and variable combination, calculate the mean and standard deviation for the variables of interest before and after the action. Note how many replicates are used for the before and after data. For the purposes of this analysis, we define replicates as the number of samples taken for the before and after years of monitoring.

Step 2. For each site-variable combination, calculate the "effect size" as the difference in the variable before and after the action divided by the pooled standard deviation. The effect size is a unitless measure of change; thus, results can be compared across projects and response variables. Equations are from deCoster et al. 2009. Calculate Cohen's *d* using the formula:

(Eq. 1)

$$d = \frac{\mu_A - \mu_B}{\sigma}$$

Where d = Cohen's d
μ_B = Mean value of the variable before the action or treatment
μ_A = Mean value of the variable after the action or treatment
σ = the pooled standard deviation.

The pooled variance is calculated as:

(Eq. 2)

$$SD_{Pooled} = \sqrt{\frac{(N_A - 1)\,(SD_A)^2 + (N_B - 1)\,(SD_B)^2}{N_A + N_B - 1}}$$

Where SD_B = Standard deviation of the before group of samples
SD_A = Standard deviation of the after group of samples
N_B = Sample size of before group of samples
N_A = Sample size of after group of samples.

Step 3. Define a group of variables and sites of interest, e.g., measures of toxics in mussels. This is done when the goal is to calculate a 'roll up' value to calculate the effect size for a variable measured at multiple sites. Calculate the average Cohen's *d* for the group of interest. The average value is typically weighted by the variance as:

(Eq. 3)

$$\bar{d} = \frac{\Sigma\, w_i d_i}{\Sigma w_i}$$

(Eq. 4)

$$w_i = \frac{1}{\text{variance of } d_i}$$

To test for significance, an estimate of variance is needed. It can be calculated as:

(Eq. 5)

$$s_d^2 = \frac{1}{\Sigma w_i}$$

Once the variance is determined, a 90% confidence interval can be calculated to give an estimate of the error associated with the estimate of Cohen's d.

Data Interpretation
To interpret the data, it can be plotted in an appropriate statistical program, such as R, and assessed. The size of the effect is relative to zero. The standard in interpreting a Cohen's *d* is that if the value is less than 0.2, it is considered to not have an effect; 0.2 – 0.8 is a medium effect; and a value of 0.8 or greater indicates a large effect (Rosnow et al. 2000).

For the purposes of this study, data were corrected so that a positive value indicates a desired effect from a management action and a negative value indicates an undesired effect from a management outcome. This was done so as to visually communicate the desired and undesired outcomes better to audiences. If the 90% confidence interval overlaps with zero, no effect has occurred.

Vetting the Results
A required step in a meta-analysis is to confirm the results with the researchers who produced the data. We presented our results to the data authors and asked them to comment on the results, e.g., did we correctly interpret the results, and can we apply results to other areas.

These results are contained in the section below entitled "Case Studies and Results with Vetted Documents." For each change analysis performed, the data authors were presented the methods and results of how their data were utilized. Following each meeting, revised versions of figures (if necessary) and a data-vetting sheet were sent. The vetting sheet contains two sections: one to provide a summary of the meeting and another for the data authors to fill out to ensure their data were interpreted correctly and to ask their permission to share the results of the analysis using their data. This serves to document the agreement of both parties on the interpretation of the data and to document whether or not the data authors agree to allow their data to be shared.

CASE STUDIES
A variety of case studies were selected to provide methods for various types of data for the meta-analysis. Each case study provides a brief description of the original project, what the management actions were, specifics of the method, and any associated caveats for the meta-analysis. The case studies each have a vetting sheet that was approved by the data author(s) to provide feedback on the analysis.

Tributyltin in Mussel Tissue
Description of Study
The question of interest is whether a partial and a subsequent full ban on the use of tributyltin (TBT) paint results in decreased concentrations in mussel tissue.

Tributyltin concentrations were measured in mussel tissue as part of NOAA's Mussel Watch program. Sampling began in 1986 and has since been conducted on an every other year sampling regime. There are 24 sample sites along Washington's coastline.

TBT is an antifoulant paint applied to ships. Two management actions occurred for this substance: a partial ban that was implemented in two states followed by a full nation-wide ban at a later date. Its use was banned on ships less than 82 feet in 1988 in Washington and Virginia, and a full ban in the United States was implemented in 2001. TBT has a fairly short half-life (1 – 3 months in the water column; up to 2 years in sediment), so a ban was expected to be a fairly rapid and effective method to remove TBT from the environment.

Data for the meta-analysis 'before' data are from either two years before the partial ban in 1988 or within two years of its implementation. All data used in the 'before' calculations are before the 2001 nation-wide ban; all 'after' data are from 2002 or after (Figure 3).

It should be noted that the Mussel Watch program was not designed specifically to capture the management actions of TBT; however, due to its sampling regime and duration, the effects of the ban are captured in the data.

Meta-analysis Results

There are 24 sites in Washington state; however, not all sites are located in Puget Sound, and not all of those that were in Puget Sound contained sufficient data (as defined by the meta-analysis project team) to be included in the current analysis. Fourteen sites had the appropriate data, and were included in the meta-analysis.

Once mussel samples are collected, they are divided into three batches, analyzed, and results are reported as one composite value for each site for each year. For the meta-analysis, we used the first five years and the most recent five years for the mean, standard deviation, and sample size. There were two exceptions to the sample size of five for the 'after' data: Port Townsend and Hood Canal have four years of data from 2002 and later because they are each missing a year of data after 2002. Data were not collected 5 years prior to the initial management action; therefore, data used are from time points as close to the earliest management action as possible, but often do not include samples prior to management actions in 1988. All samples are after 2001, and capture the full nation-wide ban on TBT.

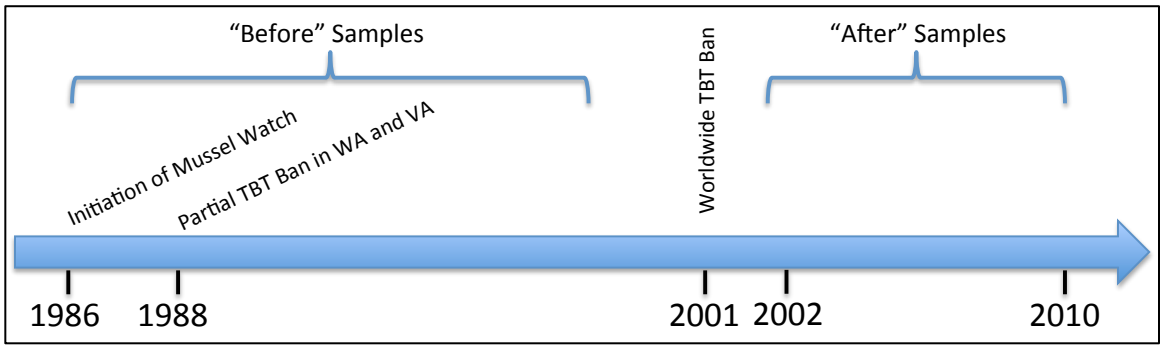


Figure 3: Timeline of mussel sampling and management actions. "Before" data encompass the initial management action but were prior to the second management action. All "after" data were

sampled following the second management action. "Before" and "after" data were calculated from pooling the earliest and most recent, respectively, available 5 years of data; therefore, there are timespans within which "before" and "after" data were sampled.

The results indicate that the management action of banning TBT had a large effect in the reduction of TBT in mussel tissue (Figure 4). Each site showed a strong decline in the concentrations, and the overall effect of all projects captured this decline.

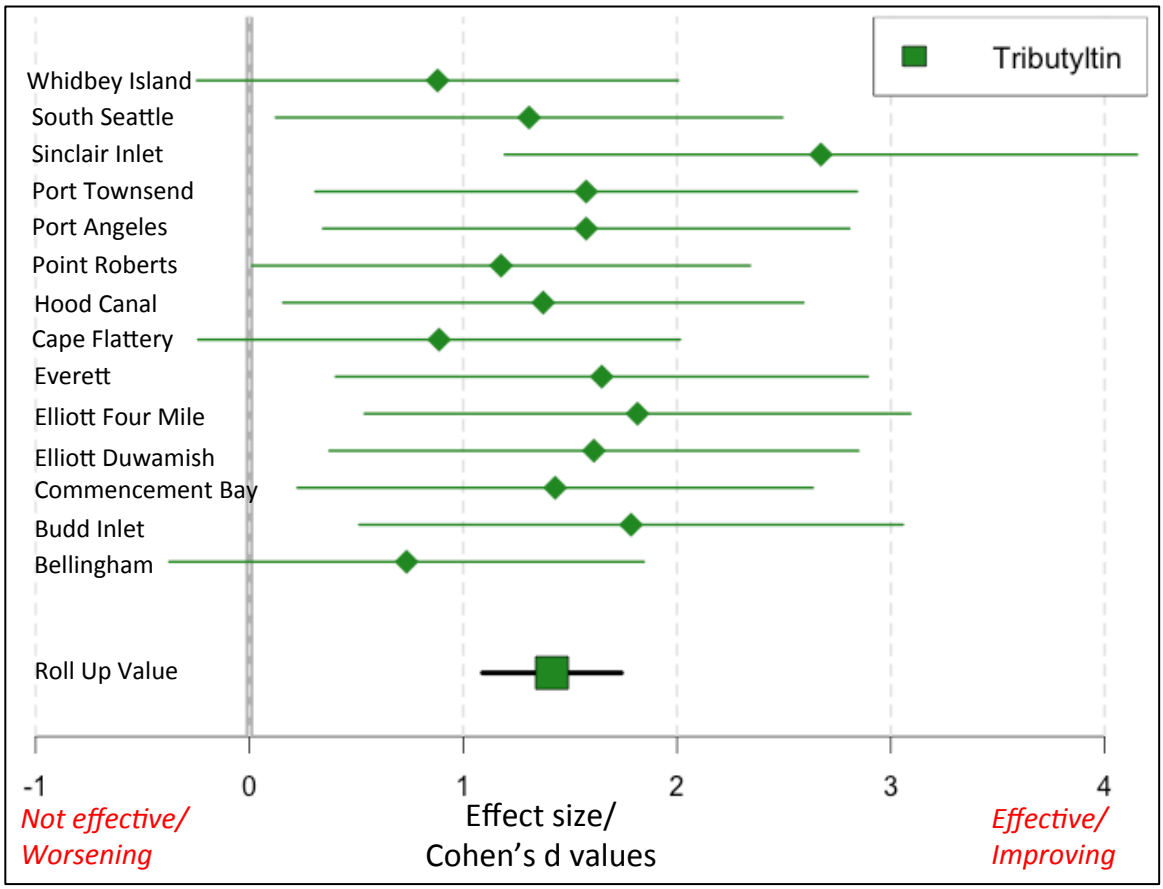


Figure 4: meta-analysis of management actions reflected in the concentrations of TBT in mussel tissue. TBT concentrations declined at the majority of the sites following the management actions. The confidence interval for Whidbey Island, Cape Flattery, and Bellingham overlaps with the zero line, indicating no change. Each diamond-shaped symbol represents a single site in which concentrations of TBT in mussel tissue were measured. The large square at the bottom of the figure represents a roll up of all projects and shows that the levels of TBT are showing an overall strong decline in mussel tissue over time. Error bars represent 90% confidence intervals.

<u>Meta-analysis vetting</u>

- Agency/ organization: WDFW
- Contacts: James West, Sandie O'Neill
- Date of meeting: 31 January 2014

Pesticide Detection in Water

Description of Study

The question of interest is whether partial bans on the use of pesticides results in a lower detection frequency over time. A joint effort between the Washington Departments of Ecology and Agriculture began in 2003 to monitor pesticides in surface waters. Salmon-bearing streams were the primary focus. Streams around Washington state were sampled; however, for the current meta-analysis, only data from sites in Puget Sound were incorporated. Sites included were one in Thornton Creek and four in the Skagit-Samish watershed. The Thornton Creek site is an urban area and the Skagit-Samish sites are primarily agricultural. Sampling was performed during times of the year that pesticides were used more frequently. Percdent detection rate was used in place of the mean for before and after data.

Meta-analysis Results

The authors of the study looked at the data in a variety of ways. One such method was the detection frequency of pesticides. A suite of pesticides was screened for, and an annual value was reported for the number of samples collected vs. the number of detections of each pesticide. Since not all pesticides were detected at all sites, the sample sizes of pesticides for each site vary. In addition, not all of the pesticides detected were included in the current report: only pesticides that had some of their applications restricted between 2003 and 2009 (Figure 5). Restrictions included, but were not limited to, a ban on homeowner use or use on specific food crops. There was no full ban placed on any of the pesticides included.

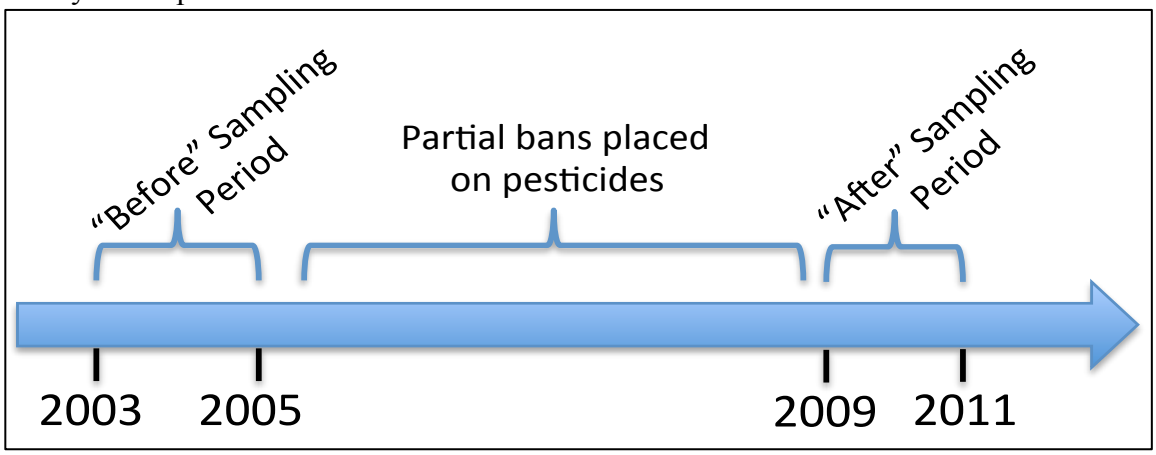


Figure 5: Timeline depicting the "before" and "after" sampling periods and the timespan during which partial bans were placed on pesticides. All management actions occurred following the first sampling time period.

Pesticides had highly variable results to the partial bans at both the individual site level (Figures 6 and 7) and at the rolled up, regional level (Figure 8). While many individual sites and individual pesticides show a response to the management actions (Figures 6 and 7), the overall result is that the partial bans have not worked at the regional scale across all pesticides (Figure 8).

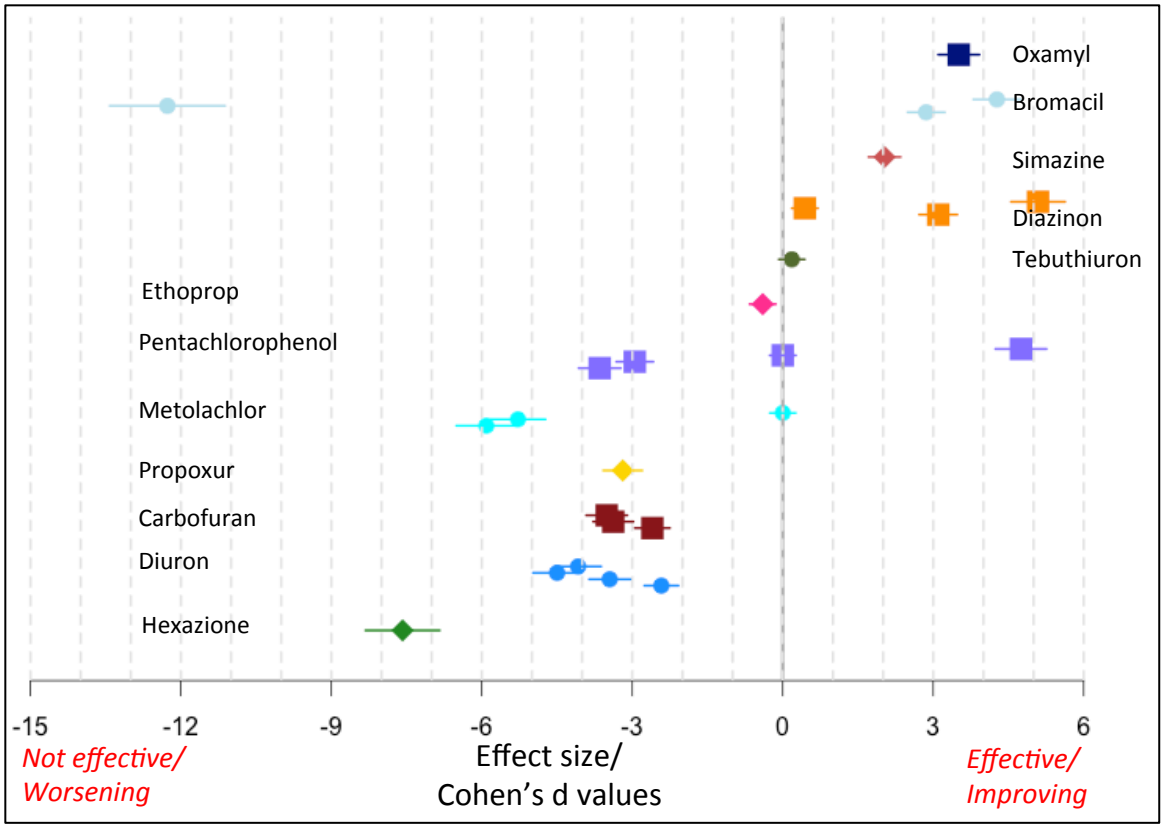


Figure 6: Cohen's *d* values for restricted use pesticides at individual sites. Each individual symbol represents an individual site and corresponds to the pesticide detected at that site. Six pesticides showed a positive response to management actions in at least one site, while the remaining pesticides showed either no change or an increase in the detection frequency. Overall, the sign of the effect (positive vs. negative) of a management action on a type of pesticide was similar despite the location sampled. The exceptions to this are Bromacil, Pentachlorophenol, and Metolachlor. Each color represents a different pesticide, and multiple markers for each pesticide indicate a particular pesticide was detected at more than one site. Error bars represent 90% confidence intervals.

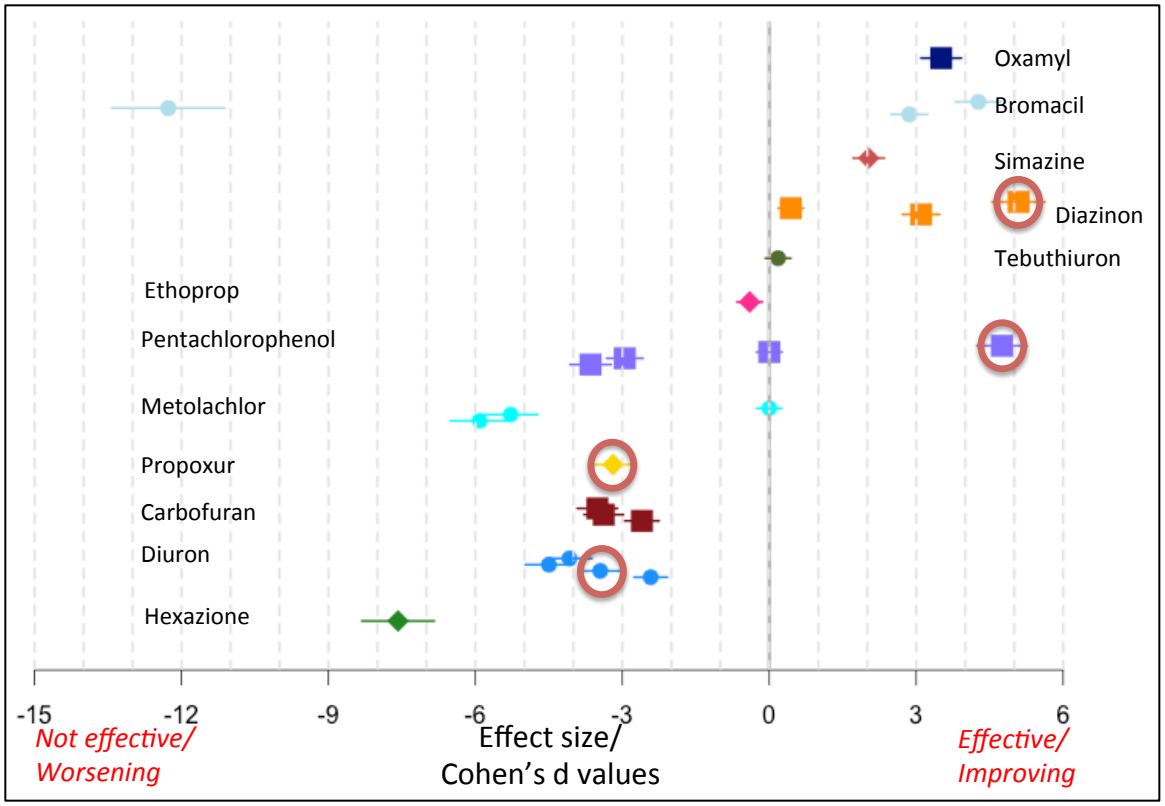


Figure 7: Cohen's *d* values for restricted use pesticides at individual sites. Red circles represent Thornton Creek, which is an urban site in Seattle. The other sites are primarily agricultural. Diazinon and pentachlorophenol detection rates were much lower following management actions, while Propoxur and Diuron detection rates increased. The management action for Diazinon was a ban on homeowner use in 2005, which was effective at reducing detection rates in all locations measured. Each color represents a different pesticide, and multiple markers for each pesticide indicate a particular pesticide was detected at more than one site. Error bars represent 90% confidence intervals.

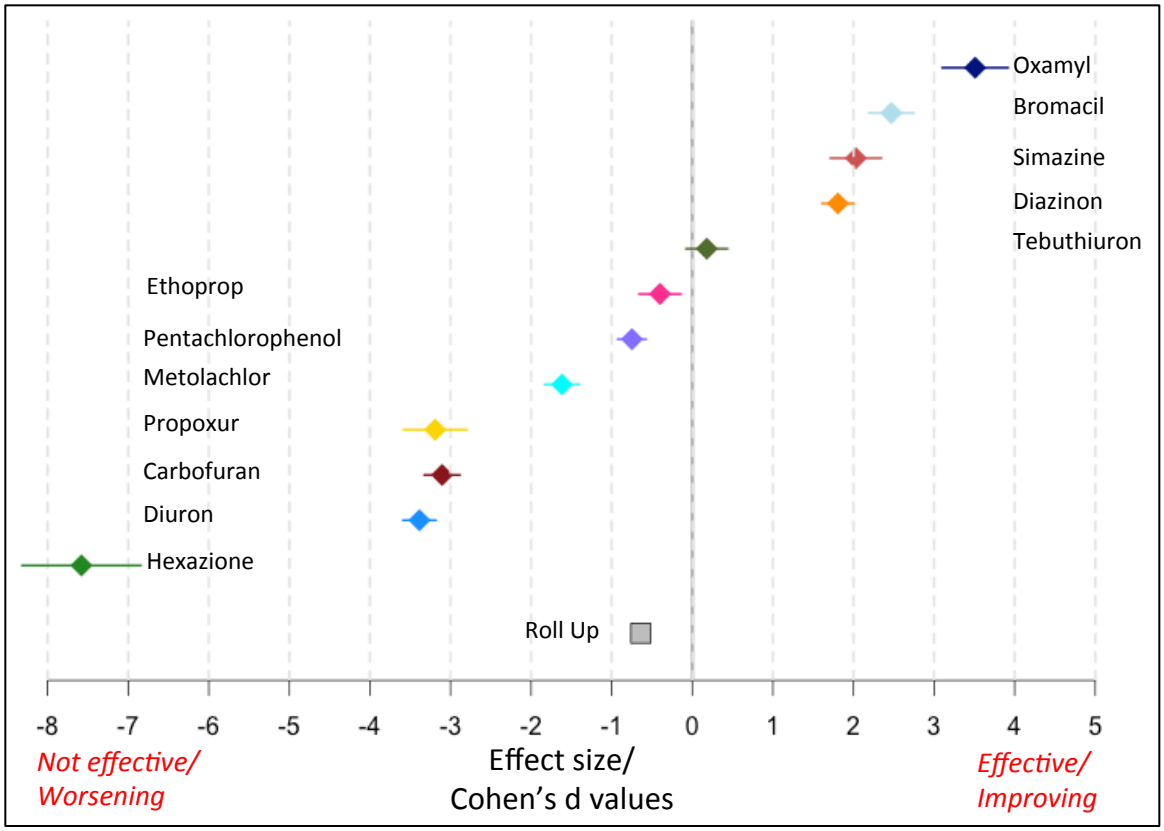


Figure 8: Roll up of Cohen's *d* values for each pesticide and the Cohen's *d* value for all pesticides at all sites. Four pesticides are showing a strong positive effect from management actions, one pesticide has not changed, and seven have a negative response to management actions. Overall, pesticides are not showing a positive effect from management actions. Pesticides are listed in the same order as in Figures 5 and 6. Error bars represent 90% confidence intervals.

<u>Meta-analysis vetting</u>

- Who attended meeting: Debby Sargent, and ~20 Ecology Staff from Environmental Assessment Program and other departments

<u>Comments from Debby Sargeant</u>:
Recommend putting the urban sites together (separate from the agricultural sites in the Skagit-Samish). Longfellow Creek is an urban site added in 2009 (check this). Early season data were not available for Longfellow, nonetheless, it still represents pesticide detections seen in urban areas (as does Thornton) and could be used for the post years.

For the urban sites, recommend looking at insecticides (like you did) diazinon, and the carbamate insecticides (carbaryl, methomyl, oxamyl, methiocarb). For herbicides look at dichlobenil (most frequently detected at a lot of sites and increasing), Mecoprop (MCPP) should decrease in later years; 2,4-D, triclopyr, prometon (should decrease); diuron and dicamba.

For the Skagit-Samish insecticides: diazinon, chlorpyrifos, malathion (big 3

organophosphate insecticides), ethoprop (another organophosphate they sometimes switch to); the carbamates: carbofuran, methomyl, and carbaryl. It would be good to look at the fungicide metalaxyl as well (fungicides are big in the NW). Herbicides: dichlobenil, 2-4,D, bromacil, tebuthiuron, and for Skagit because of potatoes (and exceedances in the criteria) metolachor.

These chemicals are on the WSDA list of Pesticides of Concern due to increasing concentrations seen in the pesticide study: dicamba, hexazinone, metolachlor, terbacil, and trifluralin. In addition dacthal (DCPA) is already on the list and seems to be increasing in detections and concentrations. It has even started to appear in some groundwater studies (this info from WSDA).

These are only three sites from a large area. They are representative of Seattle urban conditions and an example of an agricultural area in Skagit Co.

Phosphorous in Lakes

Description of Studies

The question of interest is whether the setting of TMDLs and their associated management actions reduced phosphorous in five lakes. TMDLs for phosphorous were set in five lakes in Puget Sound: Lake Fenwick and Lake Sawyer (King County); Lake Erie and Lake Campbell (Fidalgo Island); and Lake Ballinger (Snohomish County). A variety of management actions were set for these lakes to reduce the phosphorous loading to each lake and to address the existing phosphorous levels:

- Lake Fenwick: Prior to the study, a wet pond was created and aeration was done in the lake. In 1995, a hypolimnetic aeration system was introduced to the lake.
- Lake Sawyer: The final year of sampling in the report was 2001. In 1992, the management action was to divide the runoff into sub-basins with three sub-basins contributing about 64% of the phosphorus to the lake. In addition, a load allocation and a waste load allocation were set (Figure 9).
- Lakes Campbell and Erie: Management actions were: alum treatment, mechanical plant harvesting, watershed management plan, and performance monitoring.
- Lake Ballinger: Management actions were: rehab of Hall Creek and construction of two sedimentation basins in 1980 and construction of a hypolimnetic injection/withdrawal system in 1982.

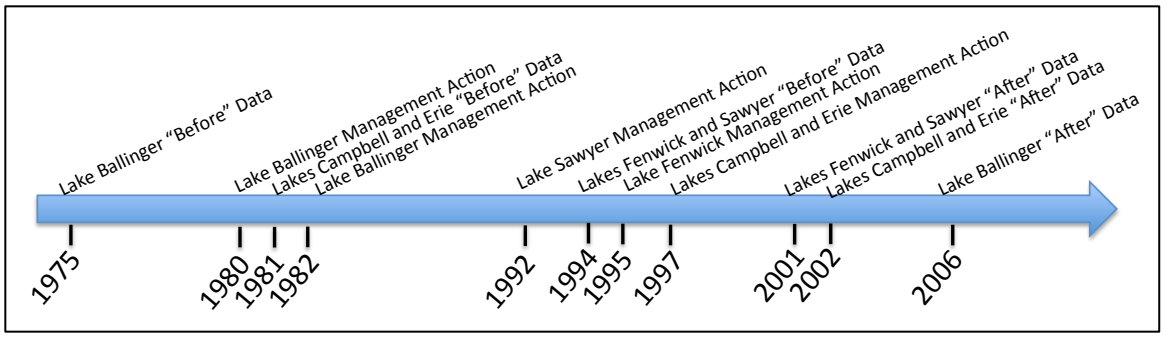


Figure 9: Timeline for management actions and collection of "before" and "after" data used in the meta-analysis of phosphorous levels in five lakes in Puget Sound.

Meta-analysis Results

The coefficient of variation was reported for Lakes Fenwick and Sawyer, and therefore was used in place of standard deviation. There was no information on standard deviation or variance provided for Lakes Erie, Campbell, or Ballinger; however, the range of values was provided in the final report. To estimate the standard deviation from the range, Equation 8 was used:

$$\frac{maximum\ value - minimum\ value}{4} \qquad \text{(Eq. 8)}$$

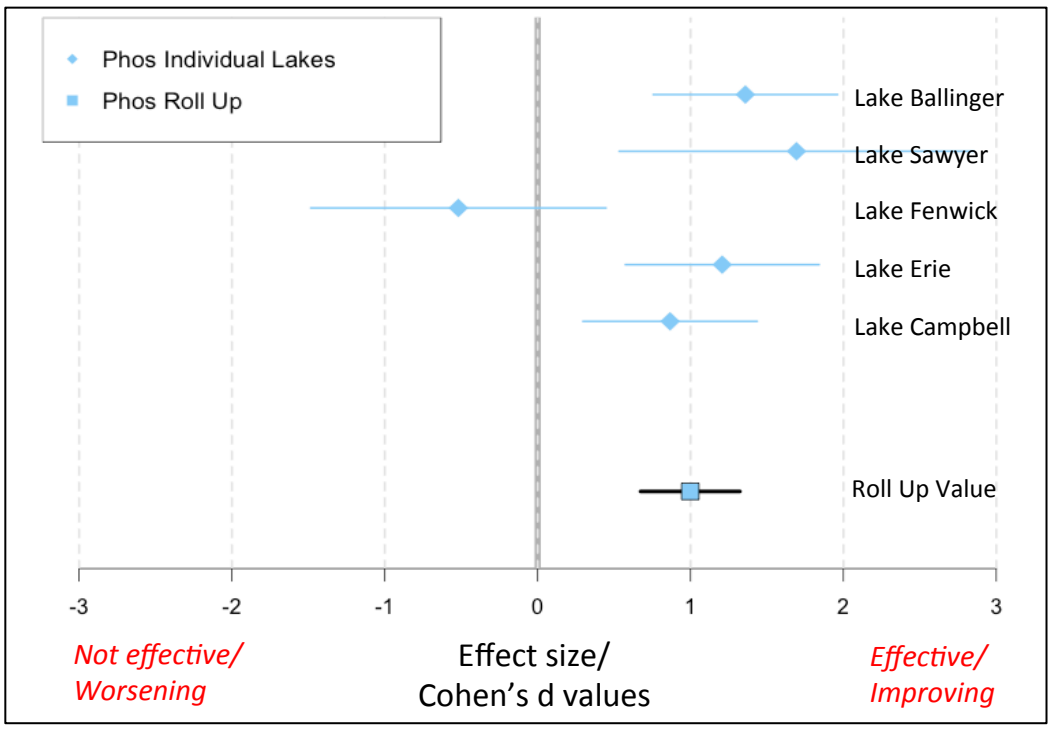


Figure 10: The overall roll up value indicates that actions to reduce phosphorous in lakes in Puget Sound are effective. The diamond markers represent individual lakes and the square marker shows the overall effect size for phosphorous in lakes in Puget Sound. Error bars represent 90% confidence intervals.

Meta-analysis vetting

- Who attended meeting: Maggie Bell-McKinnon and ~20 Ecology Staff from Environmental Assessment Program and other departments

Comments from Maggie Bell-McKinnon:

Some concerns about small sample size (N=5 lakes). No information about nutrient budgets or input sources and outflow. Other data might be available from Sally, Abella at King Co. for Cottage Lake with BMPs and Green Lake; Gene Williams at SnoCo Public Works for toxic algae study, not sure if did actions; Joan Hardy, Dept. of Health, funded by CDC; Dr. Jim Gawal, UW Tacoma, Spirit Lake and Waughop Lake, Tacoma with nutrient issues.

Fecal Coliform Bacteria in Liberty Bay, Kitsap County

Description of Study

The question of interest is whether the identification and correction of pollution sources led to levels of fecal coliform bacteria that are below regulatory limits.

In 1994, monitoring results determined that some freshwater and marine areas in Kitsap County had high levels of fecal coliform, which triggered the start of annual monitoring beginning in 1996 (Figure 11). Since that time, multiple assessments, management actions, and sampling programs have been implemented to clean up the area. Management actions from 1999 – 2004 included a Kitsap County Public Health District (KPHD) Pollution Identification and Correction (PIC) project and the city of Poulsbo had a project to clean up Dogfish Creek. Dogfish Creek clean up targeted onsite sewage systems, agriculture, and stormwater. From 2009 – 2014, management actions included a KPHD PIC Project Phase 2 and the city of Poulsbo did stormwater retrofit work.

In 2011, all marine stations were in compliance for water quality standards as per the KPHD data. In 2011, the WA Department of Ecology drafted a TMDL.

Monitoring of streams takes place at 24 sites; however, eight of these sites did not have complete enough datasets to be included in the meta-analysis. The excluded sites either had monitoring activities begin only recently or were measured sporadically and are not currently monitored. Monitoring of marine stations takes place at nine stations. All of these stations were included in the meta-analysis. Therefore, the total number of stations used in the analysis for Liberty Bay was 25.

Sixteen out of 25 sites were monitored prior to or during the initial management action of the KPHD/SSWM/City of Poulsbo Dogfish Creek Cleanup Project to target OSS, agriculture, and stormwater (1999 – 2004). Seven sites were added after this, but prior to the KPHD Liberty PIC Project and city of Poulsbo stormwater retrofits (2009 – 2014). Two sites were added in 2010, a year following the initiation of the PIC Project and the stormwater retrofits.

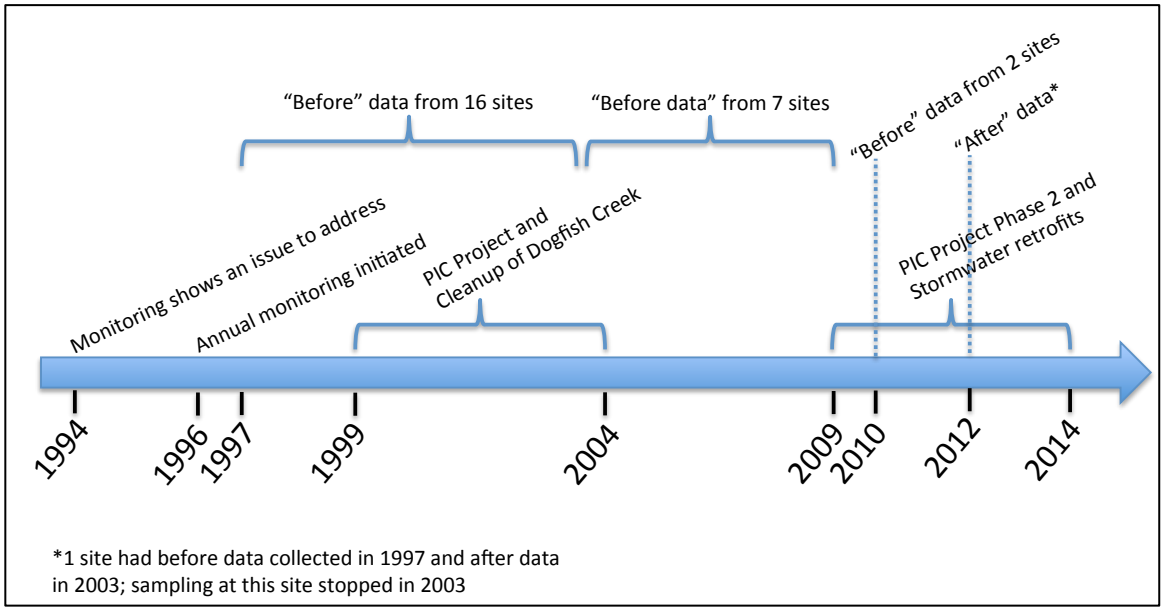


Figure 11: Timeline for management actions and the collection of "before" and "after" data used in the meta-analysis.

Meta-analysis Results

Cohen's *d* values were calculated in two ways: using the geometric mean of bacteria colony counts and the percent of times a site had counts that exceeded the regulatory limit of 100 cfu/100mL. When using the raw count data, the geometric mean and geometric standard deviation were calculated. Because the percent exceedance was used as the before and after data, Equation 6 was used to calculate the standard deviation.

Overall, management actions in Liberty Bay to reduce fecal coliform bacteria are working (Figures 12 and 13). There is greater variability in the results using the geometric mean and geometric standard deviation (Figure 12) because there is such a great amount of variability in the raw data. There is less variability in the exceedance data, and therefore the results are easier to interpret (Figure 13). We recommend using exceedance data because of the high variability in the bacteria counts and these data are what regulators use for management decisions.

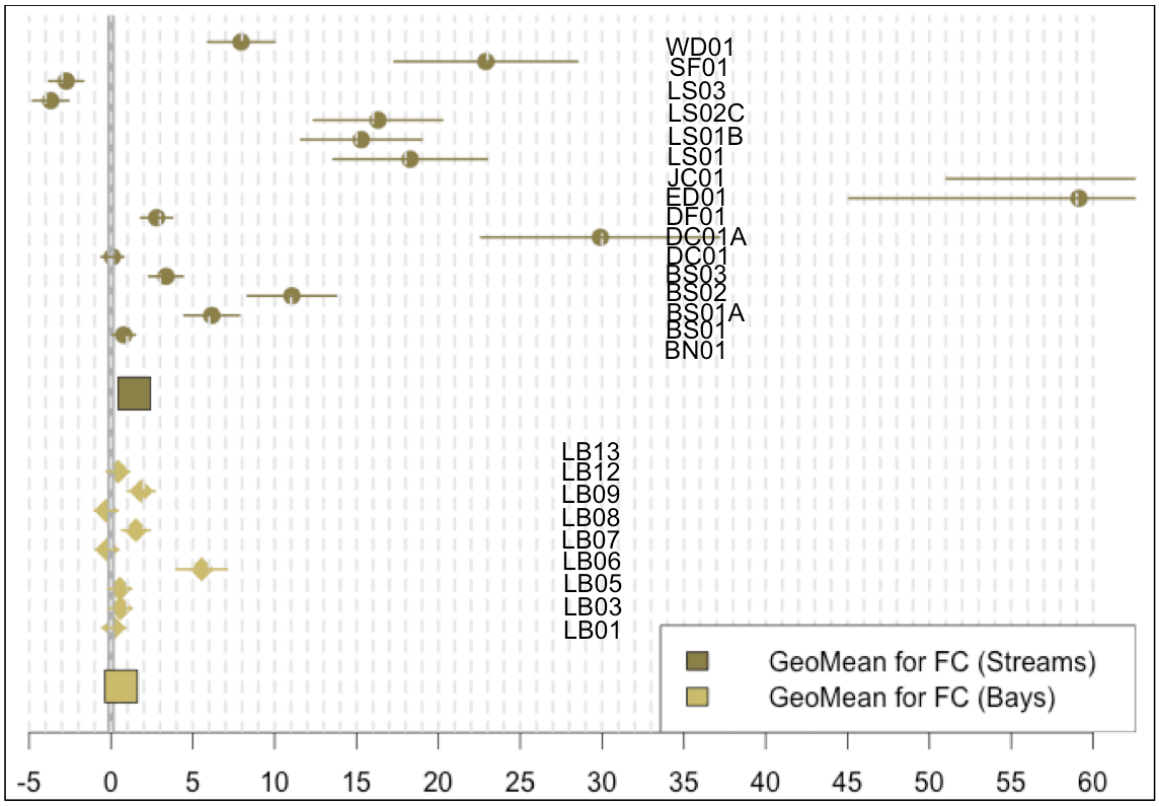


Figure 12: Cohen's *d* values for the effect size of management actions on fecal coliform bacteria counts. Overall, there is a small positive change in the geometric mean of fecal coliform counts from management actions in both fresh and marine waters in Kitsap County. There is a greater amount of variability in the strength of the response in freshwater sites compared to the marine sites. Each round or diamond shape represents an individual site and the large squares are the roll up values of that particular set of sites. Error bars represent 90% confidence intervals.

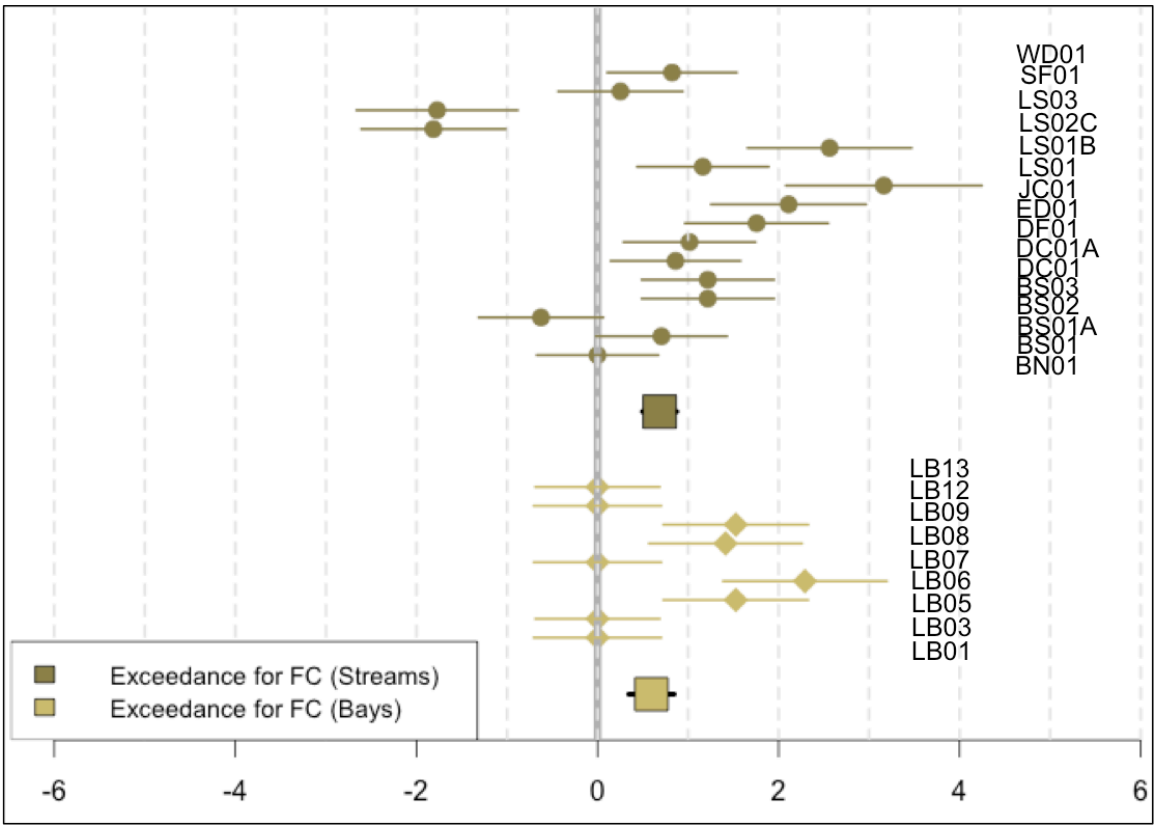


Figure 13: Cohen's *d* values for the effect size of management actions on fecal coliform bacteria exceedances. Overall, fecal coliform exceedances are decreasing in response to management actions in both fresh and marine waters in Kitsap County. Freshwater sites tend to have a stronger response than marine sites; however, the marine sites all has zero exceedances in the most recent sampling year. In addition, the marine sites that show no change were all sites that had zero exceedances in both the start and end years. Each round or diamond shape represents an individual site and the large squares are the roll up of that particular set of sites. Error bars represent 90% confidence intervals.

Meta-analysis vetting

- Agency and contacts:
  - Chris May and Mindy Fohn: Kitsap County Public Works
  - Stuart Whitford: Kitsap County Public Health District

Comments from Mindy Fohn and Stuart Whitford:

Some of the marine sites are downstream from the freshwater sites that were targeted for clean up, so connections in the data between those sites may be possible.

There is ongoing discussion surrounding the use of the geometric mean vs. exceedances. There is agreement that the meta-analysis approach is good and it is anticipated that it will be used for other projects in this location; however, we are still discussing specifics with our contract statsticians.

Olympic Sculpture Park Restoration

Description of Study

The question of interest is whether the creation of a pocket beach and a habitat bench increase fish diversity and benthic invertebrate and insect richness following removal of shoreline armoring.

The Seattle Art Museum made plans to install the Olympic Sculpture Park along Seattle's waterfront in 2007. The Museum staff was aware of potential plans to redo the Seattle seawall at a later date, and instead of experiencing major disruption during that project after the Park was installed, they decided to restore the shoreline during installation of the Park. To do this, a pocket beach and a habitat bench were created with the intent to increase the diversity and number of fish and invertebrates. Initial measurements were made in 2005, two years prior to the installation of the Park. Subsequent measurements were made in 2007, 2009, and 2011. Monitoring was performed using the same methods each year, allowing for calculations of both organism density and species richness.

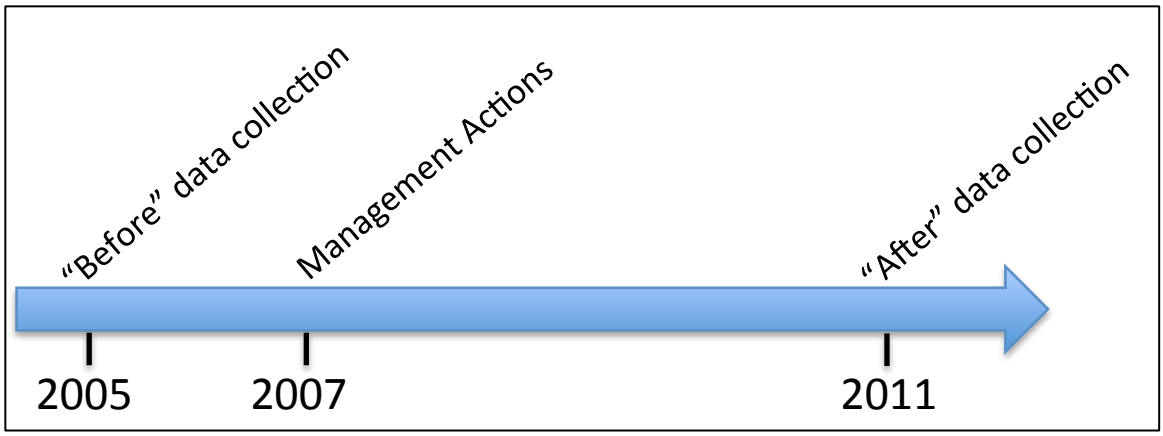


Figure 14: Timeline for collection of "before" and "after" data for the meta-analysis of the Olympic Sculpture Park habitat restoration project.

Meta-analysis Results

Density was calculated for total fish, juvenile salmon, and larval fish. Means were calculated using the number of transects used in each year (48). Data at different depths were pooled at each site. Four sites were compared: habitat bench, rip rap, pocket beach, and seawall.

Species richness was calculated for epibenthic invertebrates and insects. Seven transects were performed at each site during each timepoint for each year. Species richness was calculated for each year, using the seven transects as replicates. Four sites were compared: habitat bench, rip rap, pocket beach, and seawall.

Overall, fish densities did not increase (Figure 15). This was not an unexpected result, however, because this was a small-scale project. Epibenthic richness showed a dramatic increase for all four sites. Terrestrial insect species richness did not show an increase (Figure 16).

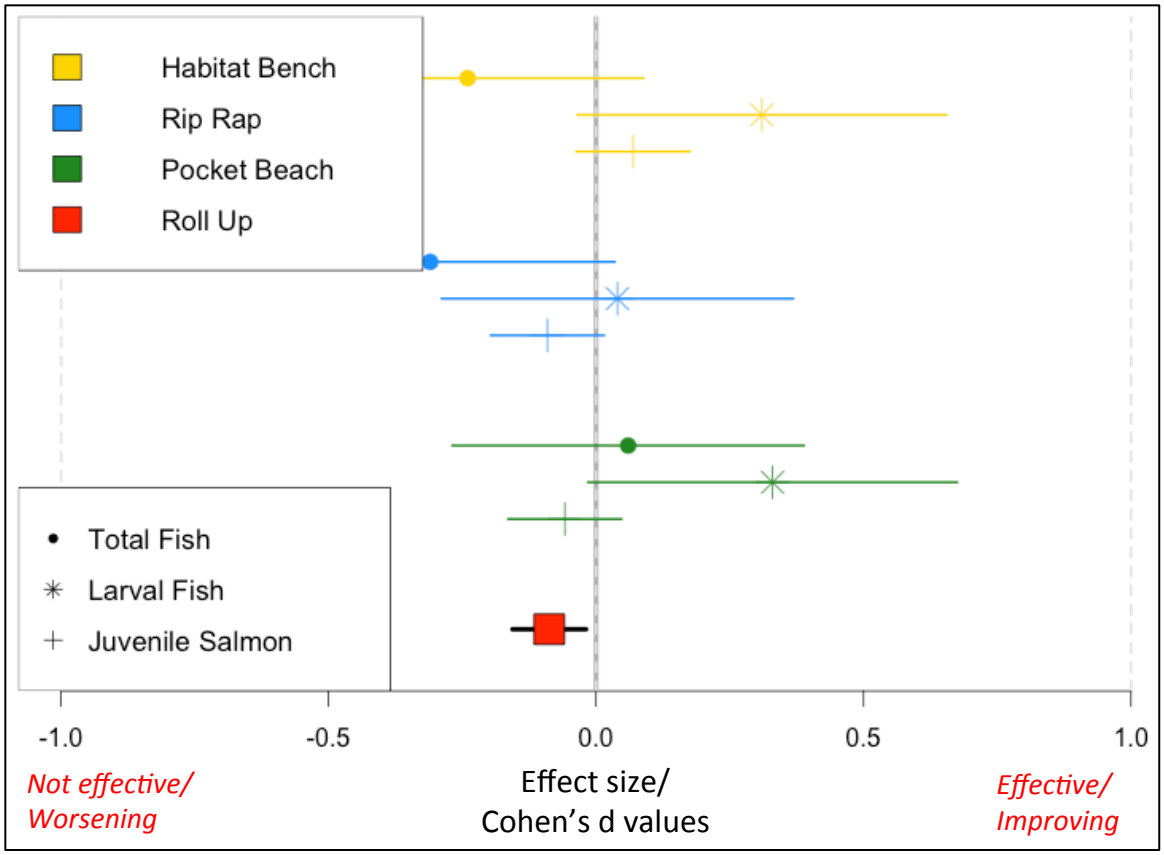


Figure 15: Cohen's *d* values for total fish, larval fish, and juvenile salmon densities at each study site. Overall, fish densities are not increasing in response to the management action; however, this is not an unexpected result. Fish density was not necessarily expected to increase because this was a small-scale restoration site and therefore is a reflection of interannual variability rather than differences between sites. The data are grouped by the three sites: habitat bench, rip rap, and pocket beach. Fish counts were not done at the seawall site. There is a value for the effect of management actions three levels of specificity of fish density. The responses in the total density of fish, the density of larval fish, and the density of juvenile salmon were evaluated. The roll up is provided at the bottom of the plot. Error bars represent 90% confidence intervals.

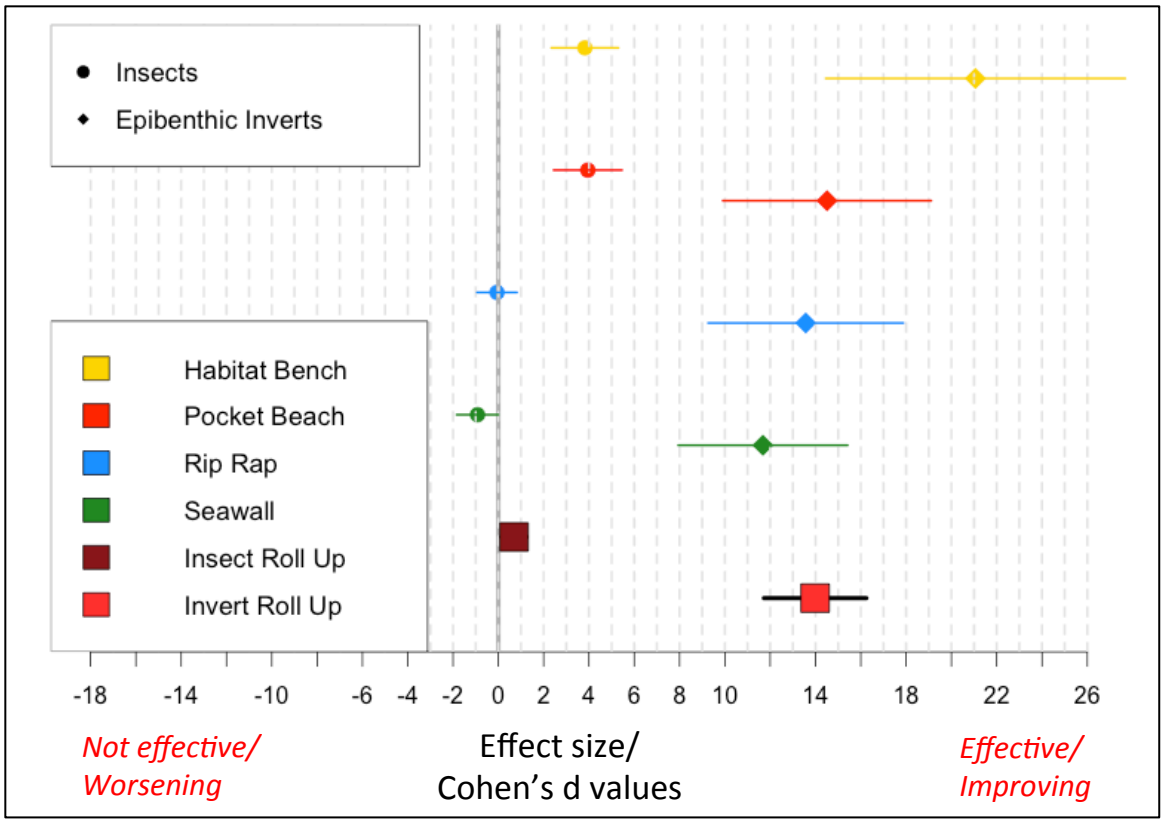


Figure 16: Cohen's *d* values for the species richness of insects and epibenthic invertebrates at each site and the roll up value for each species group. Insects and epibenthic invertebrates responded the strongest at the habitat bench and pocket beach sites. Epibenthic invertebrates also showed a strong response at the rip rap and seawall sites, while insects showed no change and a negative effect, respectively. Overall, there was a very small positive effect on insect richness as a result of the management actions. In contrast, there was a strong positive effect at all sites for epibenthic invertebrate species richness. The data are grouped by the four study sites: habitat bench, pocket beach, rip rap, and seawall. Error bars represent 90% confidence intervals.

Meta-analysis vetting

- Agency/ organization: University of Washington (School of Aquatic and Fisheries Science)
- Contact: Jason Toft

Comments from Jason Toft

Fish density: Should be noted that wouldn't necessarily expect fish densities to overall be increased by a small-scale restoration site, this more reflects interannual variability instead of site differences. Comparing across sites within each year is I think more appropriate, and is how I analyzed the data (can also do interaction with site x year); these results also have interannual variability (see reports).

Liver Lesions in English Sole in Eagle Harbor

Description of Study

The question of interest is whether the clean up and capping of contaminated sediment resulted in reduced sublethal effects to English sole.

Sampling for biological effects of PAH exposure in English sole in Eagle Harbor (on the east side of Bainbridge Island, WA) began in 1983 (Figure 17). In 1987, the site was declared a Superfund site. In 1993, a sediment cap was put in place to control the source of PAHs to the area. In 1990, a groundwater extraction and treatment system was constructed, and in 2000, a sheet pile wall was put in place to control the seeps of free creosote from subtidal and intertidal sites. From 2000 – 2002, the original sediment cap was extended and the original cap size was increased by 15 acres.

To assess the effectiveness of the management actions, four biomarkers were studied: the level of fluorescent aromatic compounds (FACs) in bile, the upregulation of CYP1A, the formation of DNA adducts in liver tissue, and the number and type of liver lesions. CYP1A was discontinued during the study and data were not included in the meta-analysis results because it was determined that it was not specific enough to only PAH exposure to be a good indicator of the effectiveness of the management actions. Data were not corrected for fish age, sex, or size.

Three wavelengths were used to analyze FACs in bile: one specific to naphthalene, one specific to phenanthrene, and one specific to benzo(a)pyrene. Data used in the meta-analysis were protein-corrected. Four types of liver lesions were reported in the meta-analysis: nuclear pleomorphism/ hepatocellular megalocytosis (NP/MH), nonneoplastic proliferative lesions (PROLIF), putatively preneoplastic foci of cellular alteration (PRENEO), and neoplasms (NEO). DNA adduct analysis was discontinued in 2004.

This dataset has a very long and consistent sampling history. In addition, there were a variety of management actions that occurred during a block of time in the monitoring period. As a result, the initial measurements in 1993 were used as the 'before' data. The management actions ended in early 2002; therefore, the late 2002 monitoring data was combined with all subsequent years of monitoring results until 2013, which is the most recent year of data. It was decided to combine the years following the management actions due to variability within the dataset and to provide a better representation of the effect of the management actions on each variable.

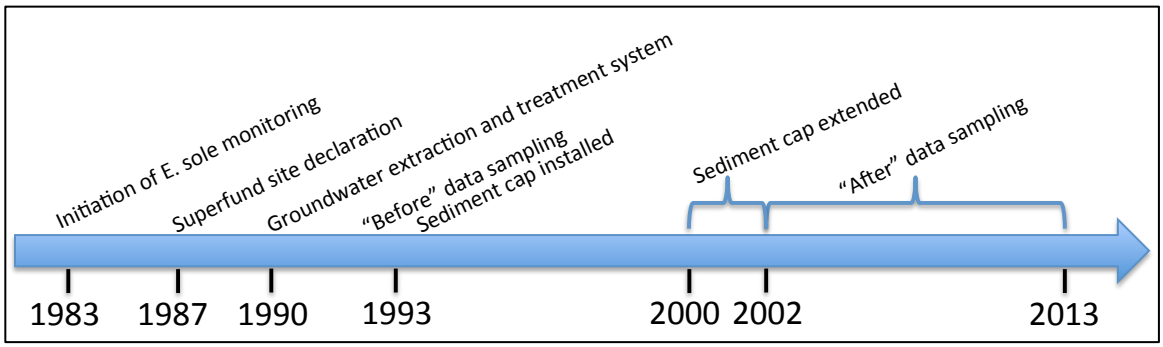


Figure 17: Timeline of management actions on Eagle Harbor and the collection years for data that were included in the meta-analysis.

Meta-analysis Results

For DNA adducts, the meta-analysis used data from September 1993 and 2002 to 2004. For liver lesions and bile FACs, the meta-analysis used data from September 1993 and 2002 – 2013. Overall, all variables showed a strong response to management actions (Figure 18). The only two variables to not show individual responses to management actions were the NEO lesions and the PRENEO lesions. All of the other individual variables showed a strong positive response to management actions.

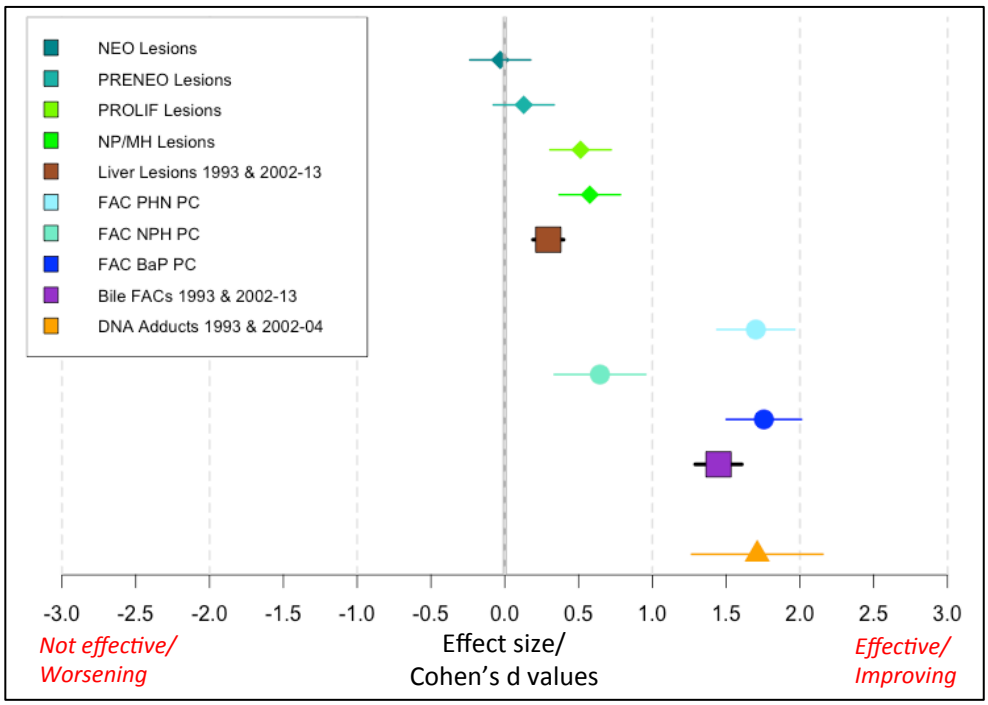


Figure 18: Cohen's *d* values for biological effects in English sole. Overall, management actions were effective at reducing the effects of PAHs in English sole in Eagle Harbor. The upper five data points represent data for liver lesions; the green diamonds are various types of liver lesions, and the brown rectangle is the roll-up value. The blue circles represent the decline in the level of FACs in bile, and the purple rectangle represents the roll-up value for FACs in bile. The orange triangle shows there was a strong decline in the concentration of DNA adducts. Error bars represent 90% confidence intervals.

Meta-analysis vetting

- Agency/ organization: NOAA, NWFSC
- Contacts: Mark Myers, Lyndal Johnson, Tracy Collier

Comments from Mark Myers and Tracy Collier**:**

Do the results make sense?

Yes, with the caveat that the improvement (reduction) in liver lesion prevalence since 2002 is somewhat muted by the brief, single point increase in prevalence (to 17%) in 2011. Without that data point, the improvement would have been far more dramatic. Note also that the comparison points for the liver lesions were the Sept. 1993 data (pre-capping), as compared to the mean of the prevalences since 2002.

There has been some evidence of erosion of the sediment cap in the area near the ferry terminal, which could increase exposure to PAHs, and there is also evidence of failure (rusting through) of the sheet pile wall surrounding the shore-side of the former Wyckoff creosoting facility, which would also serve to increase exposure of English sole to PAHs.

There is the possibility that sampling of English sole of different mean ages (N was usually 60 at each sampling event) might influence the overall liver lesion prevalence at each sampling point, since some of the lesions detected are highly associated with increasing age. However, the mean ages among the chronological sampling points used in the meta-analysis suggested that these differences were relatively small.

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Appendix 3. Effectiveness Monitoring Matrix for the Action Agenda

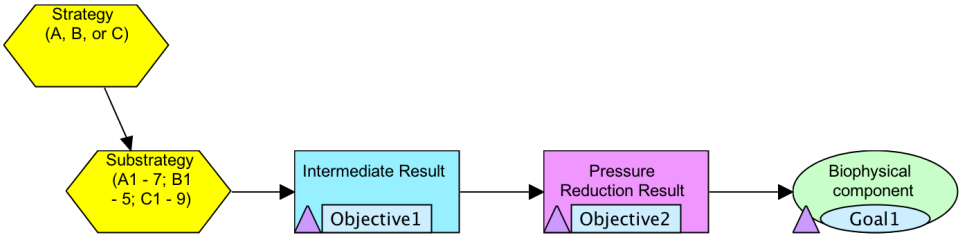
Prepared by

Constance Sullivan, Friday Harbor Laboratories, University of Washington

Leska S. Fore, Puget Sound Partnership

Scott Redman, Puget Sound Partnership

Ken Dzinbal, Puget Sound Partnership



Effectiveness Monitoring Matrix for the Action Agenda

Constance Sullivan (University of Washington, Puget Sound Institute)
Leska Fore (Puget Sound Partnership)
Scott Redman (Puget Sound Partnership)
Ken Dzinbal (Puget Sound Partnership)

Background

Puget Sound is the second largest estuary in the United States, and is part of the EPA's National Estuary Program. It is one of 28 estuaries in the United States under this designation. Each estuary in this program has an associated plan for recovery (a Comprehensive Conservation Management Plan, or CCMP) and an organization or agency to lead the recovery. In the case of Puget Sound, the Puget Sound Partnership is the backbone organization to support recovery. Its CCMP, known as the Action Agenda, details actions with partners around the state and at the federal level regarding how to coordinate efforts and what actions are necessary to achieve recovery of the biophysical portion of the ecosystem while maintaining a viable socioeconomic aspect (Puget Sound Partnership 2012).

First drafted in 2008, the Action Agenda provides details on mechanisms for not only how to recover the ecosystem via restoration activities, but also how to coordinate those activities. It also recommends how to use existing methods to implement restoration and management actions, and highlights which new plans and policies need to be created. The Action Agenda has undergone three revisions and many actions in it are underway, and there is a need to assess the effectiveness of actions. As a result, a matrix was developed to provide insight as to which substrategies can be addressed via assessment of their effectiveness. The basis for the matrix is the 2012/2013 Action Agenda; at the time of the development of this matrix, the 2014/2015 Action Agenda was not finalized.

Why the effectiveness monitoring matrix was developed

The effectiveness monitoring matrix complements the Action Agenda and will support adaptive management as actions are implemented and evaluated for their effectiveness (Redman et al. 2013). The matrix provides an approach for use of existing data to evaluate the effectiveness of the substrategies of the Action Agenda. It also aids in the identification of the types of data that are still needed to evaluate the effectiveness of actions. State and federal agencies, tribal governments, local governments, representatives of the business and environmental caucuses, and other interested partners who are implementing the Action Agenda will be able to use relevant pieces of the matrix as needed to evaluate whether the strategies and substrategies are effective.

The matrix provides a stepwise approach to evaluate the impact of actions on reducing stressors and improving ecosystem condition (See Table 1 for definitions). The effectiveness of actions and strategies can be evaluated:

- at the stage of implementation

- by measuring the reduction of stressors, or
- by assessing a change in an ecosystem endpoint.

As a result, multiple parties may use the same portion of the matrix, and apply different datasets specific to their location.

The matrix pertains specifically to Action Agenda Categories A, B, and C (Table 2). These categories detail the specific actions for ecosystem recovery. Categories D and E pertain to management coordination and financial strategies, and are not addressed in the matrix since they are not expected to lead to immediate ecosystem outcomes.

The current version is the first iteration of the matrix, and is ready for use. It is, however, designed to be modified as needed.

Table 1. Definitions for terms in the Action Agenda and the effectiveness monitoring matrix.

Term	Definition
Strategy	Describes the overall, long-term directions and approaches that are needed for protection and recovery.
Substrategy	Describes the overall, long-term directions and approaches that are needed for protection and recovery.
Near Term Action	Important new initiatives, critical next steps in ongoing work, and targeted efforts to improve implementation of ongoing programs or ensure these programs have adequate resources to deliver on their objectives.
Performance Measure	Metrics for determination of whether an NTA is complete.
Intermediate Result	Desired or expected results that would follow from the implementation of strategies and the completion of actions.
Pressure	Direct effects to the things we care about by delivery of stresses to ecosystem components.
Stresses	Delivered by pressures and experienced by ecosystem components.
Target	Targets articulate the conditions we expect to achieve by 2020. They provide more precision for the recovery goals so as to evaluate whether we're on the desired trajectory.
Indicator	In this context, they are used to define a healthy Puget Sound ecosystem, to evaluate progress towards meeting the recovery goals, to evaluate and alter management strategies, and as the basis for reporting back to the public.

Term	Definition
Strategic Initiative	Focused strategic sets of related actions where we can address significant problems in a way that will create meaningful improvements for Puget Sound.

Table 2. Action Agenda Categories and corresponding title.

Action Agenda Category	Category Title
A	Upland and Terrestrial
B	Marine and Nearshore
C	Reduce and control the sources of pollution to Puget Sound
D	Strategic leadership and collaboration
E	Funding strategy

How to use the effectiveness monitoring matrix

Within the matrix, each row represents one of the 74 substrategies in A, B, and C, and each column represents the information needed for determination of the effectiveness of each substrategy (Excel table available on project web site or upon request). Information in each cell represents the type of data that could be used to evaluate whether the substrategy is having its intended impact. The content of each cell varies depending on the level at which the substrategy is being implemented (i.e., local, city, watershed, state level). The details are not exhaustive, and are to be adapted as needed.

The descriptions below (Table 3) provide details as to how to use the matrix. Each column heading is defined so that a user will understand how to populate the appropriate rows. The user should keep in mind that the purpose of the table is to determine which actions are effective, and how to determine if the substrategy is effective. The goal is to match the information in all rows to the effectiveness questions. The rows in the matrix are to be filled out from left to right; shading of column titles indicates that these columns are related to one another. There may be similar datasets or plans or information that is used for a few substrategies; each cell does not need to be unique.

Table 3. Categories in the effectiveness monitoring matrix, definitions for each, and instructions as to how to fill out each cell.

Element	Definition	How to fill out
Category	Category of the Action Agenda	Fill in with A, B, or C
Category Title	Title of the category from the Action Agenda	Fill in with the title of the category
Number	Number of the substrategy	Fill in with the number of the substrategy
Title	Title of substrategy	Fill in with the title of the substrategy
PSEMP monitoring?	Does PSEMP monitoring support the data needs for tracking this substrategy? This information pertains specifically to PSEMP and allows the user to sort for relevance to PSEMP.	Fill in with a yes or no
Can implementation be monitored?	This question allows the user to sort to find which actions are relevant to implementation only.	Fill in with a yes or no
Can pressure reduction be monitored?	This question allows the user to sort to find out which actions are relevant to pressure reductions in Puget Sound.	Fill in with a yes or no
Can outcomes be monitored?	This question is specific to ecological outcomes, and has a long-term outlook. Not all substrategies focus on projecting to a long-term outcome, and this question allows the user to sort for long-term ecological relevance to a substrategy.	Fill in with a yes or no
Effectiveness questions	Fill in with questions that address whether or not the substrategy was effective. The data collected will answer these questions.	• To write an effectiveness question, two parts are needed: the output that is targeted, and the management action that was measured for effectiveness. • Not all substrategies will have an effectiveness question that can be asked; in these cases, fill in with n/a for 'not applicable.' If this cell is labeled with 'n/a,' all other cells in the row are also labeled as 'n/a.'
Additional effectiveness questions	For many substrategies, multiple effectiveness questions can be asked; this column is for additional questions. Subsequent cells in this row will not necessarily pertain to additional questions.	To write an effectiveness question, two parts are needed: the output that is targeted, and the management action that was measured for effectiveness.
Are outcomes biophysical or socioeconomic?	The choices for this answer refer to whether or not an outcome is tracked by performance management (socioeconomic) or by a scientific monitoring program (biophysical).	Fill in with either biophysical, socioeconomic, or both
What effectiveness programs exist?	Existing programs that outline specific effectiveness monitoring approaches that can address a particular substrategy.	• Provide a list of existing programs that address effectiveness questions relevant to that particular substrategy • If none exist, leave blank

Element	Definition	How to fill out
What data/ information/ program(s) exist(s)?	Datasets, programs, regulations, etc. that support the monitoring of the substrategy.	• Datasets: these can be in the form of agency reports, proofed spreadsheets from data authors, primary literature, etc. • Programs: agency programs that have developed methods to address the effectiveness monitoring of a particular substrategy • Policies/ regulations: relevant statutes or policies for a particular substrategy. This cell needs to be specific to the location or organization implementing a strategy or substrategy, as some statutes and policies are written at the state level and are implemented at the local level. • Note: this cell will become fairly extensive, so a separate Excel sheet or database may be needed depending on the data available
Are more studies or programs needed?	Studies that are needed to address the effectiveness question may already exist and can be used in this matrix.	• Current set(s) of available studies that complete the substrategy • Existing programs that address the substrategy. • If none exist, list any necessary studies to answer the substrategy, or list any programs that are needed to ensure the substrategy is addressed.
Could an analysis of existing data answer the effectiveness question?	Are the data gathered for this substrategy relevant for a meta-analysis? Data will need to contain measurements before and after a management action for use in a meta-analysis.	Fill in with a yes or no
Rate the quality/ quantity of available data/ information/ programs available to answer the effectiveness question	Rate the ease with which the effectiveness question can be addressed using current datasets.	0: No data were found 1: Very little data were found 2: Some data were found; however, more may be required to fully answer the question 3: Enough data were readily found to answer the question → Note: these data questions were ranked based on a search for data that was not exhaustive; more data may exist and were not found by the authors of this matrix
Implementation (near-term)	List of the actions that need to occur for this substrategy to be fully implemented. This is a short-term time scale.	• This cell can include: Programs that need to be created and implemented (i.e., monitoring programs, outreach programs, etc.), areas that need special designation (i.e., MPAs, etc.), • Regulations that need to be created and implemented, and/ or • Plans that need to be created and implemented

Element	Definition	How to fill out
Data needs for Implementation	List of data that are needed to complete the actions for implementation that were provided in the corresponding "Implementation (near-term)" cell.	This cell can include datasets that do not exist as well as existing datasets that are needed for implementation.
Pressure Reduction/ Diagnostic monitoring (medium-term) (From PSPA)	List of pressures that need to be reduced or maintained to see ecosystem improvement with respect to each substrategy. This is an intermediate-term time scale.	Using the 2014 Pressure Taxonomy (Stiles et al. 2014; personal communication from K. Stiles 2014), list the pressure sources that are associated with that substrategy.
Data needs for Pressure Reduction	List of the data that are needed to monitor the progress of stress reduction on the substrategy.	This cell includes datasets that do not exist as well as existing datasets that are needed to address pressure reduction.
Ecological Outcomes (long-term)	List of the ecological outcomes of the substrategy. This is a long-term time scale.	For example: What is the desired habitat condition? What are the species population targets? What are the water quality goals?
Data needs for Ecological Outcomes	List of the data needs to evaluate whether or not all targets have been achieved.	• This cell includes datasets that do not exist as well as existing datasets that are needed to measure the outcome • These may or may not be the same as the data needed for implementation and pressure reduction, though there will most likely be some overlap
What component(s) is/ are targeted?	List of components that are targeted.	The component list is from the list provided by the biophysical indicator project (O'Neill et al.)
Other outcomes	List of any outcomes that are not specific to the ecosystem targets.	These will include any restoration plans, regulations, etc. that were developed as part of the strategy or substrategy.
Indicators	List of indicators that provide input as to whether or not the strategy or substrategy was successfully (or not) completed.	Indicators can be shared by more than one strategy or substrategy, and there can be multiple indicators for each. Indicators can be proposed for any level (i.e., at the strategy, substrategy, pressure reduction, and component level). These are indicators that are specific to effectiveness monitoring efforts, and are not specific to the current Vital Signs indicators or any indicators that will be proposed by the Indicator Evolution project (O'Neill et al., in prep), though there may be overlap between the indicator lists. In the Miradi results chains, effectiveness indicators will be labeled as "EFF-xx." "xx" represents a number, and each indicator will have a unique identification number.

Summary of Findings

The Action Agenda contains 74 substrategies; we were able to provide at least one effectiveness question for 65 substrategies. Of the nine substrategies that did not have an effectiveness question asked, four were from Category A, four were from Category B, and one was from Category C. The remainder of this section will refer to the 65 substrategies that have an associated effectiveness question only.

Datasets were searched for using Google, searches on agency websites, and PSEMP monitoring inventories that were current on the PSEMP website as of June 30, 2014. Searches were not done intensively; a maximum of 30 minutes was spent on each substrategy. If data were easily located and there appeared to be sufficient data to readily answer the effectiveness question, the substrategy received a ranking of 3 in column P. Twenty-five substrategies received a ranking of 3. A rank of 2 means that there are data available, and either more data need to be collected or a more in-depth search could result in the data needed to address the question; 27 substrategies fit these criteria. Thirteen had either no datasets or very little data were available. Of the substrategies that are readily addressed with current datasets and/ or information (i.e., received a ranking of 3), six were from Category A, four were from Category B, and 15 were from Category C.

All of the substrategies that have an associated effectiveness question can be monitored for implementation. Of these, the pressure reduction can be monitored in 48, and ecological outcomes can be monitored in 34. Therefore, 17 substrategies can be addressed on a short time scale in comparison to the other substrategies that require measurement of the pressure(s) reduction and ecological outcomes to be analyzed for completeness and success.

Effectiveness programs and datasets exist for twelve out of the substrategies that can be addressed via an effectiveness question. Some programs contain mechanisms for designing effectiveness studies and for implementing data monitoring to determine effectiveness (i.e., WA Department of Ecology's Effectiveness Monitoring Program for TMDLs for substrategy C9.1 and Tetra Tech's effectiveness monitoring protocols for substrategy A6.1). Others contain studies of effectiveness that can be used as models for similar studies in that particular substrategy (i.e., WDFW and NOAA monitoring of Eagle Harbor for PAHs in English sole and the effectiveness monitoring of creosote removal in Jefferson County for substrategy C9.2). The effectiveness question of other substrategies can be addressed using programs that measure the effectiveness of local citizens' actions (i.e., Puget Sound Starts Here can assess effectiveness in substrategy C6.1).

Link to Miradi Results Chains

Results chains visually depict the steps for ecosystem recovery and show linkages between strategies, goals, and the information needed to achieve the goals. Results chains were developed for the 2012 Action Agenda to track the necessary steps to

track recovery. Results chains are relatively straightforward, and contain four elements: the strategy(ies) and relevant substrategy(ies), intermediate result(s), pressure reduction, and the component(s) the strategy or substrategy targets (Figure 1).

PSP developed results chains using the software Miradi (version 4.1.2). Miradi is the software used by the Conservation Measures Partnership in the Open Standards for the Practice of Conservation (Open Standards). Open Standards is the framework under which the Puget Sound Partnership is developing its adaptive management and recovery planning strategies. The Miradi software is used to visualize and track recovery strategies, actions, targets, and results.

The effectiveness monitoring matrix details how the Action Agenda's strategies and substrategies can be effective in ecosystem recovery, and therefore can use existing results chains. The results chains do not contain all of the detail that is in the matrix; however, they visually depict the matrix and show linkages between different columns.

Results chains are read left to right (Figure 1). On the left-hand side of the diagram, in a yellow hexagon, is a strategy and the associated substrategy or substrategies. Next to the strategy and substrategy(ies) are intermediate results in blue boxes. These represent the desired or expected results from implementation of the strategy and substrategy(ies). They are linked to purple boxes, which represent the pressures that are targeted for reduction. These are from the Pressure Taxonomy (Stiles et al. 2014; personal communication from K. Stiles 2014). The components are the ecosystems and associated food webs that are targeted for recovery. The pressures listed in the purple boxes need to be reduced in order for the component to be restored.

In addition to the main parts of the results chains listed above, additional details can be provided. Light blue boxes in the strategy, substrategy, intermediate result, or pressure reduction are labeled as 'objectives,' and are the desired outcome of the part of the results chain they are related to. They are derived from the Performance Measures in the Action Agenda. Light blue ovals in the green components ovals are labeled as 'goals,' and represent the future desired condition of the component. They are derived from the 2020 Targets and Interim Targets in the Action Agenda. Purple triangles represent indicators, and can be associated with any part of a results chain. They are the measures of the condition or status of the portion of the results chain they are associated with. Objectives, goals, and indicators can be represented in various parts of the results chain, and there can be more than one of each type for a single section of the results chain, or none may be needed for a particular section in the results chain.

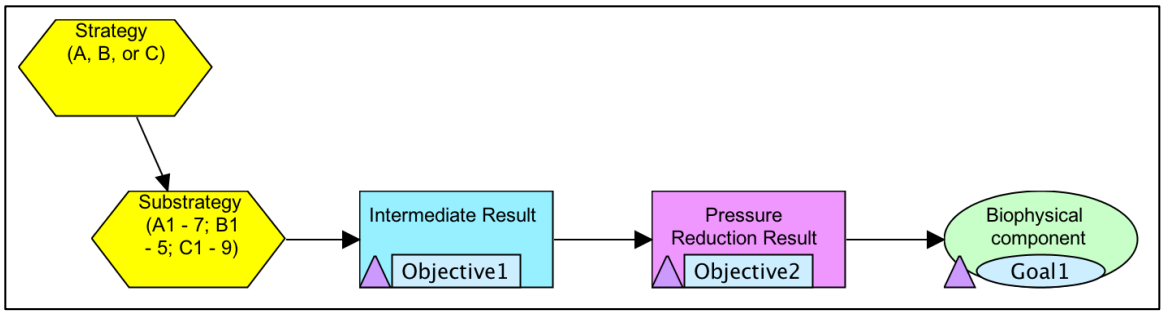


Figure 1. Key for the results chains in Miradi. This is a basic view of each type of information that goes into a results chain. The large yellow, blue, purple, and green shapes are in each results chain; the smaller blue boxes and ovals and purple triangles can be associated with any portion of the results chain, and there can be multiple incidences of each.

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Appendix 4. Effectiveness Monitoring Case Study for Island LIO

Prepared by

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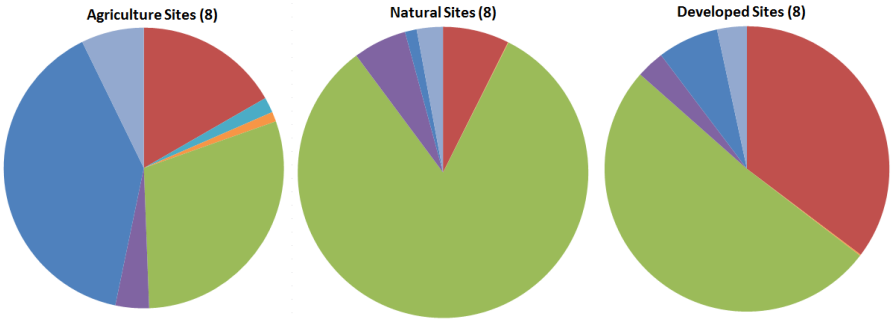

Effectiveness Monitoring Case Study for Island LIO: Evaluation of Existing Data and Next Steps for Monitoring

DRAFT

May 8, 2014

Haley Harguth, Hershman Marine Policy Fellow at the Puget Sound Partnership
Leska Fore, Puget Sound Partnership

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Context

The Surface Water Monitoring Program (SWMP) was created by the Board of Island County Commissioners in 2006 to collect water quality data to determine the current condition of Island County waters and to detect potential sources of contamination that may affect swim beaches, shellfish beds, anadromous fish streams and nearshore habitats. Their recent report reviews the actions and results of the Surface Water Monitoring Program from 2007–2011 (DuBose, 2013).

Island County, WA (County) is composed of Whidbey and Camano Islands in northern Puget Sound. The Island Local Integrating Organization (ILIO) covers Island County and its watershed (WRIA 6). At this time, the Island Local Integrating Organization, the Island County Department of Natural Resources, the Island County Department of Planning and Community Development, and the Island County Health Department are reviewing their strategies for protecting and restoring natural resources in the County.

The purpose of this document is to answer specific questions asked by Dave Wechner, Director of Planning and Community Development (Appendix 1). In addition, the Puget Sound Partnership is currently developing a regional Effectiveness Monitoring Framework to report the effectiveness of actions and strategies to restore Puget Sound. Island County has defined Near Term Actions as part of their local process (Appendix 2, Anderson 2013). We are

interested to work with Island County to understand how data from existing monitoring programs can be better used to evaluate the impact of restoration actions.

This document describes how data from the Water Quality Monitoring Program can be used to 1) answer specific practical questions, 2) refine a status and trends monitoring design, and 3) evaluate the effectiveness of local restoration and management actions.

Summary of Results

How does land use or geomorphic group affect the variation in each major water quality parameter?

- Land use practices across the County include changes associated with development and agriculture. All watersheds represent a mix of land use types (Figure 1).
- Nitrates and fecal coliform were highest at sites in watersheds dominated by agriculture (Figure 2). Fecal coliform were high at sites in watersheds that were more highly developed. Conductivity was higher at sites in watersheds with more agriculture and development (Figure 13).
- Levels of nitrates at sites within more developed watersheds were similar to sites in more natural watersheds (Figure 2).
- Fecal coliform and turbidity levels exceeded standards at many sites, including occasionally at sites in watersheds characterized as more natural (Figures 3 and 4).
- Orthophosphates levels are significantly higher at agriculture sites, but are also elevated at times in more natural watersheds; however, no state standard currently exists against which to compare measured levels (Figure 12).

Are water quality impacts due to natural phenomena or pollution; and, how is development related to water quality impacts?

- Water quality varied according to land use type. As the percent of developed area increased at sites, water quality variables also increased, indicating worsening water quality conditions (Table 3).

How can this data be used to assess effectiveness of management actions?

- At Freeland Park, water quality improved as a result of restoration and management actions.
- Fecal coliform declined at many sites over time (Table 4). Temperature increased over time at many of the sites.
- These results can be used to design a monitoring program to test the effectiveness of restoration actions, i.e., to define how much change over time represents a significant improvement or decline in water quality at each site.

Water Quality Data Analysis

Data from 24 monitoring sites throughout the County over the years 2007-2011 were provided to the Puget Sound Partnership (PSP) for additional analysis. There is current interest in re-structuring the County's water quality monitoring program to focus on questions that support

implementation and evaluation of the Island LIO's Near Term Actions as well as inform the development and implementation of the County's Critical Areas Ordinance.

The results below address the questions posed by Island County Director of Planning and Community Development, Dave Wechner (Appendix 1).

- *How does land use or geomorphic group affect the variation in each major water quality parameter?*
- *Are water quality impacts due to natural phenomena or pollution?*
- *How is development density related to water quality impacts?*

1. Land use practices across the County are diverse and create a variety of impacts.

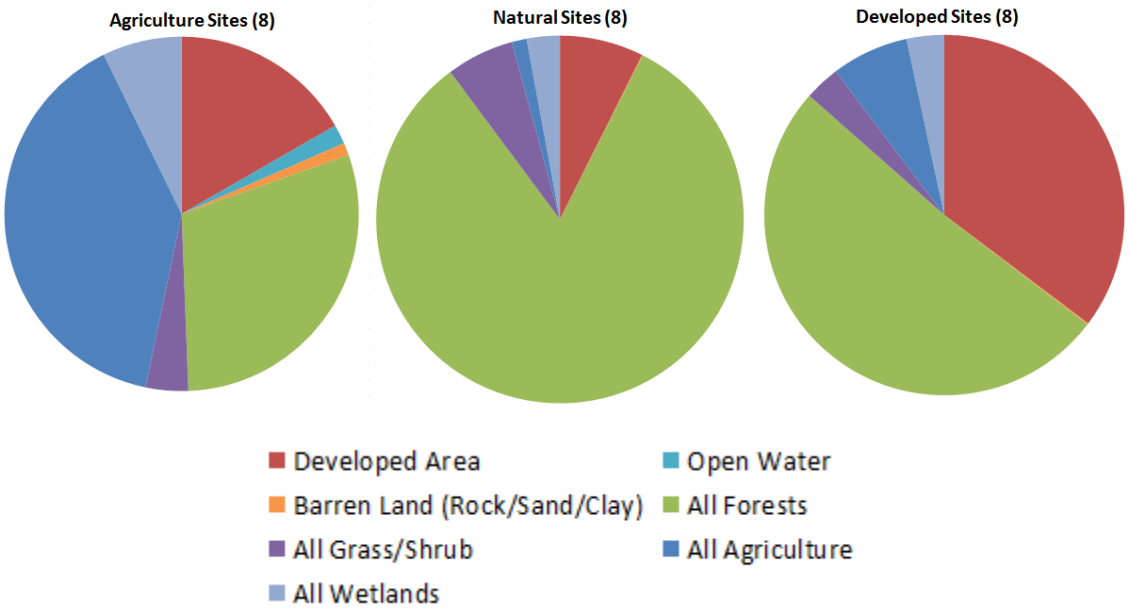

Figure 1: Land Cover Types. The total land cover composition within the upstream watershed for the three categories of sampling sites. There are eight monitoring sites for each category of land use type. The area represented in the pie charts represents the composition of the watersheds where monitoring sites are located.

The 24 sites are each located in watersheds with unique land use composition (Figure 1). The major land use occurring in those watersheds determines the classification as Natural, Developed, or Agriculture. However, each watershed is made up of a variety of land uses. Importantly, even watersheds with predominately natural condition contain development and agricultural activity. Although a control site is not available for use in comparison and analysis of the water quality at these sites, the natural sites give an approximation of the natural condition.

2. Land use practices negatively impact water quality, especially agriculture and development.

Agricultural sites showed the highest levels of disturbance in all of the monitored variables (Figure 2). Natural sites showed the least disturbed conditions. Agricultural sites frequently had the highest levels of pollutants, despite a much lower level of development. However, developed sites showed comparable water quality levels for some variables, including temperature, and pH. There were a few variables that showed similar levels across the three land use types, such as dissolved oxygen.

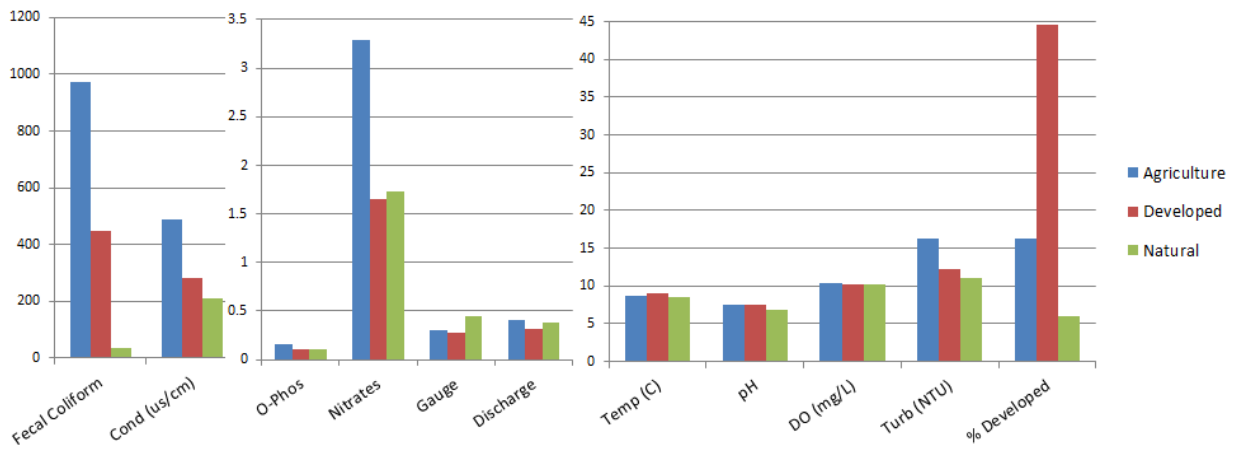

Figure 2: Land Cover Types and Water Quality**.** Values for each water quality variable are averaged for all years and all sites for each land use type, providing an overview comparison. Gauge and discharge monitoring is inconsistent through time, making it difficult to draw conclusions from the data.

3. Fecal coliform levels exceed water quality standards at the majority of agriculture and developed sites.

Fecal coliform exceeded water quality standards most frequently (Table 1), particularly in developed and agricultural sites. For fecal coliform, some sites have a designated use of primary contact recreation, and most are designated as extraordinary primary contact recreation. Natural sites had fewer exceedances, with 3 occasions at the primary contact site and 1 at the extraordinary contact sites. Turbidity was frequently higher than the IC standard (set at 14 NTU, or 5 NTU above the Island County median, as prescribed in WAC 173-201A-200 (1)(e); DuBose, 2013).

Table 1: Water quality variable, benchmark definition, predominant land use in the watershed and the number of sites in that land use type, number of times a site's annual mean exceeded water quality benchmarks out of the total number of site-year combinations that were measured, and that value as a percentage (2007-2011). The state water quality standards are shown where available, in the case that no state standard exists, the recommended benchmark adopted by Island County is shown (see DuBose, 2013 for sources).

Water Quality Variable	**Water Quality Benchmark**	**Land Use Type** (8 sites except where noted)	**Number of times sites' annual means exceeded benchmarks/ Total number of site-years**	**Percent of times that sites' means exceeded benchmarks**
Fecal coliform	Primary Contact Recreation: Max. geometric mean of 100 colonies/100mL, ≤10% of samples >200	Natural (6 sites)	3/30	0.10
		Developed (7 sites)	27/35	0.77
		Agricultural (6 sites)	19/30	0.63
	Extraordinary Primary Contact Recreation: Max. geometric mean of 50 colonies/100mL, ≤10% samples >100	Natural (2 sites)	1/10	0.10
		Developed (1 site)	5/5	1.00
		Agricultural (2 sites)	8/10	0.80
Nitrates	IC Standard for surface water, adopted from WA state drinking water standard (10mg/L)	Natural	0/48	0.00
		Developed	1/48	0.02
		Agricultural	5/47	0.11
Turbidity	IC Standard (14 NTU)	Natural	7/48	0.15
		Developed	14/48	0.29
		Agricultural	27/47	0.56
Temperature	7 day average of the daily max. temperatures no greater than 16°C (60.8°C) for core summer salmonid habitat	Natural	0/48	0.00
		Developed	0/48	0.00
		Agricultural	0/47	0.00
pH	Range for salmonid habitat (6.5-8.5)	Natural[1]	6/48	0.13
		Developed	0/48	0.00
		Agricultural	0/47	0.00
Dissolved Oxygen	Min. for salmonid spawning, rearing, migration for WA state (8.0 mg/L)	Natural	9/48	0.19
		Developed	3/48	0.06
		Agricultural	3/47	0.06

Notes: 1) Exceedance at natural site 12a: Deception Park Bog, where an acidic bog keeps pH levels very low.

The Fecal Coliform water quality standard is a two-part criteria, including both a maximum geometric mean value and frequency that samples exceed a maximum, as defined for the type of water body use. These two criteria provide different information to explain the water quality problems at a particular site. Table 2 breaks apart the two criteria to show which sites violated each part of the standard. The frequency that samples exceeded a maximum allowable level of fecal coliform colonies violated the standard more frequently than the geometric mean values would independently indicate. The higher amount of red highlighted cells on the percent exceedence side of Table 2 illustrates this result.

Table 2: Fecal coliform values by year and site shown, including both required criteria of the water quality standard: geometric annual mean values and percent of samples that exceeded a maximum defined for the type of water body use. Values that exceeded the standard are highlighted in red.

	Geometric Mean (Number of colonies/100mL)					% Exceedence Samples (Number of samples that exceeded max./Total)				
	2007	**2008**	**2009**	**2010**	**2011**	**2007**	**2008**	**2009**	**2010**	**2011**
Extraordinary Primary Contact Recreation (Fecal Standard: Geometric mean ≤ 50, with not more than 10% of samples exceeding 100)										
Agriculture Sites										
158a	6.83	23.13	11.99	4.31	7.80	11.54%	17.39%	6.67%	4.55%	12.50%
58a	67.58	108.00	216.38	54.19	128.47	54.17%	42.11%	47.62%	38.10%	43.75%
Developed Sites										
32a	80.14	144.93	29.18	16.54	39.16	47.06%	45.45%	21.43%	20.00%	33.33%
Natural Sites										
119a	4.98	4.46	4.27	2.12	9.53	0.00%	3.70%	0.00%	3.70%	5.88%
97a	4.00	9.26	2.11	2.01	2.82	0.00%	19.05%	0.00%	0.00%	0.00%
Primary Contact Recreation Sites (Fecal Standard: Geometric mean ≤ 100, with not more than 10% of samples exceeding 200 per year)										
Agriculture Sites										
14a	22.68	35.72	25.26	18.78	23.75	17.39%	19.23%	8.70%	4.17%	6.67%
36a	32.37	220.45	17.75	17.51	21.44	11.11%	50.00%	14.29%	7.69%	16.67%
36b	5.13	49.22	37.36	10.05	50.01	0.00%	26.32%	36.36%	18.18%	31.25%
38a	20.03	43.00	25.75	11.08	12.46	16.67%	23.53%	15.38%	6.25%	6.25%
42a	57.33	148.93	83.36	50.32	26.05	40.00%	41.67%	50.00%	21.43%	25.00%
67a	12.72	16.39	9.05	13.87	7.76	0.00%	17.65%	0.00%	7.14%	8.33%
Developed Sites										
134a	72.56	68.10	75.24	58.28	27.55	37.50%	35.29%	16.67%	11.11%	10.00%
148a	64.20	55.91	19.67	43.20	39.31	23.81%	23.81%	11.11%	20.83%	12.50%
188a	35.53	21.29	27.02	5.22	14.10	30.77%	15.79%	25.00%	5.56%	13.33%
44a	682.45	394.05	54.64	29.74	34.09	70.00%	57.14%	19.23%	19.23%	18.75%
45a	25.42	47.55	40.63	24.54	26.52	6.90%	18.52%	19.05%	8.70%	13.33%
74a	43.96	83.91	51.36	37.21	16.92	17.39%	33.33%	15.00%	19.23%	0.00%
82a	21.16	27.38	11.09	11.61	14.13	0.00%	18.75%	8.33%	11.76%	6.67%
Natural Sites										
108a	21.94	18.68	3.28	7.57	15.32	7.69%	14.29%	0.00%	0.00%	6.67%
12a	2.09	2.37	0.68	1.53	1.69	9.09%	0.00%	0.00%	0.00%	0.00%
48a	4.25	9.67	6.57	3.41	2.77	4.17%	0.00%	9.52%	0.00%	0.00%
70a	12.08	9.33	1.86	2.31	3.98	0.00%	6.25%	0.00%	0.00%	7.69%
76a	5.86	16.24	10.22	8.05	3.34	7.69%	9.52%	9.52%	3.70%	0.00%
83a	11.90	23.99	11.14	8.35	5.38	0.00%	14.81%	12.00%	3.70%	6.25%

4. **Some sites characterized by more natural conditions in the watershed also exceed water quality standards.**

To provide an overview of conditions at each site, we averaged all of the samples for each month across all years. For example, at site 14a (Green Road) there were 5 years of samples, and we averaged values for all years for each month. Note this is not how the values are calculated for the water quality standard; rather, they are derived from samples collected during a single year.

When values were calculated this way, sites in all three land use types were higher than the water quality standard at certain times of the year (Figures 3 and 4). At certain times of the year, even natural sites exceed water quality standards. This typically occurred during summer months, when very low water levels can concentrate pollutants and also create difficulty in collecting an accurate sample. The variation between each land use type's pattern over the year indicated that the influence of seasonality was inconsistent across sites, and monitoring methods may need to be adapted to more local conditions. For fecal coliform, values were much higher in the summer months for agriculture and developed land uses. In contrast, turbidity levels tended to be higher in the summer months but were not consistent across land use types. (See Appendix 3 for figures of remaining variables).

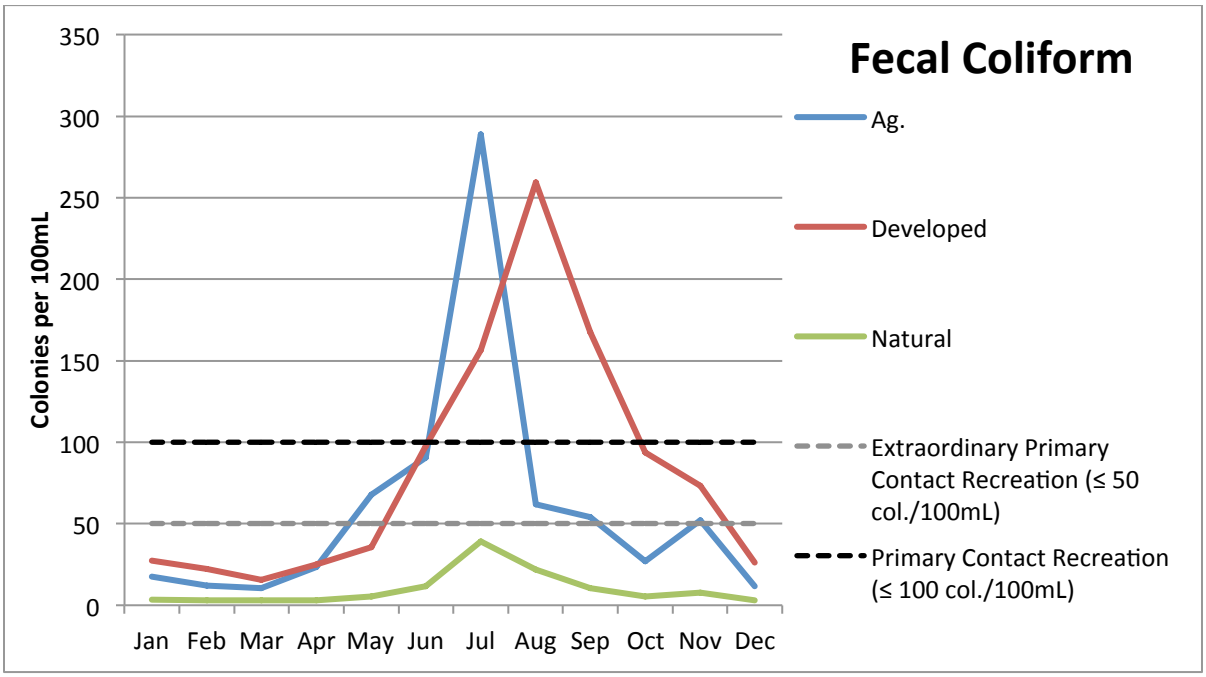

Figure 3: Monthly Fecal Coliform values. Geometric means were calculated for each month across the sites in each land use type. The maximum fecal coliform standard for each designated use is shown with dotted lines. On average, Agricultural and Developed sites exceeded the standard for a large portion of the year. A few outlier events skewed the Agriculture Summer monthly averages. Those events don't appear to be errors.

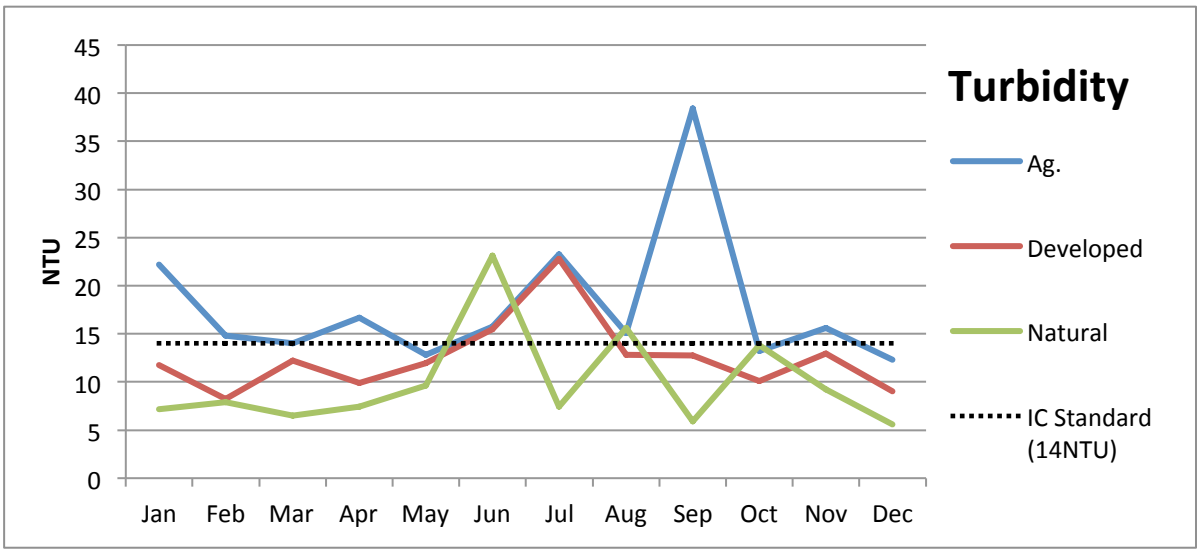

Figure 4: Turbidity values were averaged across sites within each land use group for each month across all years. The Island County turbidity standard is shown with the dotted line. All types of land cover show variability in turbidity levels throughout the year. Average values for natural sites exceeded the recommended standard for turbidity levels at times.

5. Water quality is inconsistently correlated with development

The relationship between water quality variables and percent developed area was inconsistent for sites in different land use groups (Table 3). For developed sites, percent development was most strongly correlated with nitrates and fecal coliform, and showed a positive correlation with many of the water quality variables, indicating worsening water quality. For natural sites, percent development showed an unexpected negative correction with orthophosphates and conductivity indicating these variables went down as development increased. For agriculture sites, correlation with percent development had mixed results.

Table 3: Correlation values for percent development and water quality measures. A darker color indicates a stronger correlation. Blue indicates a negative correlation, while red indicates a positive correlation.

	% Developed Area		
	Ag	Dev	Nat
Fecal Coliform	-0.26	0.56	-0.33
Orthophosphates	0.08	0.07	-0.69
Nitrates	0.18	0.72	-0.06
Temp	-0.38	0.47	-0.13
pH	0.31	0.04	0.21
Conductivity	0.21	0.03	-0.47
Dissolved Oxygen	0.36	0.48	0.18
Turbidity	-0.02	0.34	0.00
Gauge	0.09	-0.44	-0.39
Discharge	0.51	-0.61	0.46

6. **Trends in water quality measures showed a reduction in fecal coliform; other variables were not consistent.**

   Trends were calculated by regressing water quality variables against year for 2007-2011 (Table 4). Data for a few sites sampled in were excluded to be consistent across sites. The seasonal Kendall trend test is designed to correct for seasonality in calculating trends. For this analysis, seasonality was not strong or consistent enough to correct trends for seasonality.

   The trends varied across sites and land use type. Fecal coliform declined at many of the sites, suggesting that actions to reduce septic and agricultural run-off are working. Turbidity also declined at many sites, particularly those with the highest percent of development. Temperature increased at several natural sites, but was not corrected for possible differences in weather. Orthophosphates at developed sites decreased over time. Conductivity increased across many sites, a trend typically related to increasing development in the area. Some sites did show improvement across many variables, such as Site Number 134a (Freeland Park), where the majority of the variables showed improvement (see Box 1 for details about restoration actions). Many trends were inconsistent across sites, and were not predicted by the percent of developed area in the watershed.

Table 4: Trendline slopes of the lines for each water quality variable and site regressed against years (Red = Positive trend, White = No change, Blue = Negative trend; for Dissolved Oxygen (DO), the colors are reversed). A darker color indicates a stronger trend. Sites are listed in increasing order of percent developed area in their watershed, and color coded according to their land use type (Green: Natural, Blue: Agricultural, Red: Developed).

Site Num	Site Name	% Dev. Area	Fecal Coliform* (col./100ml)	O-Phos (mg/L)	Nitrates (mg/L)	Temp (°C)	pH	Cond (us/cm)	DO (mg/L)	Turb (NTU)	Gauge (ft)	Dis-charge (in)
119	(a) S. Whidbey State Park	1.9%	0.68	-0.02	0.31	0.46	0.05	7.97	0.29	-0.69	0.03	0.08
83	(a) North Bluff Creek	2.0%	-2.87	-0.07	0.08	-0.18	-0.03	-8.81	-0.15	-0.28	-0.01	0.01
76	(a) Willow Pond	3.4%	-1.32	0.00	0.10	-0.43	-0.02	2.75	-0.05	0.62	0.11	
12	(a) Deception Park Bog	3.6%	-0.16	0.00	0.07	0.10	-0.20	6.31	0.08	16.11	0.32	
97	(a) Smuggler's Cove	6.4%	-0.96	-0.03	-0.25	-0.19	-0.05	-4.22	-0.09	-0.51	0.01	0.00
14	(a) Green Road	8.3%	-1.48	-0.03	0.04	-0.41	-0.06	-0.09	0.33	2.13	0.02	0.10
70	(a) Sunset at West Camano	8.8%	-2.32	-0.01	0.02	0.23	-0.12	2.38	0.08	0.00	0.04	-2.71
108	(a) S. Camano Drive	9.8%	-2.44	0.00	-0.06	0.35	0.01	-2.72	0.10	0.34	0.01	0.49
42	(a) Utsalady at Good Road	11.3%	-16.12	0.05	0.01	0.22	-0.04	27.25	-0.10	-0.96		0.14
48	(a) North Sunset Drive	12.1%	-0.92	-0.02	-0.02	-0.22	-0.09	0.07	0.16	-3.20	0.04	0.23
36	(a) Terry's Corner	13.3%	-22.48	0.00	0.03	0.40	-0.06	8.14	-0.09	-1.96	0.09	-0.62
36	(b) Lutheran Church	13.3%	5.06	0.00	-1.14	0.52	0.01	55.84	-0.49	-0.31		0.04
67	(a) Sunrise at Iverson	18.3%	-1.24	-0.01	-0.09	0.65	-0.06	8.93	-0.18	-3.10	0.00	0.04
58	(a) Ebey's Landing	19.0%	6.80	0.00	-2.71	-0.15	0.06	-28.47	-0.02	-1.71	0.05	0.18
158	(a) Wanamaker Rd.	19.0%	-1.69	-0.03	-0.08	-0.27	0.01	19.28	-0.33	-2.99	0.06	0.08
45	(a) North Camano at Nellie	22.1%	-2.08	-0.03	0.07	-0.29	-0.12	-0.09	0.02	0.32	0.31	-0.02
38	(a) Utsalady at Arrowhead	26.2%	-4.70	-0.01	-0.02	0.26	-0.13	0.48	-0.16	-1.41	-0.11	0.43
82	(a) Bonnie Lane	26.8%	-2.98	-0.01	0.05	0.10	-0.03	-0.08	-0.08	0.18	0.06	0.85
74	(a) Cavalero at Country Club	27.2%	-10.08	-0.03	0.10	-0.15	0.00	-7.03	0.29	2.03	0.05	0.05
134	(a) Freeland Park	39.7%	-9.98	-0.04	-0.07	-0.66	-0.14	-3.08	0.88	-3.72	0.01	
32	(a) West Beach	46.5%	-21.03	-0.04	-0.09	-0.26	-0.01	9.34	0.06	-2.57	0.03	0.10
148	(a) Berg and Conrad	56.2%	-6.25	-0.02	0.05	0.05	-0.04	-1.82	-0.02	-1.45	0.03	0.04
44	(a) Rocky Point	68.6%	-166.10	-0.04	0.19	-0.19	-0.05	4.02	0.02	-1.85	0.00	0.06
188	(a) Cavalero at Simonson	69.6%	-5.89	-0.02	-0.19	0.33	-0.07	-0.43	-0.17	-1.13		-0.02

* Fecal coliform rates were calculated using geometric annual means

Box 1: Freeland Park, Holmes Harbor Water Quality Success Story

Island County's focused work at Holmes Harbor, which encompasses Freeland Park (Site 134), produced measureable positive outcomes for the area's water quality (Figure 5). In 2007, a special Holmes Harbor Shellfish Protection district was created and began implementing actions across the watershed, including both outreach and enforcement measures to better understand water pollutant sources and educate residents about available solutions. These actions generated immediate improvements in water quality trends. As sources such as leaky septic systems or farm runoff were identified one-by-one with dye testing, corrective actions were taken. The public engaged in outreach activities and received information on proper disposal of pet waste. In addition to the installment of waste disposal stations at parks, informational signs were installed to inform the public about watershed boundaries, and homeowners attended workshops on residential storm water mitigations projects.

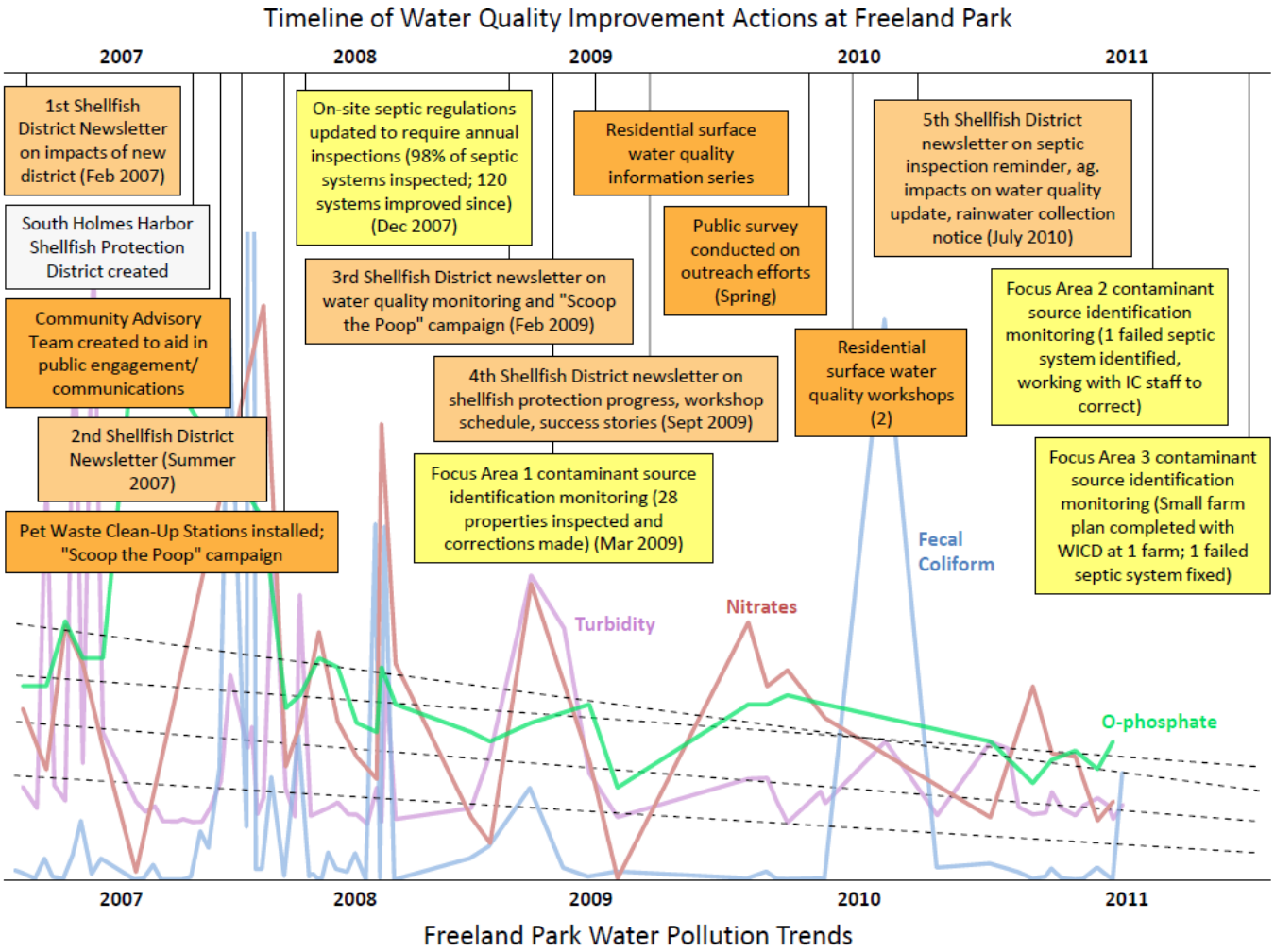

Figure 5: Water Quality Improvement Actions and Trends at Holmes Harbor. The timeline of water quality improvement actions is shown at the top, with similarly themed actions grouped by color. The dotted lines at the lower half of the figure display the trendlines for turbidity, nitrates, fecal coliform, and orthophosphates. Each pollutant has a downward trend, indicating lowered level of pollutants and improved water quality.

7. **Results from this monitoring program can be used to estimate the amount of change in water quality measures that would represent a significant change in site condition.**

For each site and for each measure of water quality, we can estimate the variance associated with each measure in the absence of any management actions or human disturbance that might change the value. For example, assuming there were no such changes in 2010, we can use data from that year to estimate the average value for a selection of water quality measures (Table 5). Using the mean and the variance, we estimated the range of expected values for a site in the absence of any action as the 90% confidence interval. Any observed values outside that range can be interpreted as a change in site condition.

Confidence interval is calculated as:

$$\overline{X} \pm z_{0.9}\left(\frac{\sigma}{\sqrt{n}}\right)$$

As an example, for site 58a (Ebey's Landing), the confidence interval for fecal coliform would be calculated as:

$$920.2 +/- (1.645)(2500.4/(21)^{1/2}) = [22.7,1817.8]$$

If we want to reduce the impact of agricultural practices at site 58a, we need to check the confidence interval, which ranges from approximately 23 to 1818. Thus, fecal coliform is highly variable, and even with 21 samples in 2010, detecting a change in fecal to less than 23 is going to be unlikely. Thus, a change will be hard to detect for this variable at this site. In contrast, the annual mean for conductivity is also quite high, but the confidence interval for the mean ranges from 843-1065, indicating there is room for measureable improvement in conductivity and it might be a better measure to track change over time. Nitrates are also quite high and lower values could potentially be detected as a result of management actions.

In contrast, water quality at site 108a (South Camano Drive) is in good condition, any improvement is unlikely to be measureable because the range of values for the mean are already quite low and these water quality measures only go to zero. Sites with good values may not need any restoration actions or such frequent monitoring, but could be assessed occasionally to check for decline.

The baseline data collected so far can be used to prioritize sites for restoration and protection. The data also help determine where monitoring should be continued, and how monitoring resources might be more efficiently utilized. Now that site condition is known for many locations, monitoring resources can be balanced to evaluate the effectiveness of actions as well as to track status and trends over time.

Table 5: Data are shown for two sites to calculate the 90% confidence interval for the water quality measures observed in 2010. Shown are the yearly average, the standard deviation of the measures, the lower and upper bound for the 90% confidence interval of the mean, and the approximate range of the confidence interval. Values observed outside this range likely indicate a change in site condition.

Site ID	Site name	Average	StDev	N	LB_90%	UB_90%	CI_90%_approx
Fecal Coliform							
108a	South Camano Drive	25.6	34.6	16	11.4	39.9	11 - 40
58a	Ebey's Landing	920.2	2500.4	21	22.7	1817.8	23 - 1818
Conductivity (us/cm)							
108a	South Camano Drive	101.4	13.2	15	95.8	107.0	96 - 107
58a	Ebey's Landing	953.9	350.0	27	843.1	1064.7	843 - 1065
Nitrates							
108a	South Camano Drive	1.3	1.4	8	0.5	2.2	0.5 - 2.2
58a	Ebey's Landing	11.3	11.5	27	7.6	14.9	7.6 - 14.9

Measuring Effectiveness of Restoration Actions: Ebey's Prairie Case Study

1. How do we measure the effectiveness of management actions?

Once initial data analysis is complete, the next step in effectiveness monitoring is to link that information to the restoration goals. This step requires that goals and actions be established, and conceptually mapped using a process such as Open Standards to describe the results chains connection actions to the intended outcomes (Figure 6). These models are a useful tool to organize and plan where and when restoration actions should take place, and how the intended outcomes can be evaluated.

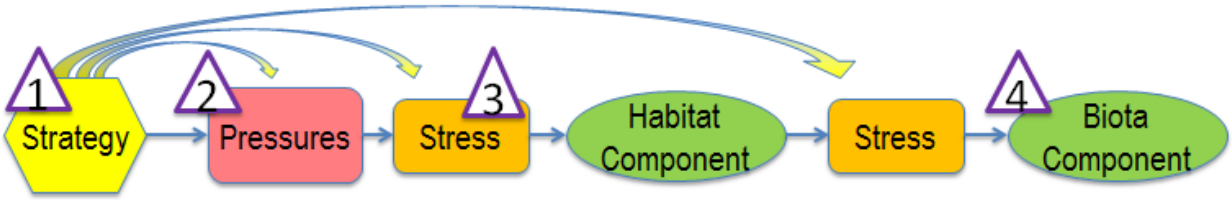

Figure 6: Results Chain for Effectiveness Monitoring**.** The following evaluative questions are asked at thestages of the project indicated by the purple triangles: 1) Was the strategy implemented?; 2) Did the strategy reduce the pressure?; 3) Did reduction of stress improve habitat?; 4) Did improvement of habitat yield more biota?

2. Description of how to link actions to outcomes.

Island LIO has recently completed their Near Term Actions (NTAs) (Appendix 2) and intends to design an effectiveness monitoring program to guide and evaluate the progress toward those outcomes. We focused on Island LIO NTA 8: *Implement a small farm water quality improvement project in Ebey's Prairie*, to demonstrate how an effectiveness monitoring framework might be constructed. This NTA was selected because of its relationship to the data collected by the Water Quality Monitoring Program and due to its recent focus in Island County's environmental management efforts. NTA 8 outlines the following goal: The project will include water quality treatment technology (for example grassy swales, filter strips, phytoremediation) and landowner farm practices (manure management, filter strips) to reduce non-point stormwater pollution, and respective performance measures:

- By December 2015, reduce nutrient and bacteria levels in stormwater runoff.
- By December 2015, implement five water quality BMPs in watershed.

NTA 8 was mapped to a results chain to identify opportunities for monitoring (Figure 7). The existing water quality data can be utilized in this framework to answer questions in multiple phases of NTA 8 implementation. Much of the water quality data will serve to evaluate the status of the pressures on the environment of Ebey's Prairie. Implementation monitoring asks new questions using survey instruments designed to the specific audience and setting at the project location. Long term outcomes for biota may also require different data to evaluate the health status and trends of those populations.

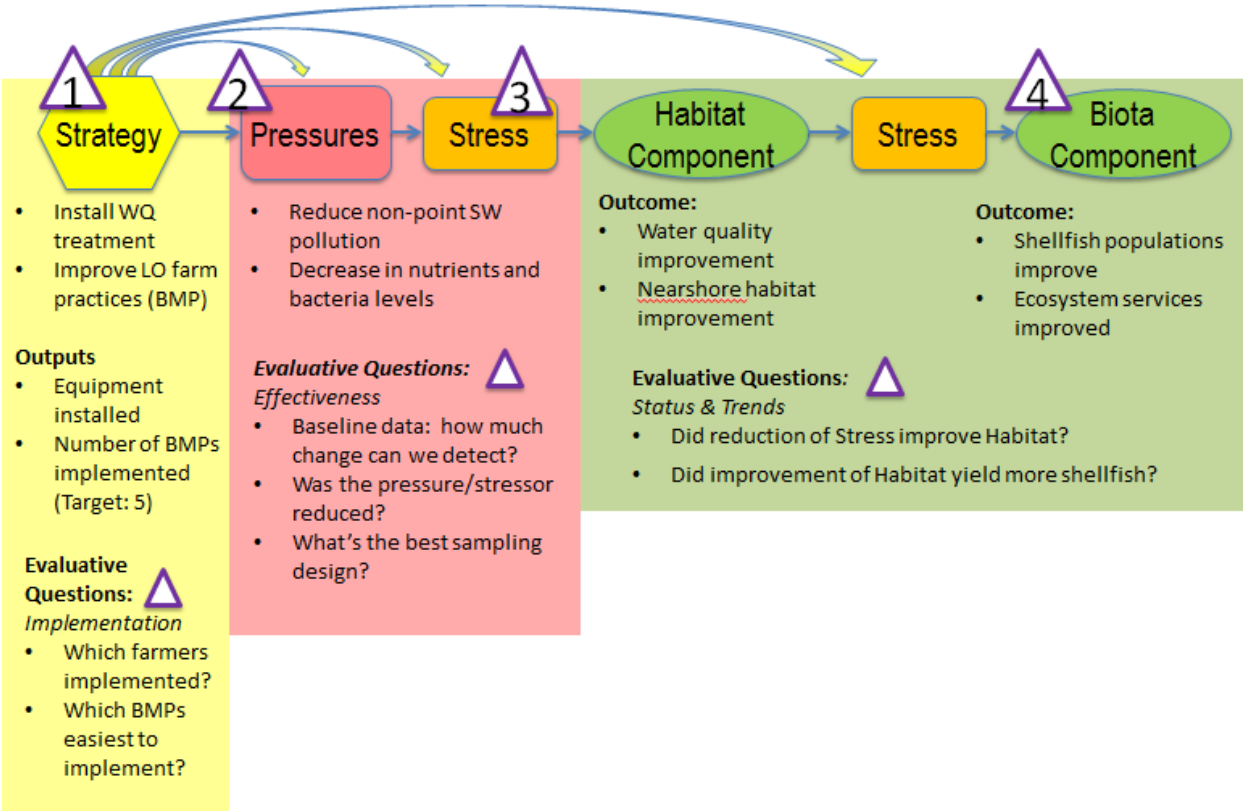

Figure 7: Results Chain and Effectiveness Monitoring of Island NTA 8: Ebey's Prairie Farms Water Quality

Next Steps for an Effectiveness Monitoring Program

- *Measure what's important.*

Identify which key ecological components are of most important for restoration and protection.The current Near Term Actions reflect the importance of nearshore areas, salmon populations, and freshwater resources (Appendix 2).

- *Where possible, connect monitoring to specific actions.*

For example, in Ebey's Prairie, use monitoring of water quality to test which management actions are successful, and define actions that follow success or failure. Make the expected outcomes and the assessment questions explicit for all types of monitoring.

- *Create a balanced portfolio of monitoring efforts.*

Include a mix of implementation monitoring, effectiveness monitoring for specific projects, and status and trends for long-term monitoring. Develop a status and trends monitoring program for water quality trends that uses a statistical power analysis of current data to determine type and frequency of sampling.

- *Coordinate with other regional monitoring efforts as appropriate.*

The Regional Stormwater Monitoring Program and the Monitoring and Adaptive Management Program for Chinook Recovery are both regional monitoring programs that coordinate sampling across Puget Sound. Where possible, leverage and coordinate monitoring with these programs.

References

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DuBose, K. 2013. Island County Surface Water Monitoring Program: Water Years 2007-2011. Island County Environmental Health (ICEH). Coupeville, WA. 186 pp.

Zar, J.H. 1984. Biostatistical Analysis, 2nd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Appendix 1

Appendix 1: Island County Memorandum: Request for funding Statistical Analysis – Water Quality data

ISLAND COUNTY

PLANNING & COMMUNITY DEVELOPMENT

PHONE: (360) 679-7339 ■ from Camano (360) 629-4522, Ext. 7339 ■ from S. Whidbey (360) 321-5111, Ext. 7339 FAX: (360) 679-7306 ■ 1 NE 6th Street, P. O. Box 5000, Coupeville, WA 98239-5000. Internet Home Page: http://www.islandcounty.net/planning/

~ MEMORANDUM ~

TO: **Keith Higman, Director, Health Administration**
Lori Clark, Environmental Health Specialist

FROM: **Dave Wechner, Director, Community Development**

DATE: **September 24, 2013**

SUBJECT: **Request for funding Statistical Analysis – Water Quality data**

After reviewing the Draft 5-year Water Quality report as presented by Karen DuBose and Health water quality staff, I am in agreement that the County would benefit from some analysis of data exploring these questions:

1) How does land use or geomorphic group affect the variation in each major water quality parameter?

2) By comparing "natural" to "developed" watersheds, can we determine what water quality impacts are/may be associated with natural phenomena and are not associated with pollution?

3) Are there discernible significant differences in water quality based on density of development (parcel size relative to total watershed acreage and water quality indicators)?

I understand Puget Sound Partnership monies can be utilized for this statistical analysis, and supporting utilizing those funds as available.

Appendix 2

Island County Local Integrating Organization (LIO) Near Term Actions (NTAs) (September, 2013).

	NTA description
1	**Develop an implementation strategy for SMP compliance.**Island County will develop an implementation strategy for SMP compliance that includes the following elements: a) develop an accurate evaluation of shoreline health that meets the state requirement for "no net loss" and SMP effectiveness based on guidance from the Department of Ecology; b) retain a consultant to set a baseline percentage of shoreline armoring and percent vegetative cover that will be used to quantitatively and qualitatively evaluate shoreline health status, trends and compliance monitoring; c) conduct annual county-wide shoreline evaluations for trend analysis.
2	**Develop technical guidance document and trainings for residents on new SMP guidelines**
3	**Improve Island County GIS capability to support land use analysis, planning, permitting decisions, and enforcement with respect to Adaptive Management and Shoreline Master Program requirements.** Island County will develop Standard Operating Procedures for updating data and consistency in its data storage network to ensure usage consistency and relevant data.
4	**Decrease the use of shoreline armor, or in those instances where armor is absolutely necessary, increase the utilization of soft-shore protection to address shoreline protection concerns.** This effort will address two target audiences, IslandCounty permitting staff and shoreline property owners. Education, outreach and behavior change strategies will be used. Island County will engage its permitting staff and shoreline property owners in an extensive education and outreach campaign to meet its target of decreasing the use of shore armor and soft-shore protection. The campaign will utilize appropriate behavior change strategies and technical/scientific data to support changes within the community. Island County will seek funding to provide technical assistance to landowners and to monitor program effectiveness.
5	**Remove hardshore armor and, where feasible, replace with softshore protection where erosion control is needed to protect houses.**Develop a program for education & behavior change on shoreline armoring in IslandCounty. Social marketing will be applied to program development. Financial incentives (i.e. free site visits from experts, and grants for cost share, design, permitting, etc) will be offered to implement armor removal and possibly install soft shore protection. This program will include monitoring beach ecosystem health on removal and conversion projects (from hardshore to softshore) to provide justification.
6	**Restore tidal inundation.** Island County will restore tidal inundation to one or more isolated pocket estuaries or tidal wetlands. The project selected will address either poor design or malfunctioning tidegates in order to improve habitat for juvenile salmon.
7	**The City of Oak Harbor will implement Freund Marsh restoration and stormwater improvement project.** The project will restore natural treatment functions to reduce nutrient loading and improve

	flow rates by increasing infiltration in OakHarbor, the only urban watershed in the County. The project will complete the Freud Marsh improvements including a trails network and interpretive center to educate public about stormwater, water quality and wetland issues.
8	**Implement a small farm water quality improvement project in Ebey'sPraire.**The project will include water quality treatment technology (for example grassy swales, filter strips, phytoremediation) and landowner farm practices (ex. manure management, filter strips) to reduce non-pointstormwater pollution.
9	**Stormwater technical assistance and incentive programs implementation.** Island County will implement a stormwater retrofit program to target private properties. The program will include designing and conducting workshops for landowners and providing incentives for compliance (incentives may include cost sharing for rain gardens, no-cost engineering).
10	**Develop and implement a stormwater monitoring Program.** IslandCounty will enhance its stormwater monitoring program to address stormwater discharges from the built environment. The monitoring is intended to focus community attention on source identification and key areas of concern. Based on the monitoring data, technical assistance will be provided to landowners.
11	**Implement a noxious and invasive weed eradication program.**
12	**Identify, map and prioritize blocked and failing culverts and replace 1-2 priority culverts using fish-friendly passage designs.** Fish-blocking culverts are negatively affect flood risk, scouring, erosion, land slides, water quality. IslandCounty will map all existing culverts noting which are blocked and failing, and will create a prioritization schedule for replacing these culverts.