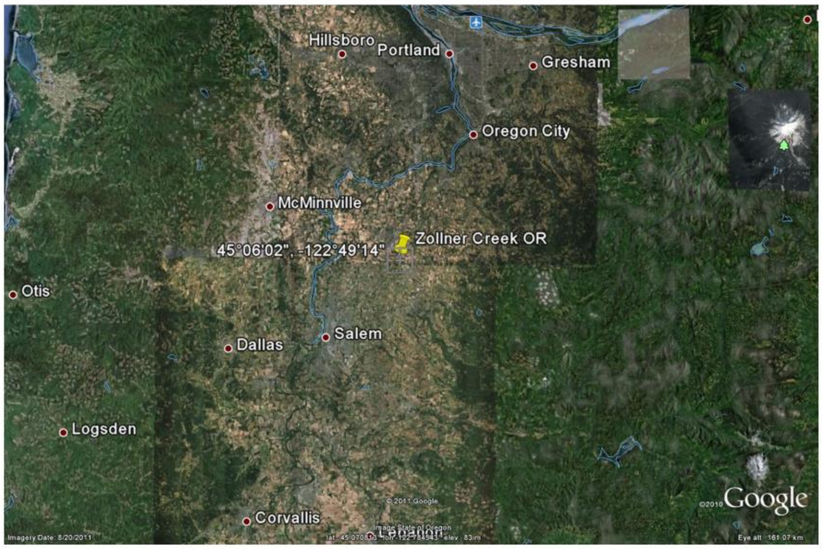
CRITFC Lab 6 – Setup of New Study for Oregon Stream, Anadromous Behavior, and Bioaccumulation of Pesticides in Lamprey and Salmon

CRITFC Labs 6 and 7 will use simulations of Zollner Creek, Oregon. The creek is located in the heavily cultivated Willamette Valley, with row crops, orchards and vineyards, grain and grass fields, and large poultry farms (all land uses that can be seen in this photograph). It is a USGS National Water Quality Assessment Program (NAWQA) site, and abundant data are available for multiple years. It is also a principal agricultural site in a TMDL, and ODEQ has collected additional data (Williams and Bloom 2008).

Zollner Creek is in the Pudding River Watershed



The Oregon criteria for chlorpyrifos was exceeded

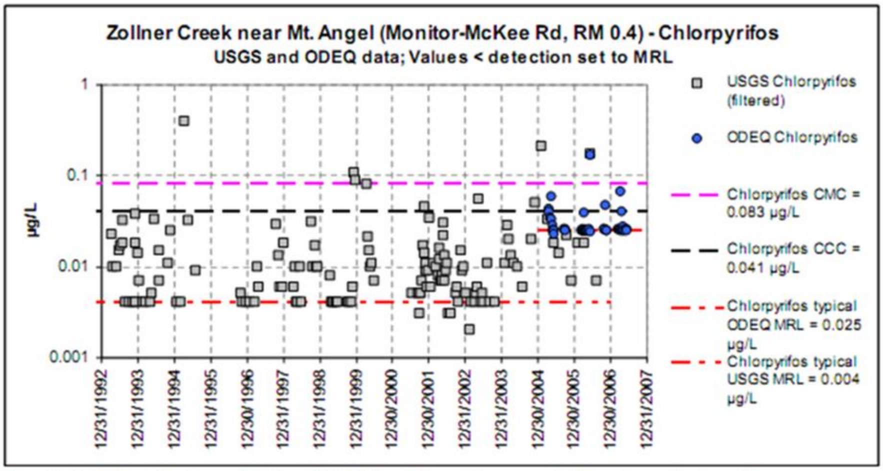


Figure I - 9: Zollner Creek near Mt. Angel (RM 0.4) – Chlorpyrifos concentrations - Logarithmic scale

The TMDL (Williams and Bloom 2008) was a good source of data.

Legacy pesticides (no longer used) include dieldrin

Table 4 - 4: Water Quality Criteria

	Freshwater				Human Health For Consumption of:				Drinking Water MCLs
Compound	Acute µg/L		Chronic µg/L		Water + Organism[B] µg/L		Organism only[B] µg/L		µg/L
Chlordane	2.4	Table 20	0.0043	Table 20	0.00046	Table 20	0.00048	Table 20	2
Dieldrin	2.5	Table 20	0.0019	Table 20	0.000071	Table 20	0.000076	Table 20	
Chlordane	2.4	Table 33A	0.0043	Table 33A	0.00080	Table 33A	0.00081	Table 33A	
DDT	1.1	Table 20	0.001	Table 20	0.000024	Table 20	0.000024	Table 20	
DDD 4,4'-					0.00031	Table 33A	0.00031	Table 33A	
DDE 4,4'-					0.00022	Table 33A	0.00022	Table 33A	
Dieldrin	0.24	Table 33A			0.000052	Table 33A	0.000054	Table 33A	

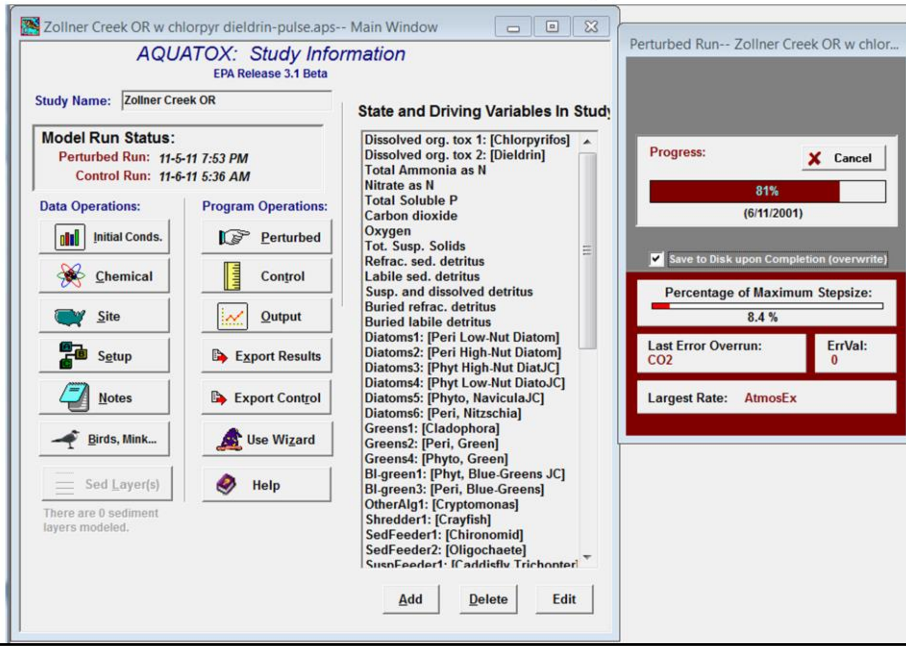
MCL - Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
Table 20 and 33A are contained in OAR 340-41-0033

Table 4 - 5. FDA Action levels for fish (edible portion)

Pesticide	FDA Action Level
CHLORDANE	0.3 ppm (300 µg/kg)
DDT, DDE, & TDE	5 ppm (5000 µg/kg)
ALDRIN & DIELDRIN	0.3 ppm (300 µg/kg)

The TMDL (Williams and Bloom 2008) was a good source of data.

Use calibrated model with chlorpyrifos & dieldrin

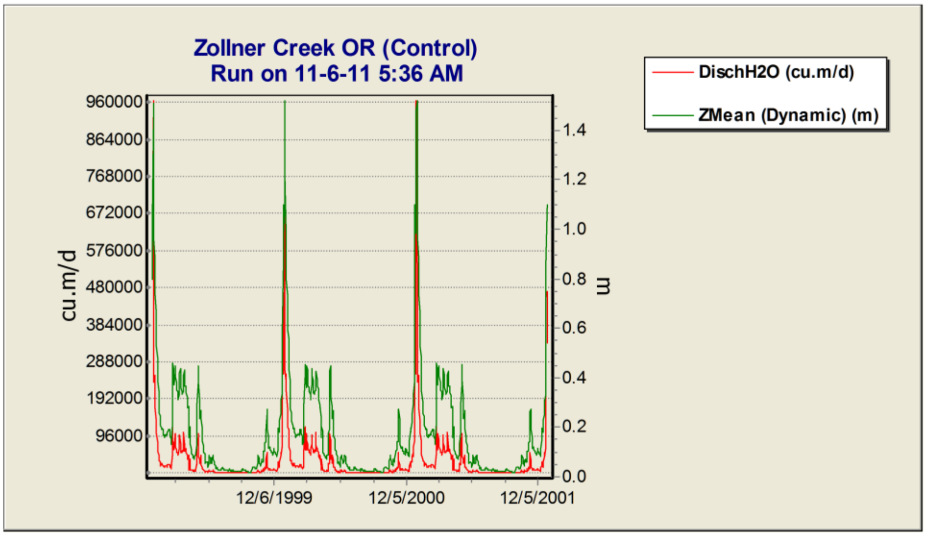


To save space, the study file *Zollner Creek OR w chlorpyr dieldrin-pulse.aps* was saved with the results cleared; therefore, you should run both Control and Perturbed simulations first. The study was developed starting with a study file from the Lower Boise River ID, used in earlier labs.

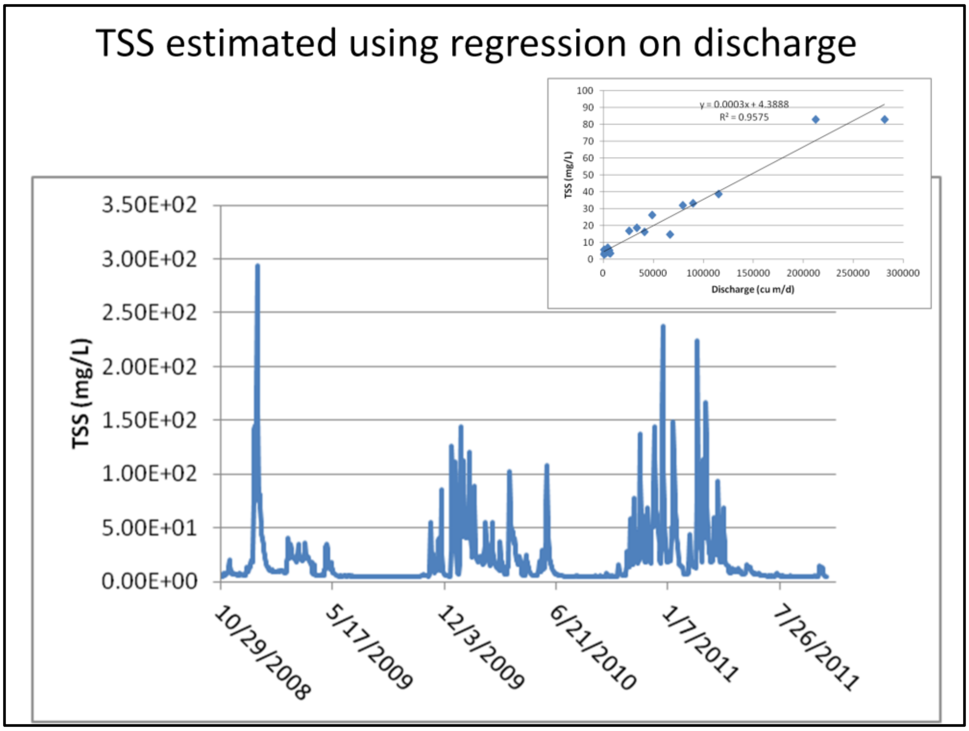
Suggested tasks using Zollner Creek study

- Explore boundary conditions
  - Area, depth, volume
  - Driving variables (discharge, nutrient loadings, TSS)
  - Pesticide loadings
- Parameters for lamprey and salmon, including setup for anadromous behavior
- Simulated bioaccumulation
  - Chlorpyrifos, dieldrin
  - Chinook salmon, lamprey
- Action levels for human consumption
- Lab 7 will examine ecotoxicity as a continuation

Discharge and water depth are important

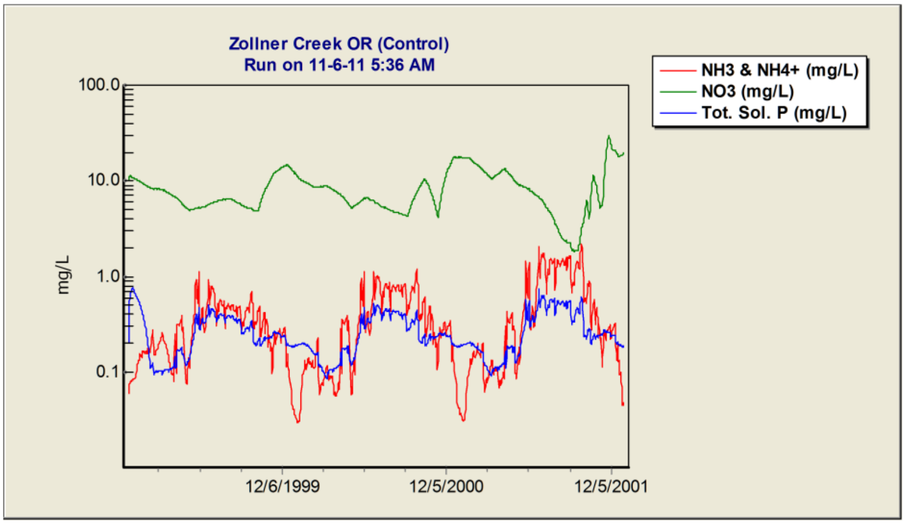


Discharge was taken from USGS Web site (see *Zollner Cr Disch.xlsx*). Mean depth was **calibrated** by varying area of creek and Manning's roughness coefficient. Initial width was estimated from Google Earth photo (see slide 1). Reach length is arbitrarily long (5 km!) so that model will run faster. Site constants can be found in the site record (Site→Edit Underlying Site Data).



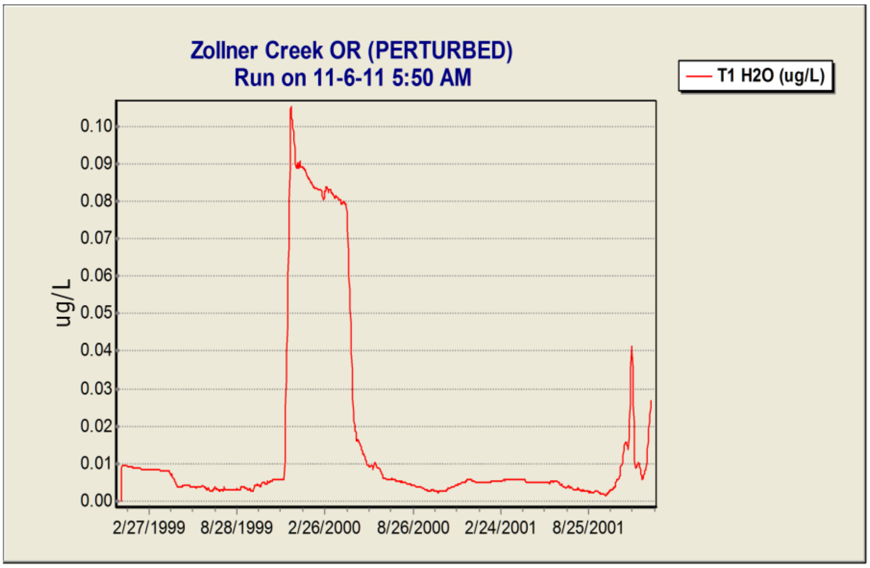
Time-varying total suspended solids are important because of the control on light climate for periphyton. Therefore sporadic measurements were regressed on discharge in order to obtain daily values (see *Zollner Cr Disch.xlsx*).

Nutrients, especially nitrate, are high due to agricultural runoff



See *Zollner Cr obs ldg data chlorpyr.xlsx* for other loadings, most taken from extensive USGS site data.

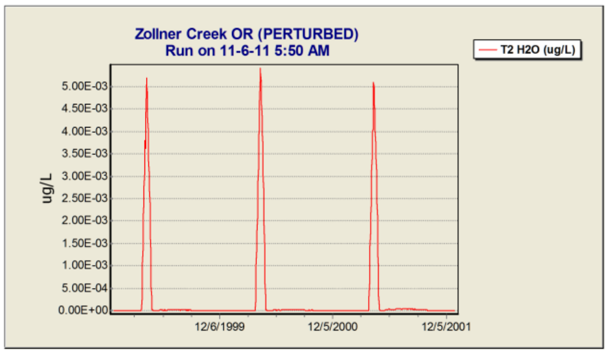
Time-varying chlorpyrifos loading extracted from USGS site record



Because the frequency of sampling was sufficient, the chlorpyrifos data were imported from the USGS file; the only conditioning of the data was to substitute very low concentrations when data were below detection limits (see *Zollner Cr obs ldg data chlorpyr.xlsx*).

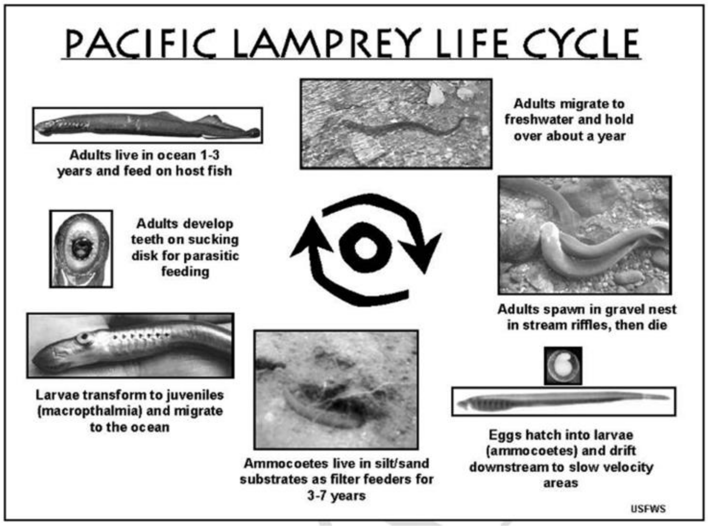
Pulsed loadings of dieldrin in solution provide a compromise between worst-case and best-case

Date	Dieldrin ug/L	or	Date	Dieldrin
4/1/1997	0.006		3/30/1997	0
4/1/2003	0.003		4/15/1997	0.006
4/1/2006	0.002		4/30/1997	0
5/1/2007	0.009			
mean	0.005		triangular distribution	

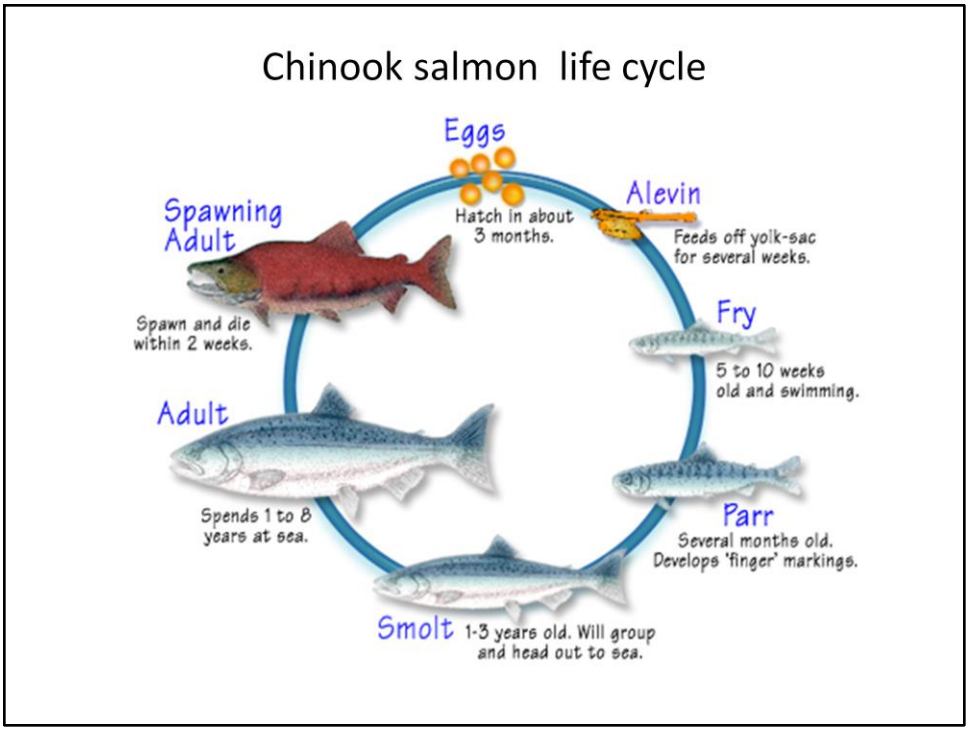


The legacy pesticide dieldrin, banned from agricultural use in 1974, presumably is sequestered in sediments unless scoured by high flow. Limited data for Zollner Creek, four samples that exceed the detection level, present a challenge for modeling. They are too few to develop a regression on flow, such as was done for TSS. If the four values are imported into the model they will be interpolated as continuous exposure—a worst-case scenario. The compromise, which may be too lenient, is to model the concentration in water as a repeating pulse (a triangular distribution). The table is taken from *Zollner Cr obs ldg data chlorpyr.xlsx* (see Dieldrin tab).

Pacific lamprey larvae live as filter feeders in sediments for several years



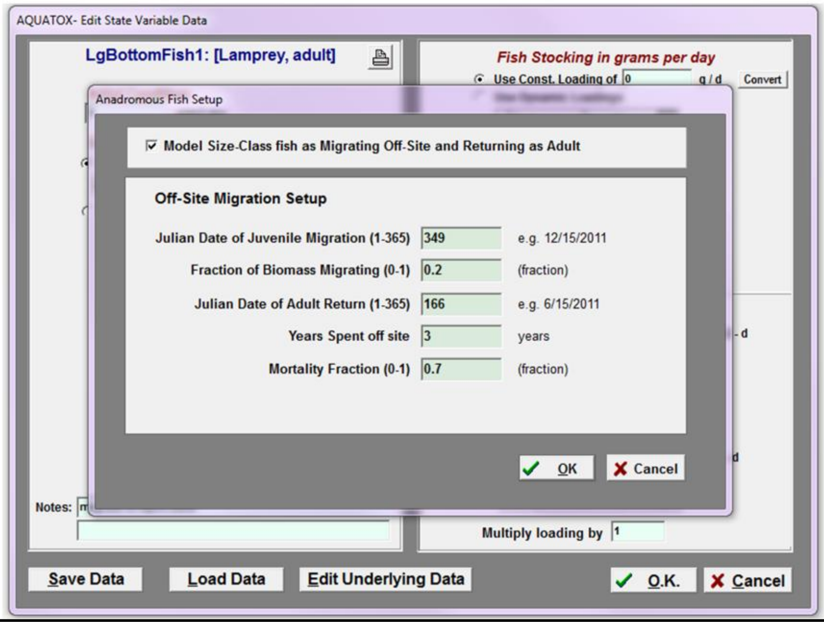
DRAFT Outline of the Pacific Lamprey Conservation Plan, 2008



Juvenile salmon migrate to the sea after about a year and then return as adults several years later.

National Marine Fisheries Service. 2008. Endangered Species Act Section 7 Consultation, Biological Opinion: Environmental Protection Agency Registration of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion.

Setup for anadromous fish (lamprey)



Anadromous fish live most of their adult life in saltwater, but they return to freshwater to spawn, and juveniles grow for a few months to a few years before going to saltwater. **The ability to represent both growth and exodus of juvenile fish and the spawning and death of returning adult fish was programmed especially for the Columbia River watershed and first applied in this short course**. The algorithm uses simple relationships to compute off-site growth and depuration of toxicants.

Unfortunately, this approach requires a year spinup to compute the biomass and toxicant linkages between juvenile and adult anadromous fish. A three-year simulation takes about 40 minutes on a fairly fast computer, and that precludes extensive experimentation within the timeframe of the short course. However, various scenarios can be explored off-line with a simple spreadsheet model, *Anadromous_Model.xlsx*.

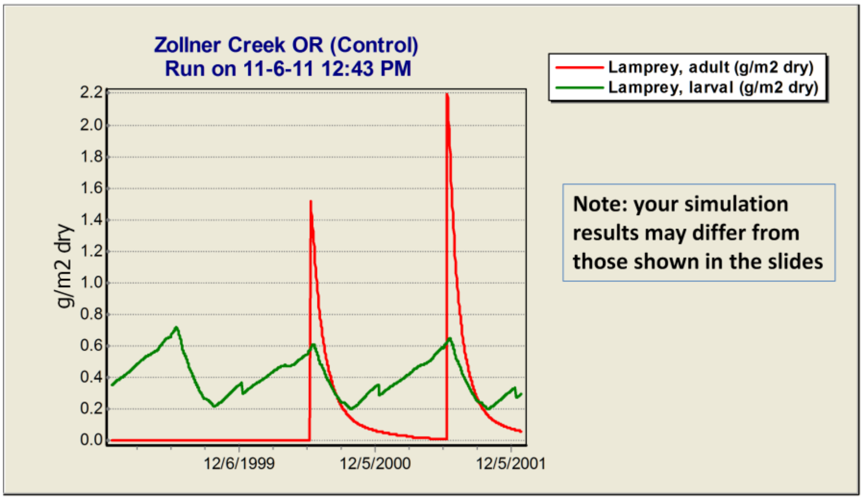
Spreadsheet for Anadromous Calculations

New Interface Inputs	Chinook salmon		
Date of juvenile migration	2-Apr		
Fraction of biomass migrating	100%		
Date of adult return	2-May		
Years spent off-site	4		
Off-Site Mortality Frac	0.7	frac	
AQUATOX Calculations From Existing Parameters			
Clearance Rate (K2)	0.0026941	1/d	
Growth Multiplier	160.00	frac	*Taken from mean weights*
Initial Lipid	20%	g lipid / g ww	
Return Lipid	20%	g lipid / g ww	
Biomass departing	0.05	g/m2	
Conc in Departing Fish	1.60	ppb	ug/kg ww
"Off-Site Environment" Intermediate Calculations			
Initial Lipid Norm Conc	8.0	ug / kg lipid	
Time off site	1491	days	
Depuration effect	1.8%	multiplier	
Growth effect	0.625%	multiplier	
"Off-Site Environment" Results (passed back to AQUATOX)			
Biomass Returning	2.400	g/m2	fn growth and mortality
Return Conc	0.000	ug/kg ww	fn depuration and growth effect
Return Lipid Norm Conc	0.001	mg/kg lipid	
Data Above	0.011195%	pct remains	from original dry weight value.
	0.011195%	pct remains	from original lipid normalized value.

Dieldrin				
(Optional) Clearance Rate Calculator Inputs				
Nondissoc	1	fraction		
WetWt	4000	g	25	g
LipidFrac	20%	g lipid / g ww		
LogKow	5			
Clearance Rate Calculator Output				
K2 or Clearance	0.00269			
*LogK2 := -0.536 * LogKOW - Log10(Nondissoc) + 0.116 * POWER(WetWt,RB)/LFrac;*				

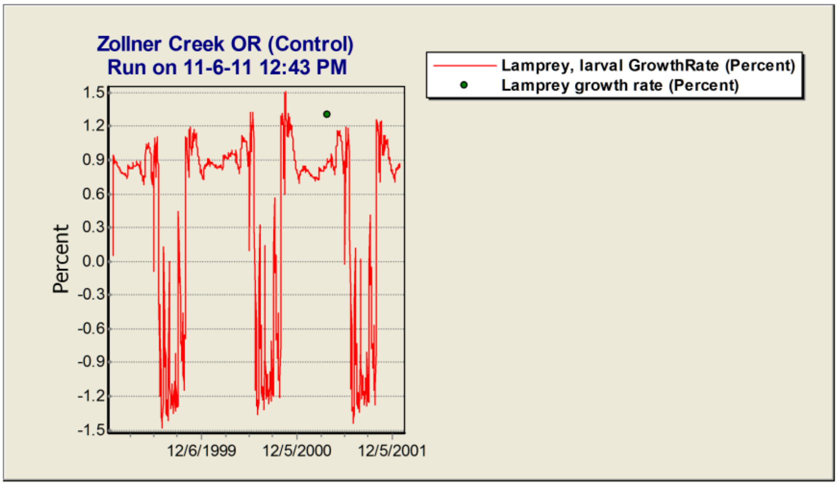
Anadromous_Model.xlsx

In this simulation the larval lamprey are stable over the period of the simulation and the adults exhibit an annual return and slow decline (they do not eat)

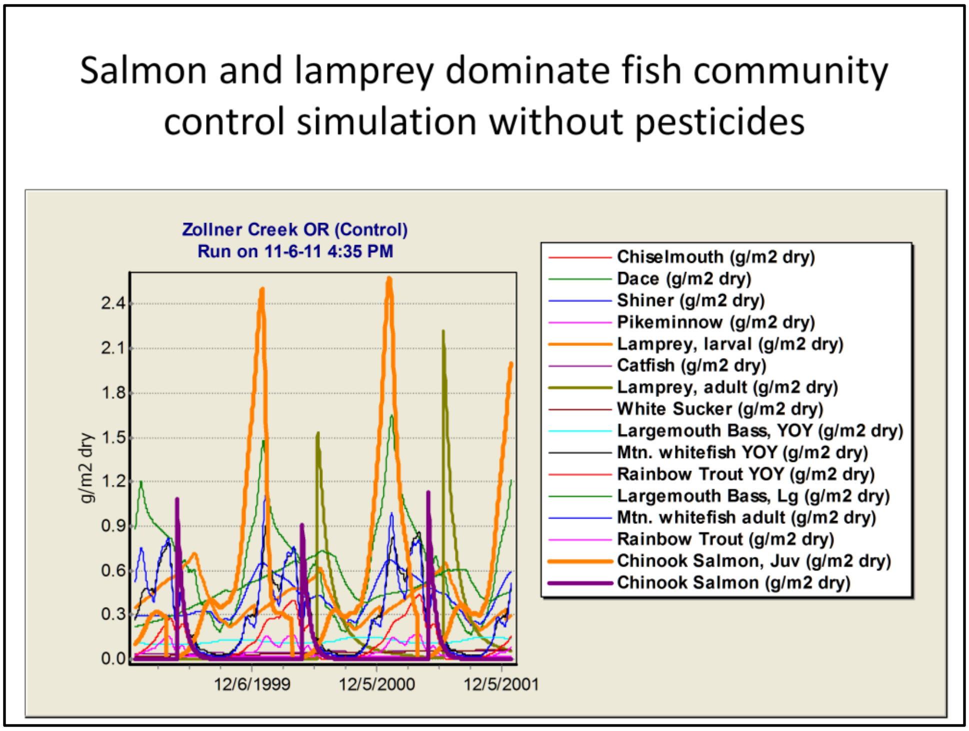


Based on the anadromous setup window, larval lamprey migrate out of the system in December of each year and adults return in June. Because there are no migrated juveniles in the "off-site" location until December of 1999, adult return does not occur until June of 2000.

The simulated growth rate of larval lamprey is close to the observed rate



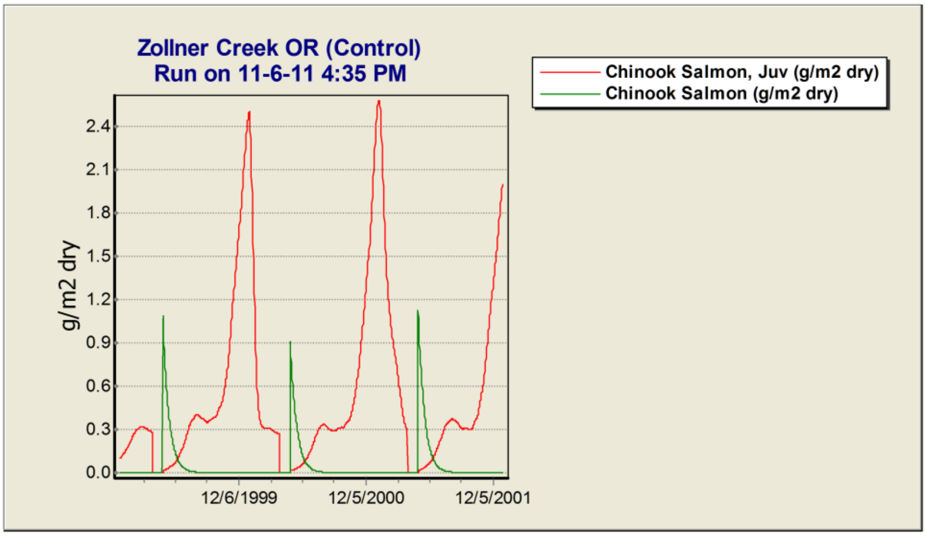
Additional calibration could improve this fit, especially if more data were available (meaning we'd have a higher confidence in the data). Lowering the respiration rate would be one way to increase growth rates.



Dace and Mountain Whitefish also exhibit high biomasses. Viewing as a percent exceedance graph helps to see which biomasses are highest over the longest period of time. Also statistics can be generated and sorted showing the following mean biomasses:

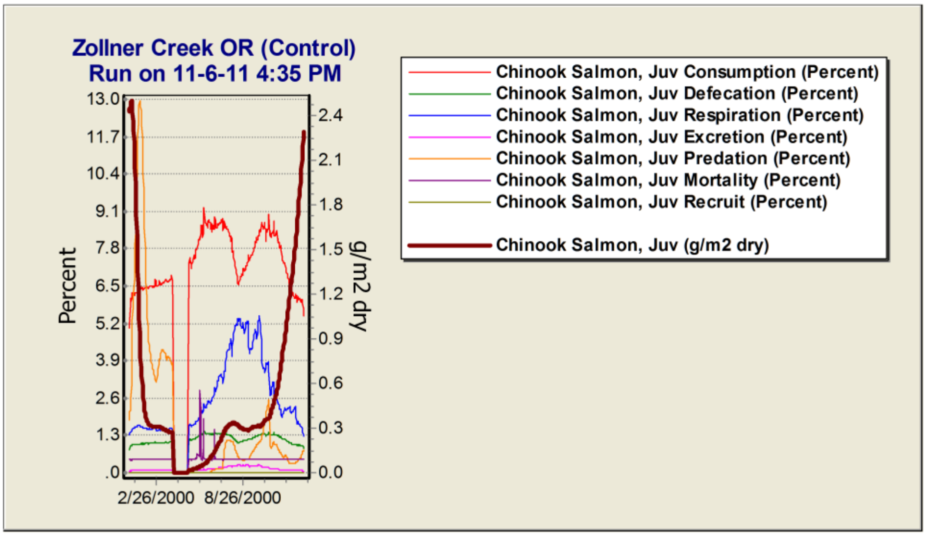
Dace (g/m2 dry),	0.65
Chinook Salmon, Juv	0.54
Largemouth Bass, Lg	0.48
Shiner (g/m2 dry),	0.41
Lamprey, larval	0.40
Mtn. whitefish YOY	0.30

In the control simulation the peak juvenile salmon biomass may be too high



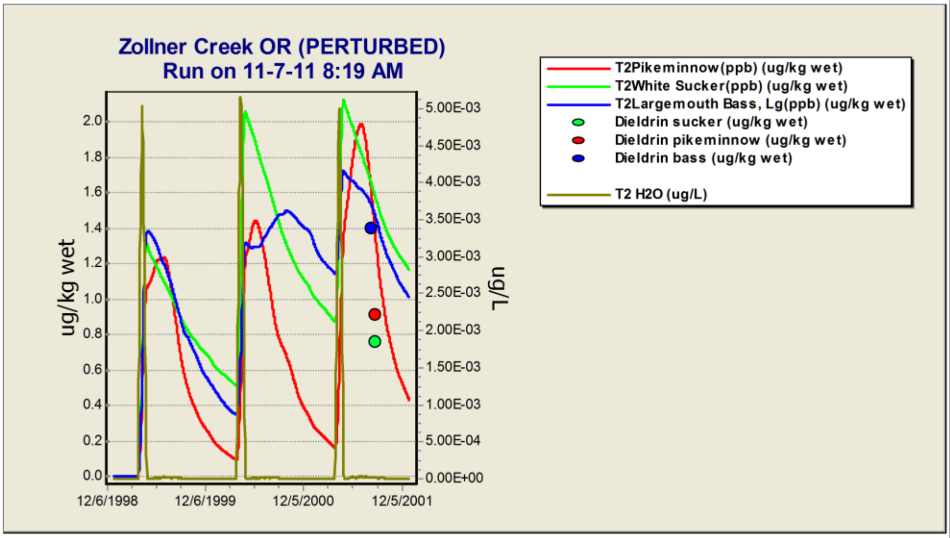
Unfortunately, we do not have observations of salmon biomass in Zollner Creek. If you believe the salmon biomass is too low for the adults and too high for the juveniles, you may wish to calibrate them further on your own. For the adults, decreasing the off-site mortality rate will have a direct effect. For the juveniles, increasing mortality, increasing the minimum biomass at which feeding occurs, and changing the mean weight (from 25 g, which seems low) would have some effect.

Plotting the rates may provide some insights into what is behind the high biomass



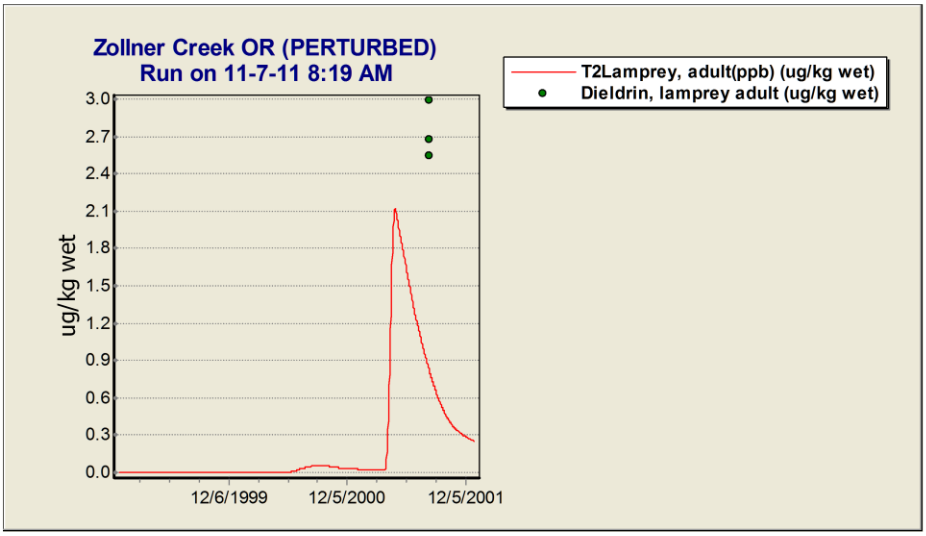
For the juveniles, increasing mortality, increasing the minimum biomass at which feeding occurs, and changing the mean weight (from 25 g, which seems low) would have some effect. In edit mode you can select a shorter period to plot.

Dieldrin tissue concentrations are verified with limited data for three species



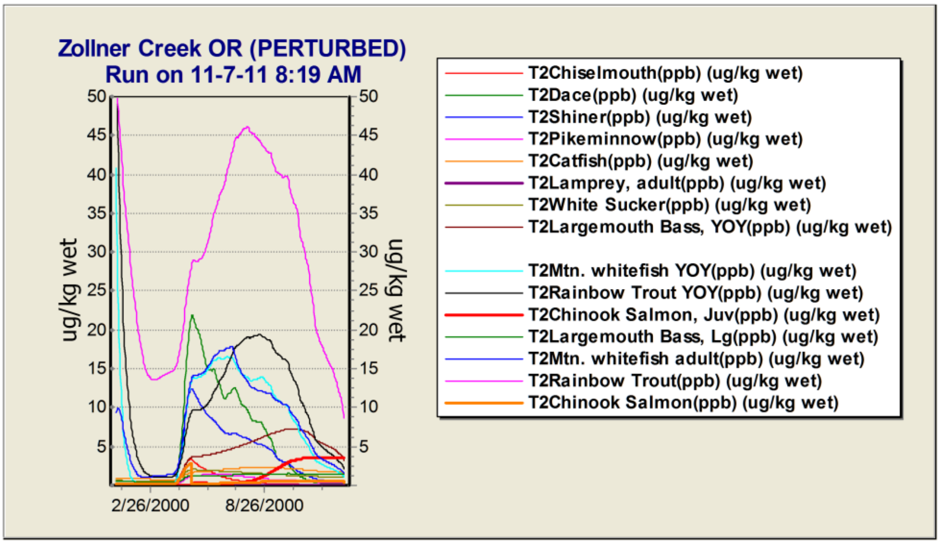
Finally we get to the bioaccumulation of toxicants! We were unable to find any tissue data for chlorpyrifos, but we did find some data for dieldrin.

Dieldrin in adult lamprey (data from 2009)



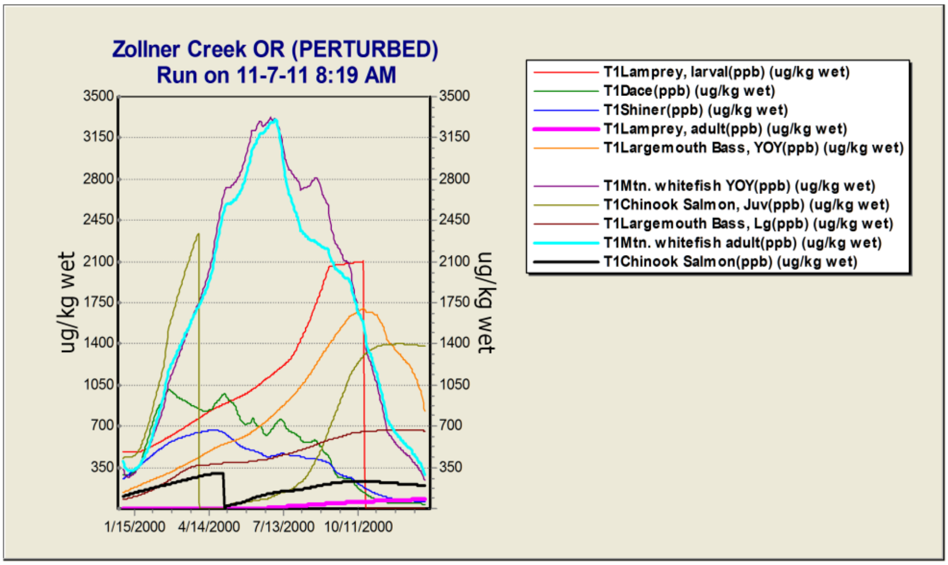
Observed tissue concentrations of dieldrin taken from Willamette Falls on 8/17/2009.

Predicted concentration of dieldrin in fish exceeds action level of 2.3 ug/kg



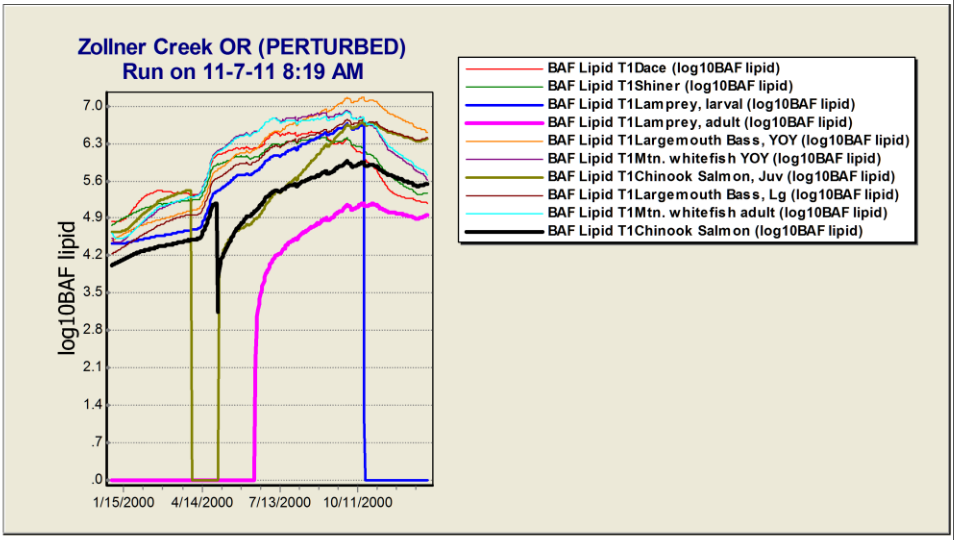
Keep in mind that this is approaching a worst case simulation. However, the results suggest that additional samples, especially of piscivorous fish, should be taken.

Chlorpyrifos in fish (ug/kg wet)

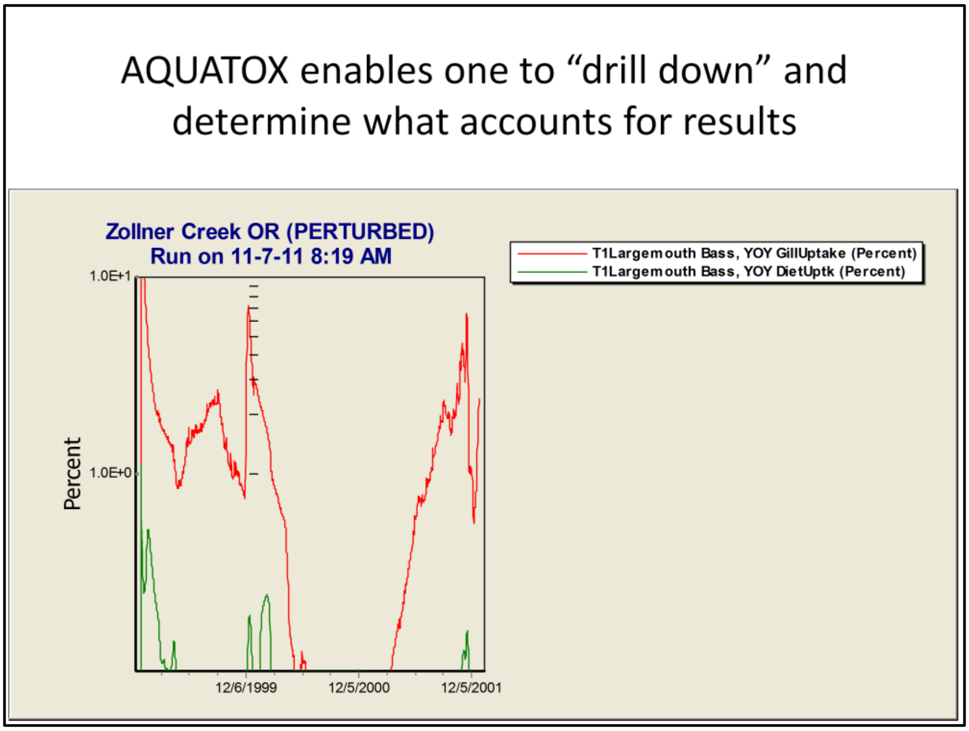


Mountain whitefish have the highest predicted concentration of chlorpyrifos, followed by trout and juvenile salmon. Exposure to chlorpyrifos is seasonal compared to pulsed exposure to dieldrin.

Lipid-normalized Log BAF for chlorpyrifos in fish



The log bioaccumulation factors normalized to lipid content are easier to interpret than chlorpyrifos concentrations. According to the simulation, adult lamprey enter the system “clean” (assuming they are not exposed to chlorpyrifos offshore); however, they rapidly take up the toxicant once in the watershed. Larval lamprey have a high lipid-normalized BAF, but then they migrate out. The highest BAF in the simulation is in YOY bass; being small with a high respiratory demand we would expect them to take up chlorpyrifos rapidly across the gills.



In the previous slide we noted that the lipid-normalized BAF for chlorpyrifos was highest for YOY bass, and we speculated that it was because of high uptake across the gills—this plot proves the point.

Clearance rate is a fn of lipid, weight, and KOW
Clearance calculator.xlsx can be used off-line

Depuration as fn lipid, wt, and KOW			
Dieldrin			
Clearance Rate Calculator			
WetWt	4000	g	(also try 25 g for juvenile)
LipidFrac	20%	g lipid / g wet	
LogKow	5		
Nondissoc	1	fraction	
Clearance Rate Calculator Output			
K2 or Clearance	0.00269		
*LogK2 := -0.536 * LogKOW - Log10(Nondissoc) + 0.116 * POWER(WetWt,RB)/LFrac;*			

Clearance calculator.xlsx is in the Lab 6 folder. It duplicates the classic estimation procedure in AQUATOX and can give you a "feel" for the importance of lipids and weight for depuration. Note that chlorpyrifos and dieldrin both have a log KOW of 5, so clearance would be the same.

Closure?

- You may wish to examine other aspects of the results or even make changes and re-run the model
- However, Lab 7 is a logical continuation