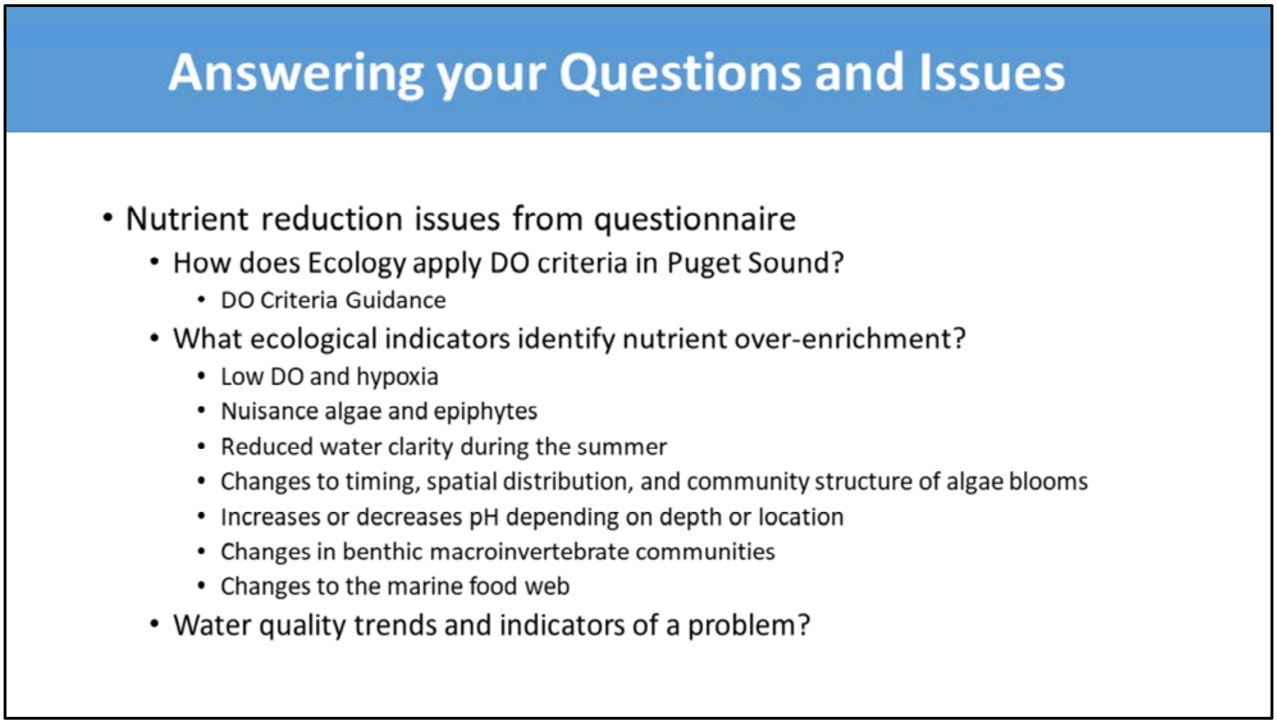
Good morning, welcome to those of you here and on the WebEx. This morning I'm going to recap a little of what we've heard over the last three Forums and set us up for the rest of today's presentations by talking about our general approach to using the Salish Sea model and the first part that we are calling bounding scenarios

Summer Science Forums

- Christopher Krembs (Ecology)
- Bryson Finch (Ecology)
- Teizeen Mohamedali (Ecology)
- Ben Cope (EPA Region X)
- Parker MacCready (UW, School of Oceanography)
- Marisa Litz (WDFW)
- Jan Newton (UW, Applied Physics Lab)
- Stephanie Jaeger, Kim Stark, and Gabriella Hannach (King County)
- Bart Christiaen (WDNR)
- Rich Sheibley (USGS)

I want to start off by recognizing and thanking the speakers who have contributed their time and shared their work at the last 3 Forums. We've listened to a lot of great information and I'm sure that all of us have walked away with as many new questions as we've had answers.

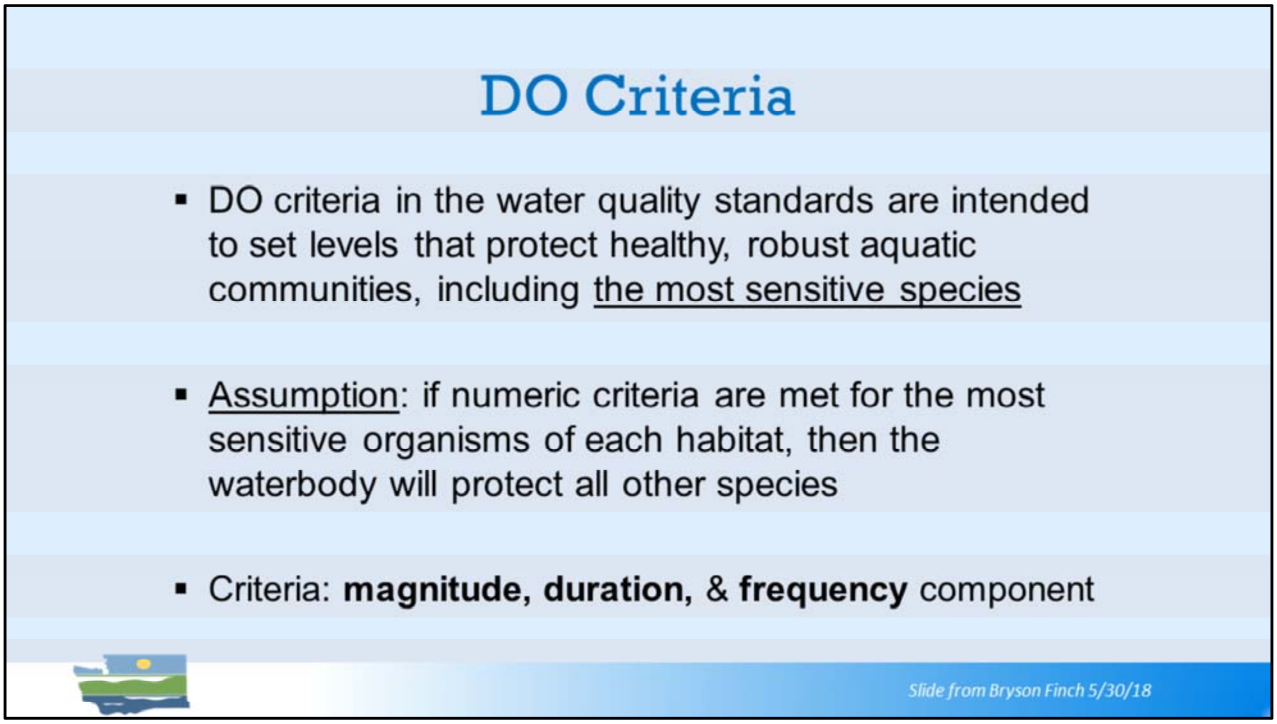


First, I want to bring your attention back to the Implementation Issues questionnaire that many of you provided input on last spring. The intention for this questionnaire was to help me understand what your issues and questions are so that we can address them in this Forum.

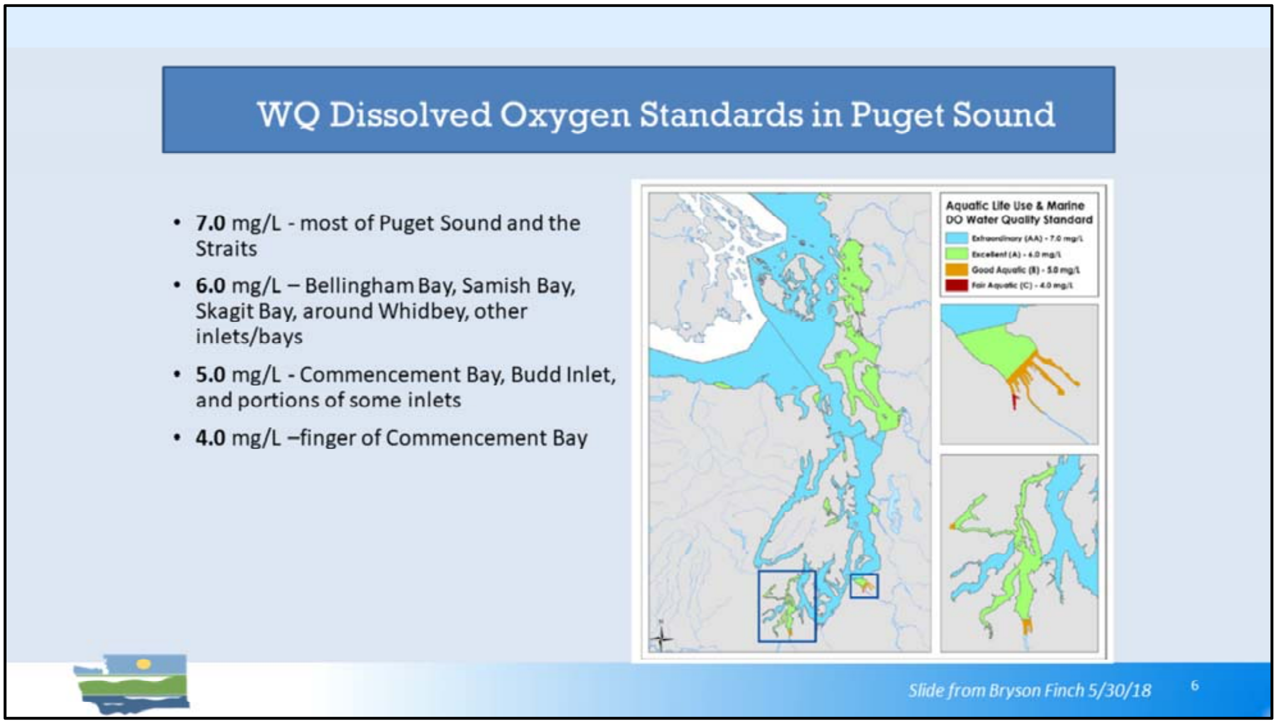
These are the types of questions that we've tried to cover. *Read questions in first level* bullets.

In some cases, more work and data collection is needed to provide more certainty of our understanding to problem and processes leading to it. This isn't necessarily the last time that we will be talking about these issues either. I'm going to take a little time to reflect on what we've covered.

The first questions we addressed regarded the state water quality standards for dissolved oxygen in Puget Sound. Ecology's water quality standards lead, Bryson Finch, prepared a guidance document that described our criteria, how we apply it, where it came from, and why we think it is an appropriate standard.



Dissolved oxygen levels established in the water quality standards are intended to set levels that protect healthy, robust aquatic communities, including the most sensitive species.



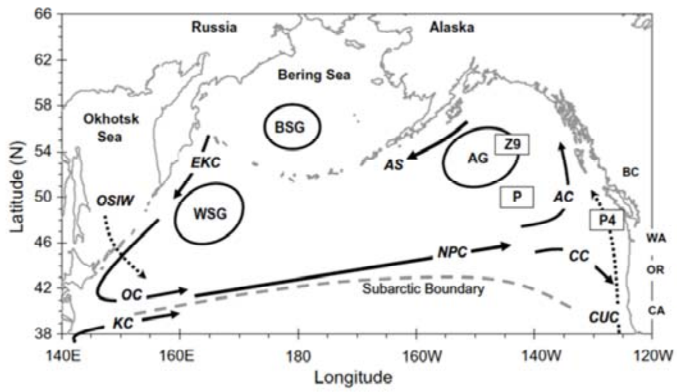
We have numeric criteria established for large and small areas of Puget Sound. It is when the natural, or what we call the reference condition, is below these criteria that the allowance for human depletion kicks in. That 0.2mg/L allowance applies to the sum of human sources, and for now we are limiting it to human sources that discharge to Washington waters in the Puget Sound region.

There was a lot of good information presented about what is known about water quality trends based on long-term monitoring data and the oceanographic processes in the Pacific Ocean, the Salish Sea, and the Puget Soundthat affect those trends.

Source of the Pacific Subarctic Upper Water (PSUW)

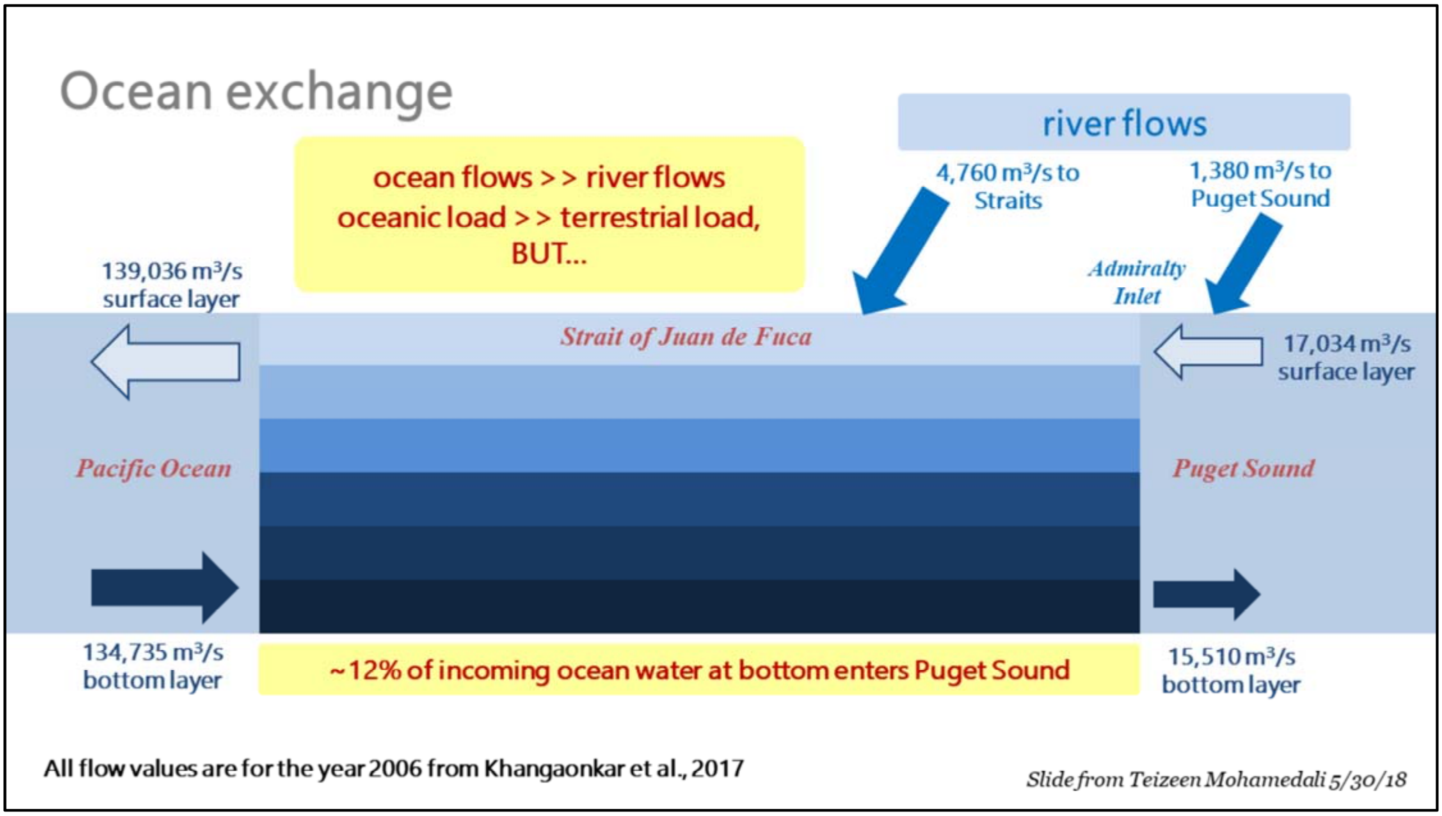
Whitney et al. (2007, Progress in Oceanography) Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific

- Increased stratification in the western subarctic gyre decreases ventilation of the PSUW
- PSUW takes about 7 years to cross the Pacific
- If it goes slower it loses more oxygen



Slide from Parker MacCready 7/16/18

In July, Parker gave us a look at ocean processes and drivers that affect how the deep Pacific ocean enters the Salish Sea. The El Nino Southern Oscillation and the Pacific Decadal Oscillation can affect whether we have good years or bad years in terms of conditions that affect marine water quality. Trends in deep ocean water are continuing to decrease in dissolved oxygen concentrations and increase in nitrogen.



Teizeen also emphasized that a lot of the ocean water entering the Straits doesn't even make it into Puget Sound, only about 12% of the incoming ocean water at the bottom enters Puget Sound.

Explain the graph.

The bottom line is that the mass balance of nitrogen varies with season, time of year, and location. The Salish Sea Model helps us keep track of that.

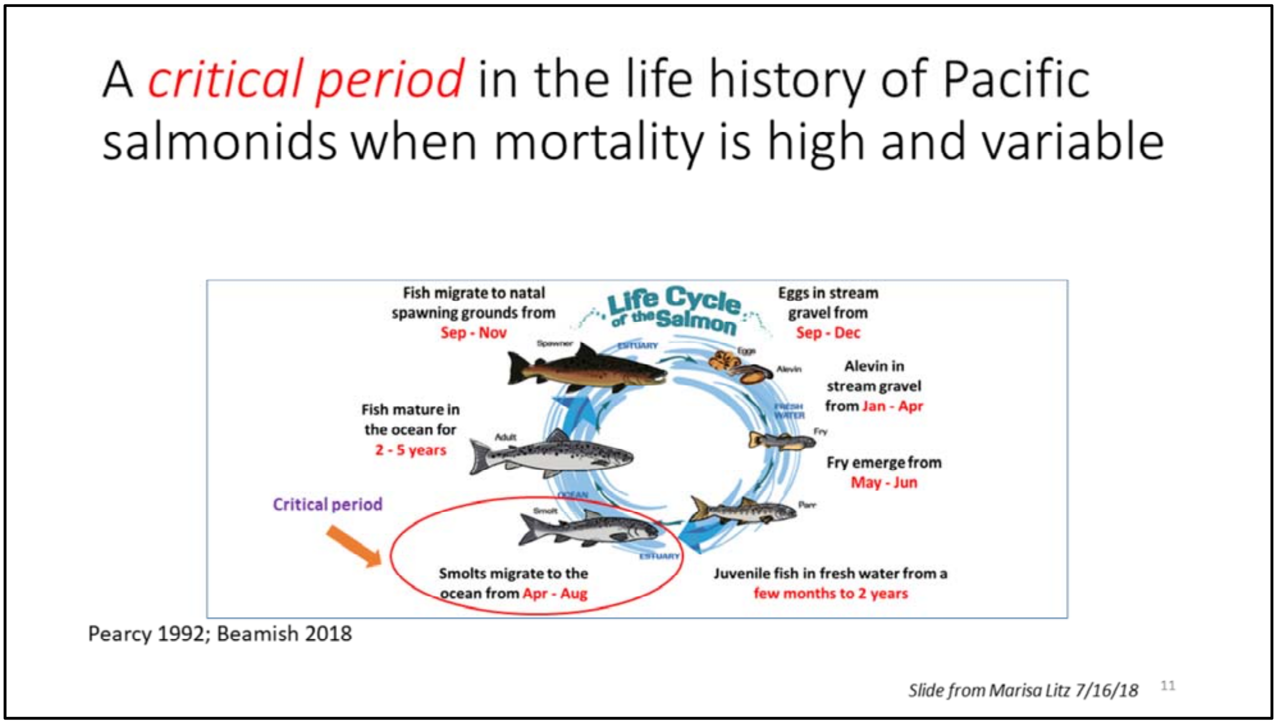
Summary

- We know that the **DO** of source waters **has declined** by 20% (20 uM) in the last 40 years.
- It is likely that **Nitrate has increased** by about 2 uM (6%) over that same time.
- The Juan de Fuca Canyon and Strait are effective conduits – during upwelling winds – for pulling in Pacific water from as deep as 300 m. This then feeds the estuarine inflow of the Salish Sea, which is strongest during summer in part because the Fraser River flow is larger then.

Slide from Parker MacCready 7/16/18

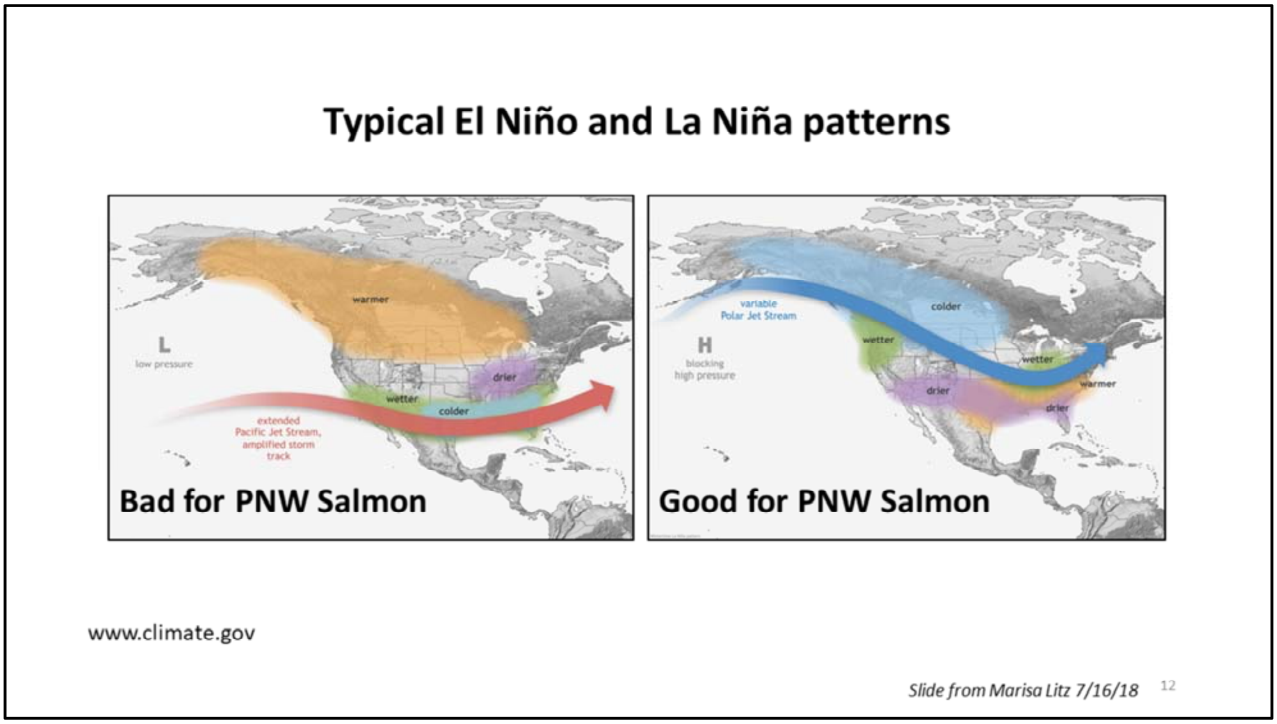
Estuarine circulation pulls deep ocean water into the Salish Sea and is regulated by watershed inputs, the largest and most dominating force is the Fraser River. The temporal variability of oceanic processes like El Nino and La Nina or the PDO are going to produce good years and bad years.

Additional stressors like warmer water temperatures will also affect the severity of impact from nutrient over-enrichment as well as other problems like harmful algal blooms. We have to consider this inter-annual variability when we think about providing resilience in the ecosystem for when conditions are really poor.



Marisa provided context about the life history of salmon in Puget Sound and the ocean, as well as the factors that affect their survival and reproductive success. There are many factors that affect their survival during each life history stage from eggs in streambeds, to migration as smolts, to ocean survival and returning spawners in Puget Sound watersheds.

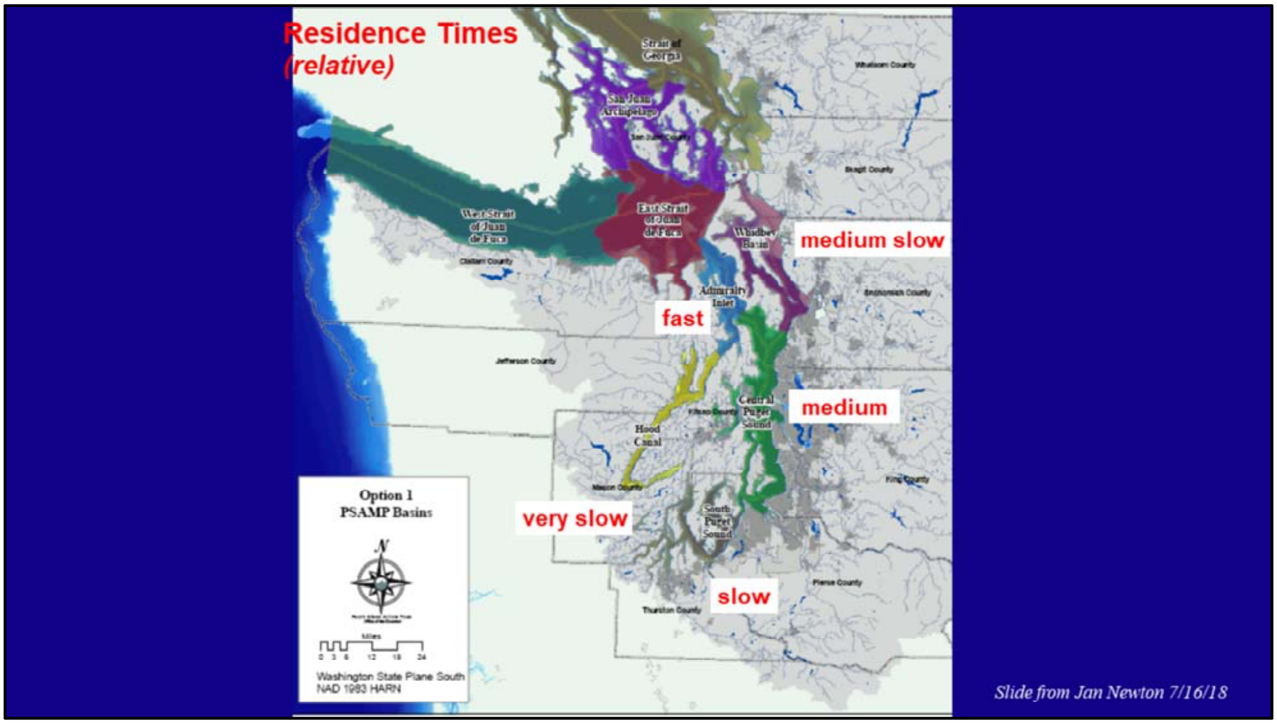
There are numerous pressures affecting salmon recovery and Marisa noted that the critical time for smolt survival is when they are utilizing our nearshore habitats and estuaries during the time we see the most problems with nutrient over-enrichment and extended durations of low DO. We are not going to successfully recover Puget Sound salmon if we can’t provide functioning nearshore habitats supported with good water quality.



Marisa pointed to bad and good years for salmon survival that follow the ENSO and PDO processes that Parker described affect the upwelling of deep ocean water off our coast. Inter-annual variability is something that we have to account for in our understanding of the problem and implications for how we manage our nutrient impacts. Do we manage to protect only for good years and accept degradation during bad years or do we create resilience so that Puget Sound can get through those bad years without significant harm to salmon, forage fish, and all aquatic species.

Jan continued on the theme that Parker started. She talked about the hydrodynamics of Puget Sound and how "place matters". She also reflected on some of the differences between Puget Sound and shallow large-estuaries like Chesapeake Bay. Unlike those shallow estuaries that have large productive areas, in Puget Sound the biologically productive and significant area is within a narrow fringe of nearshore habitat.

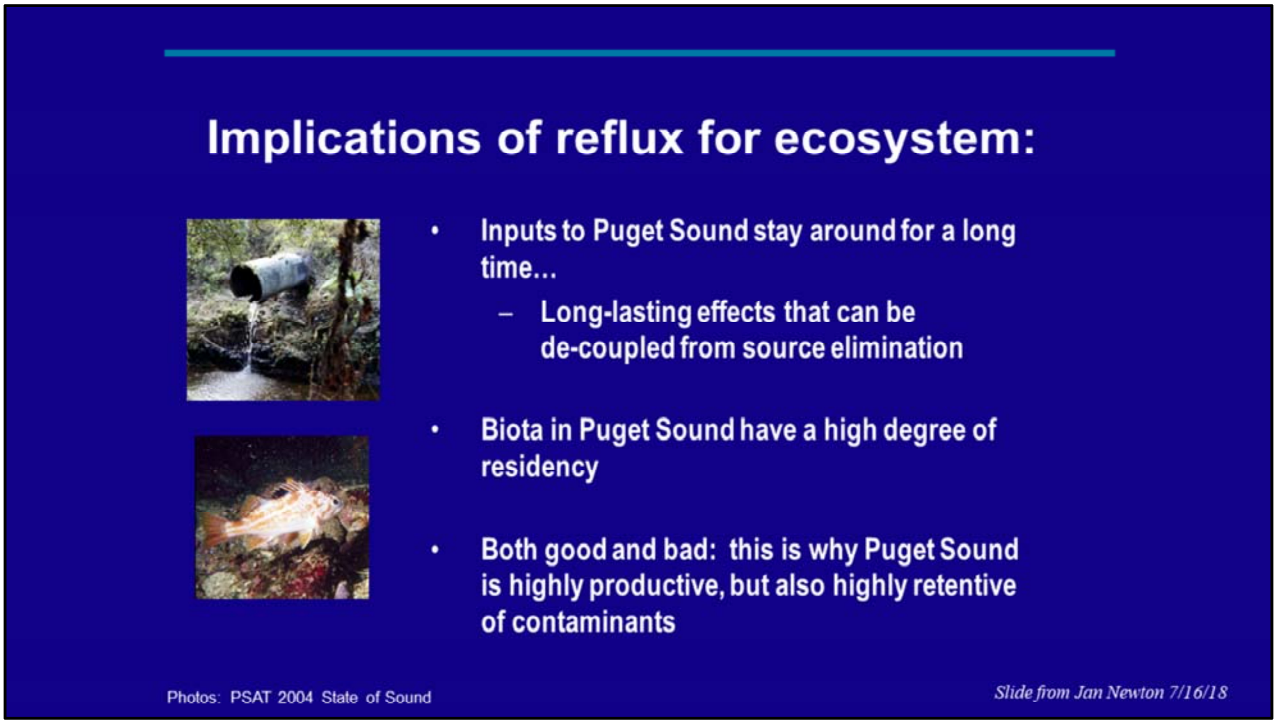
This is where salmon smolts grow bigger before going out to sea, where forage fish spawn, and eelgrass beds support a diversity of organisms. Many nearshore habitats occur in shallow inlets and bays which also happen to be the most sensitive areas to human nutrient sources according to our modeling.



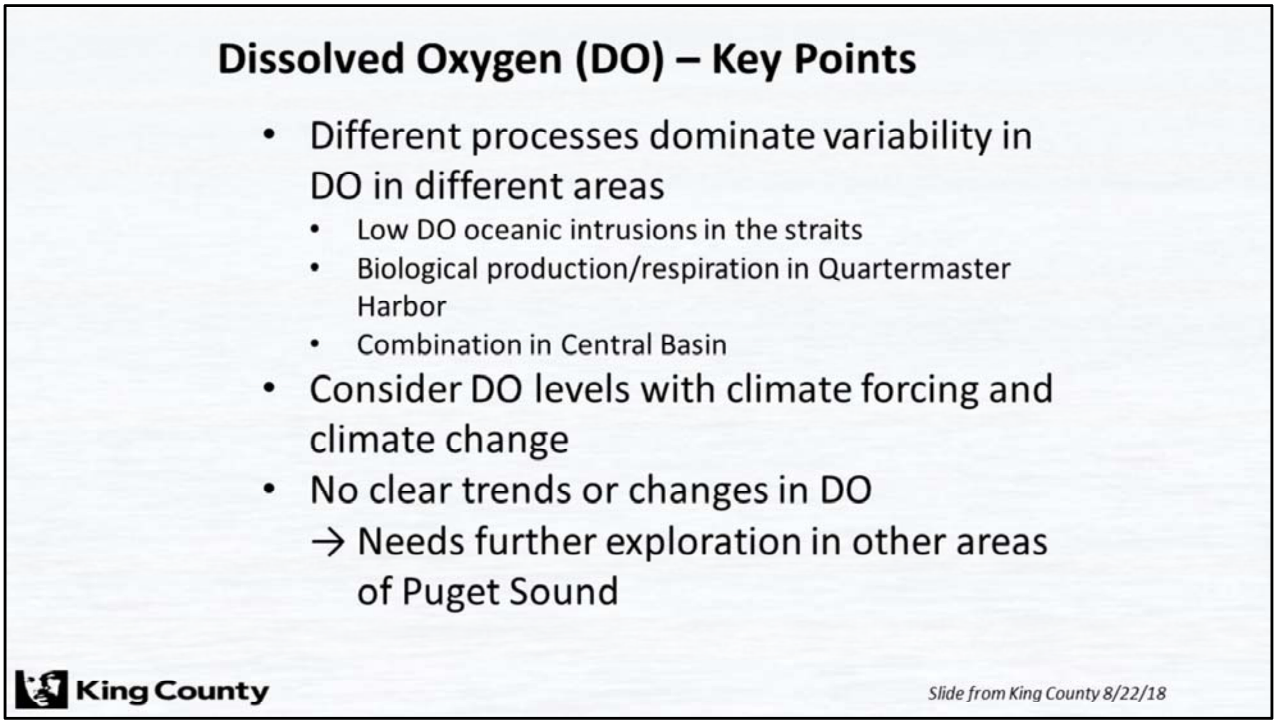
It is important that we think about Puget Sound consisting of different basins with different dynamics and characteristics. Jan talked about the importance of residence time on the effect of nutrients on water quality. We don't expect water quality in the Central Puget Sound or Main basin to be that bad compared to South Sound basin or Whidbey basin because residence times are different in each of these basins.

When we discuss the Salish Sea model outputs and how different nutrient reduction scenarios affect Puget Sound, we will be framing improvements in terms of these different basins. Not all basins work the same and within a basin, there can be strong spatial and temporal variation.

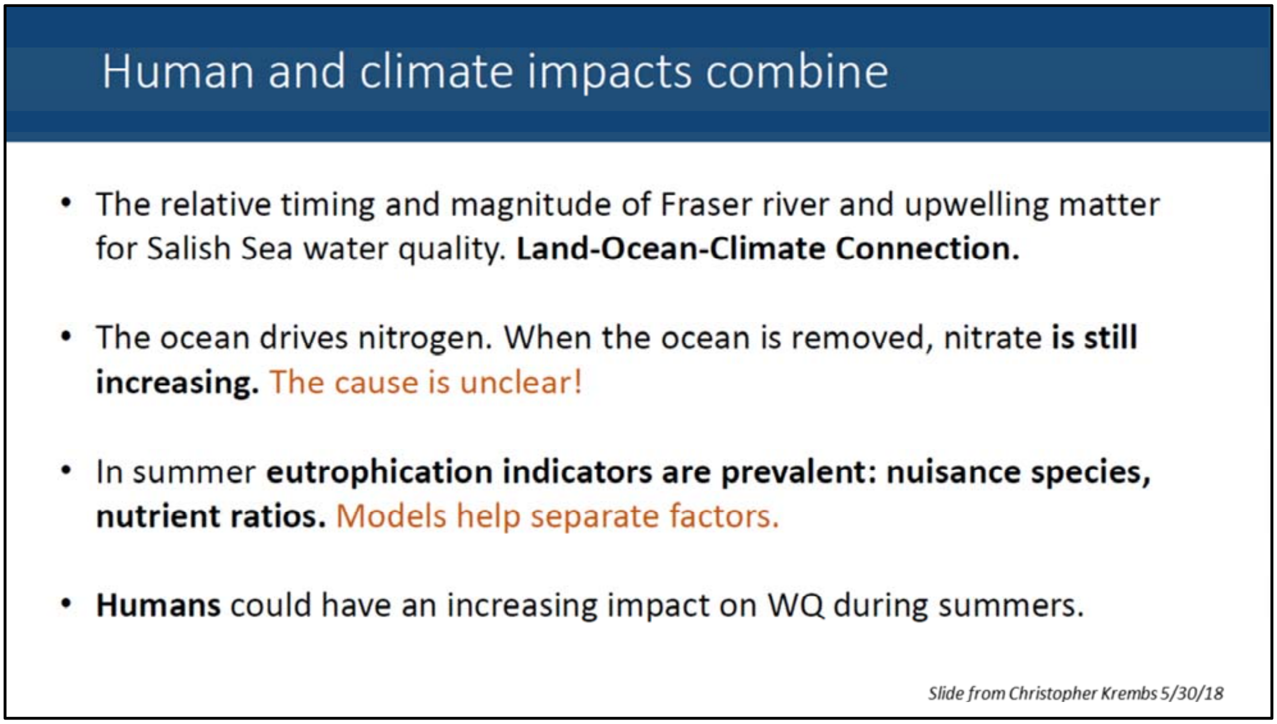
place matters



Jan reiterated the importance of reflux, noting that what flows into Puget Sound from our marine and watershed sources sticks around, sloshing around with the tides, and having far-field effects that make it difficult to quantify the source of problems with conventional water quality monitoring. That is why we need to have a complex, computer model like the Salish Sea model to quantify the effects that humans have on marine water quality.



Stephanie talked about the monitoring that King County does in the Puget Sound main basin. Their findings are generally aligned with what the Salish Sea model is predicting. We don't expect to see the same level of impact in a deep, mid-channel site in the main basin as we do in other basins that are more sensitive to human impacts like the South Sound Basin.



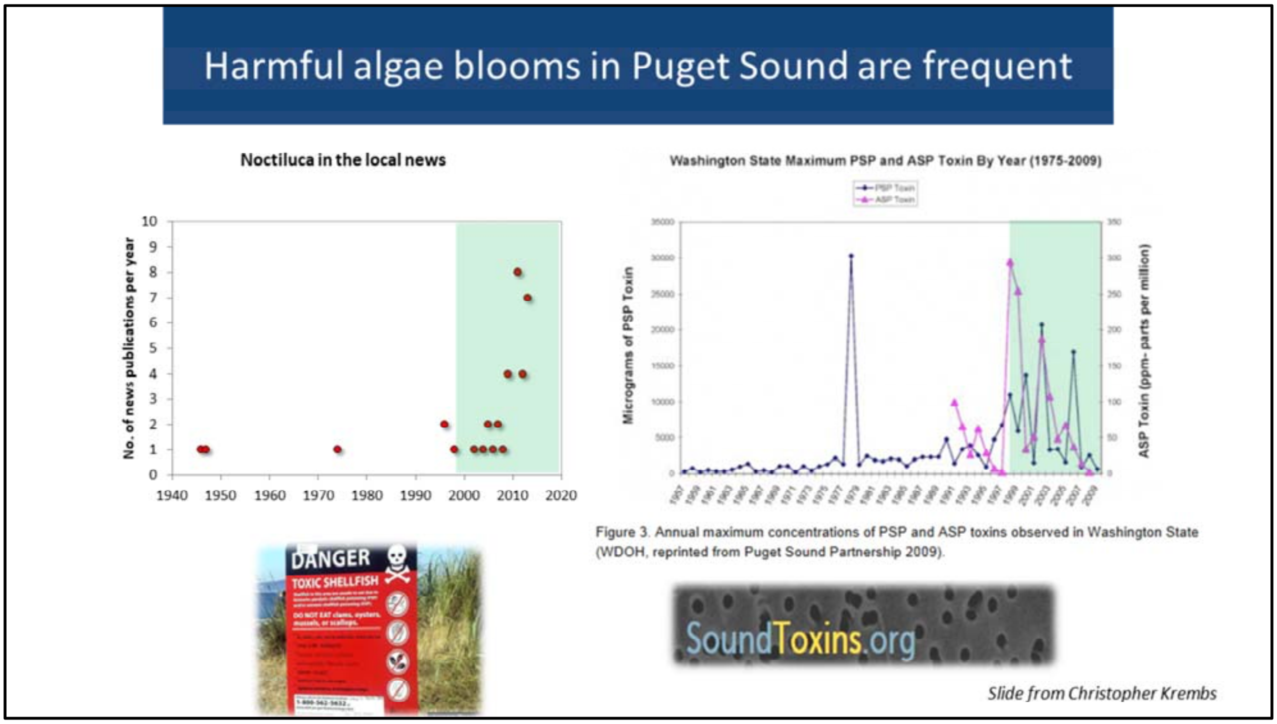
When Christopher analyzes all of the marine monitoring data from Ecology, UW, and King County, and looks at the Puget Sound overall, he overall increases in nitrogen that is not due to oceanic loading. These changes are happening primarily in shallow inlets and bays

Many questions that we recieved asked how nutrient over-enrichment connects to aquatic life uses and the different aspects of Puget Sound ecology and health.

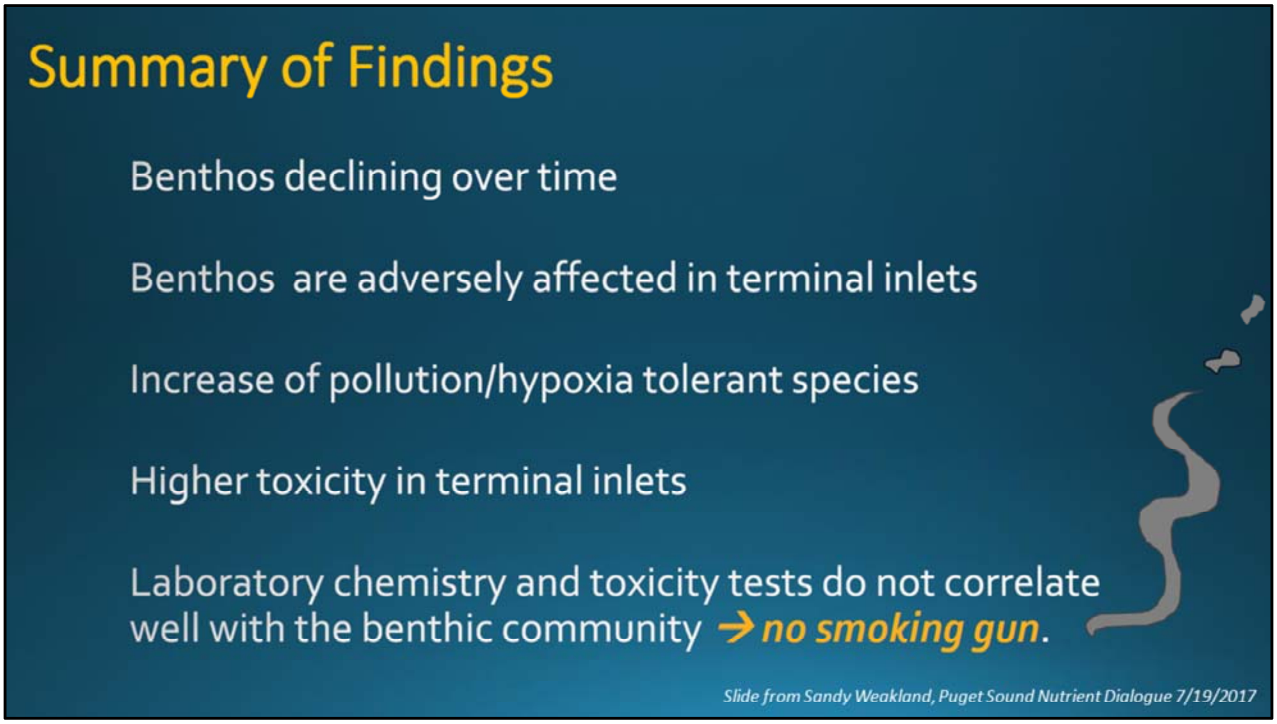
Christopher Krembs shared observations that have been made over the years as part of Ecology's long-term marine monitoring program. Algae blooms are natural and part of a productive ecosystem. We are not saying that blooms in and of themselves are a problem. But nutrient over-enrichment can alter the timing and extent of blooms, and the dead algal cells contribute to lowering DO on the benthos.

This primary productivity feeds the base of the marine food web, and it can either produce healthy food when productivity is rich in nutritious foods like diatoms. Or the productivity may result in less nutritious base of the marine food web with dinoflagellates like noctiluca or jellyfish.

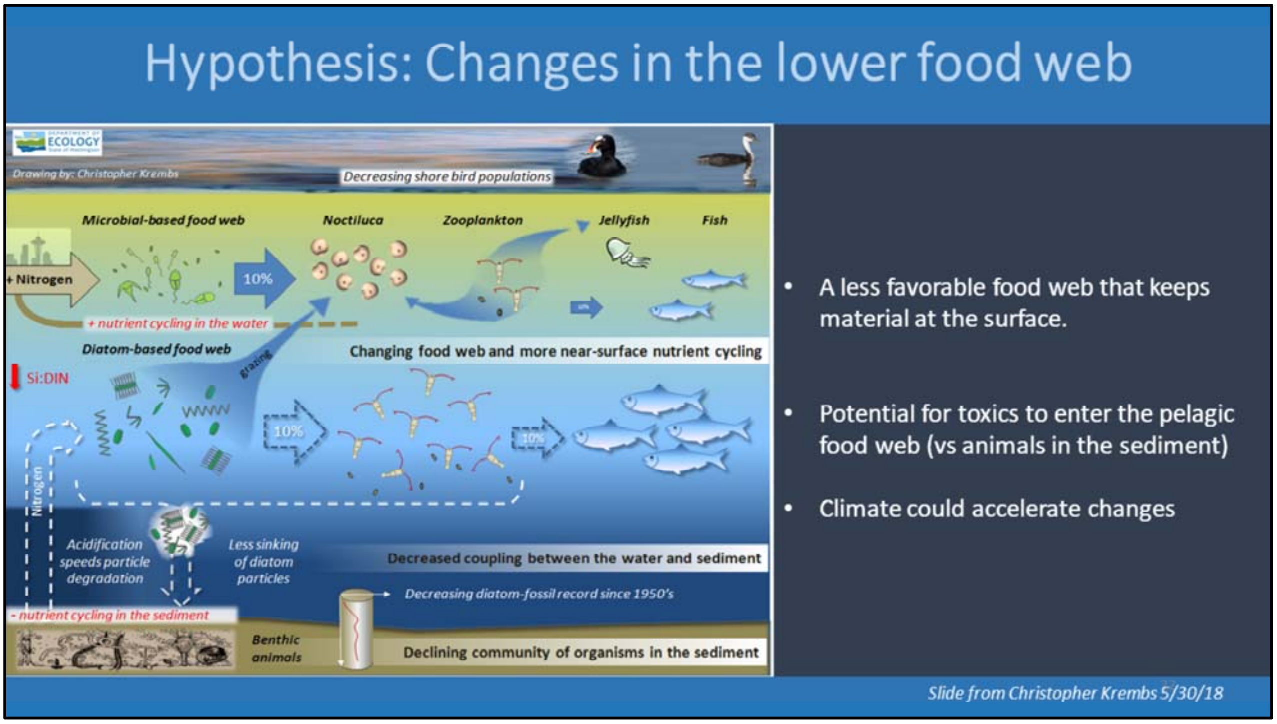
We still need more data to understand trends in the timing, density, and composition of algae blooms in the South Sound and Whidbey Basins.



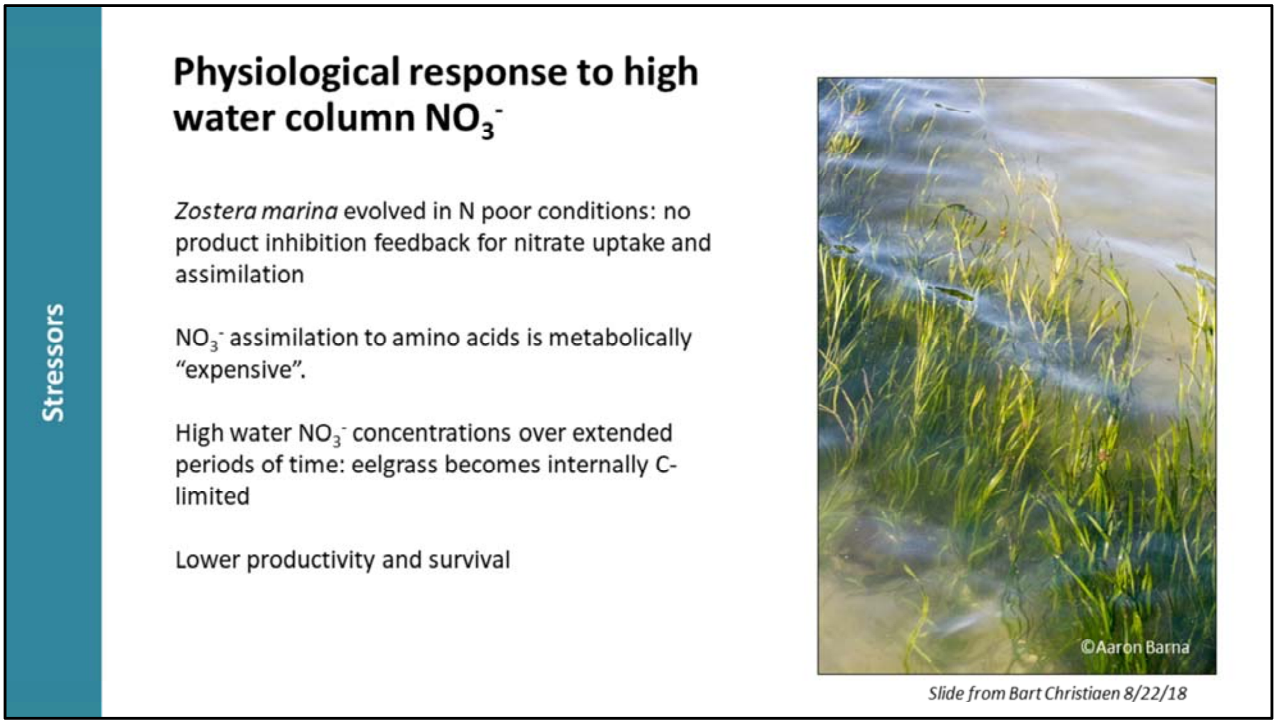
Christopher Krembs provided this slide to me from another presentation he gave recently. He and Brandon Sackmann had looked through historical records for local news about noctiluca blooms in Puget Sound. The graph on the left has red circles for each year noctiluca blooms were in the local news with the y-axis representing the number of publications per year. We recognize there is reporting bias in these data so this is really a qualitative measure, but they do seem to point to an increasing frequency of noctiluca blooms over the last 80 years.



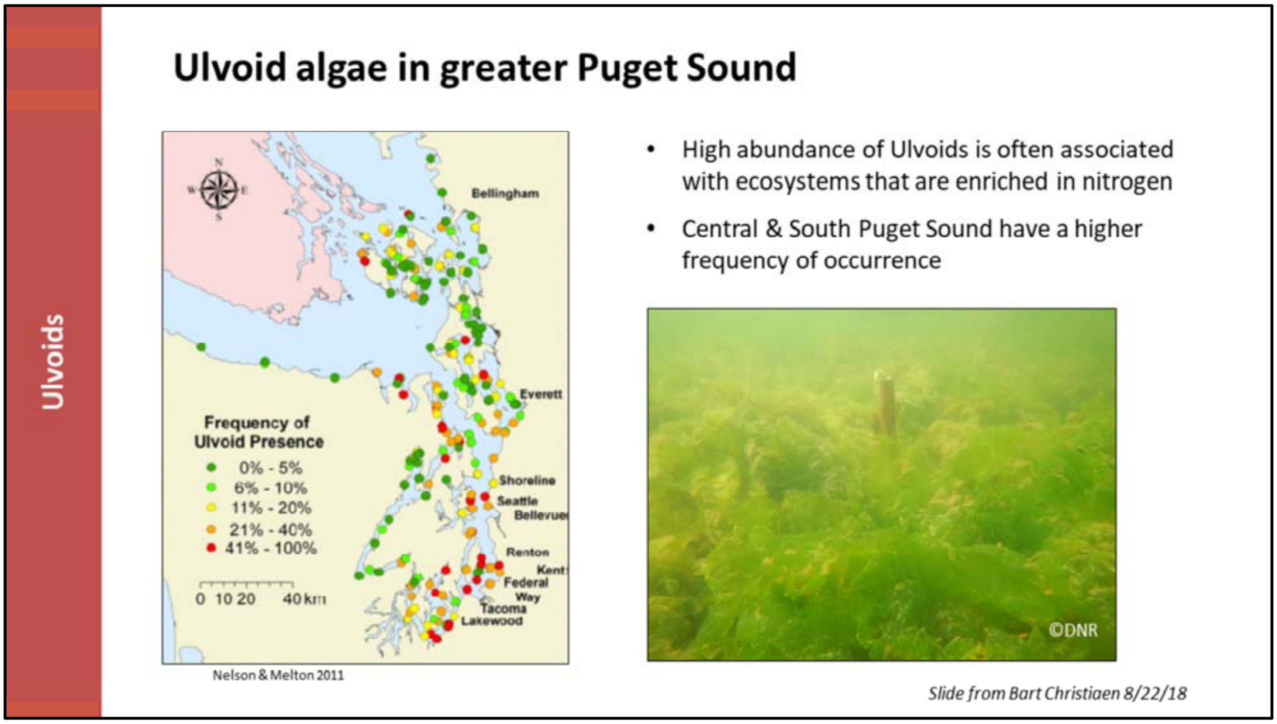
Last summer at the Puget Sound Nutrient Dialogue we heard from one of our marine sediment scientists, Sandy Weakland, about long-term trends in declining benthic community diversity and species richness they have measured for Ecology's long-term marine sediment monitoring program. They find that many benthic macroinvertebrate communities are increasingly favoring species that are tolerant of pollution and hypoxia.



Christopher talked about the emerging science that is pointing to changes in the marine food web that could be due in part to nutrient over-enrichment. Even though there are additional pressures affecting the food web (like temperature), reducing human nutrient sources may have a beneficial effects that support maintain a diatom-based food web and benefits on up the food chain for salmon and orcas.



Bart Christiaen talked about 3 mechanisms through which increased nutrients can promote seagrass decline: physiological responses like the way eelgrass productivity and survival is affected by nitrogen availability, competitive interactions, and biogeochemical changes in the benthos.



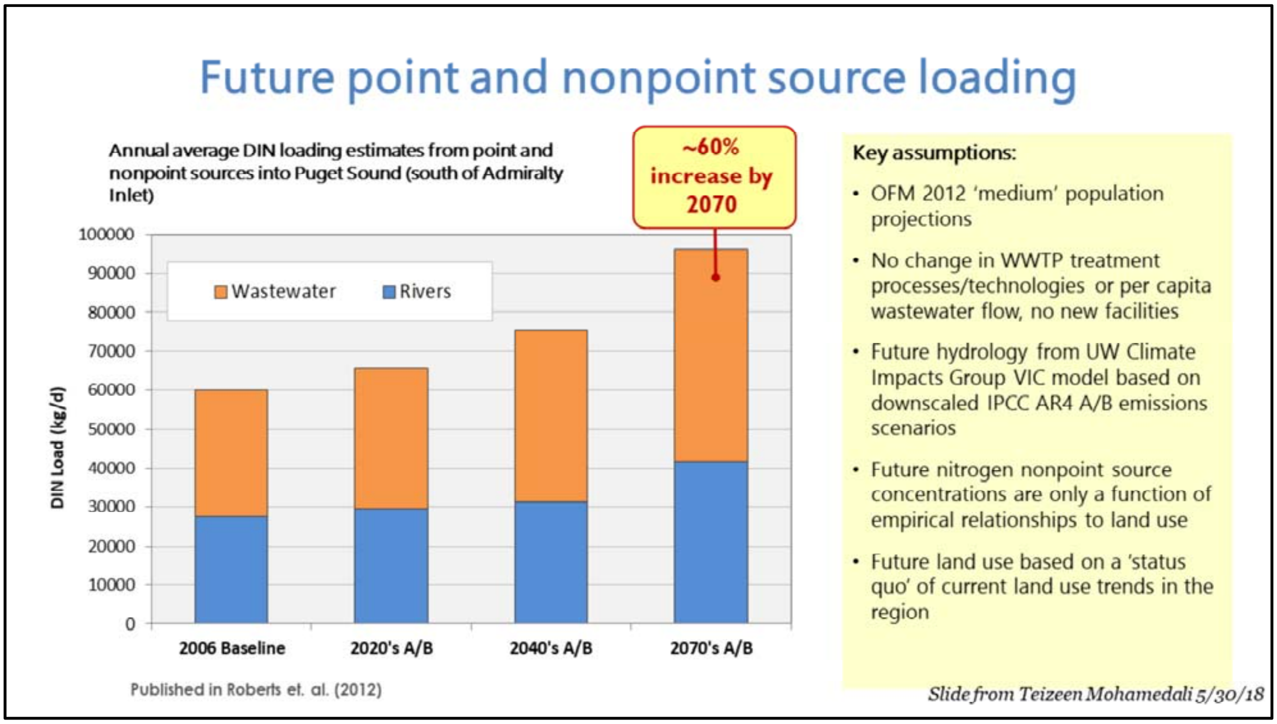
Competitive interactions that can also degrade nearshore habitats. Large blooms of green algae are a common occurrence in many coastal regions exposed to eutrophication and we see this happening in Puget Sound also. These blooms are caused by opportunistic species that have the ability to expand very rapidly when they are not limited by nutrients or light. Quite often they consist of species that belong to the genus Ulva. These species can either grow attached or free-floating, and they can accumulate at certain locations due to currents and tides.

In addition to this nuisance specie there are others epiphytic species that respond to nutrient over-enrichment and can also degrade eelgrass habitats.

Rich Sheibley described the importance of watershed nutrient attenuation and what we need to do to restore and protect those functions.

There are point and nonpoint nutrient source reductions that will be needed in watersheds, and at the same time we should be restoring and protecting the ability for our Puget Sound watersheds to naturally remove and transform nitrogen from our rivers and streams.

Why take action now??



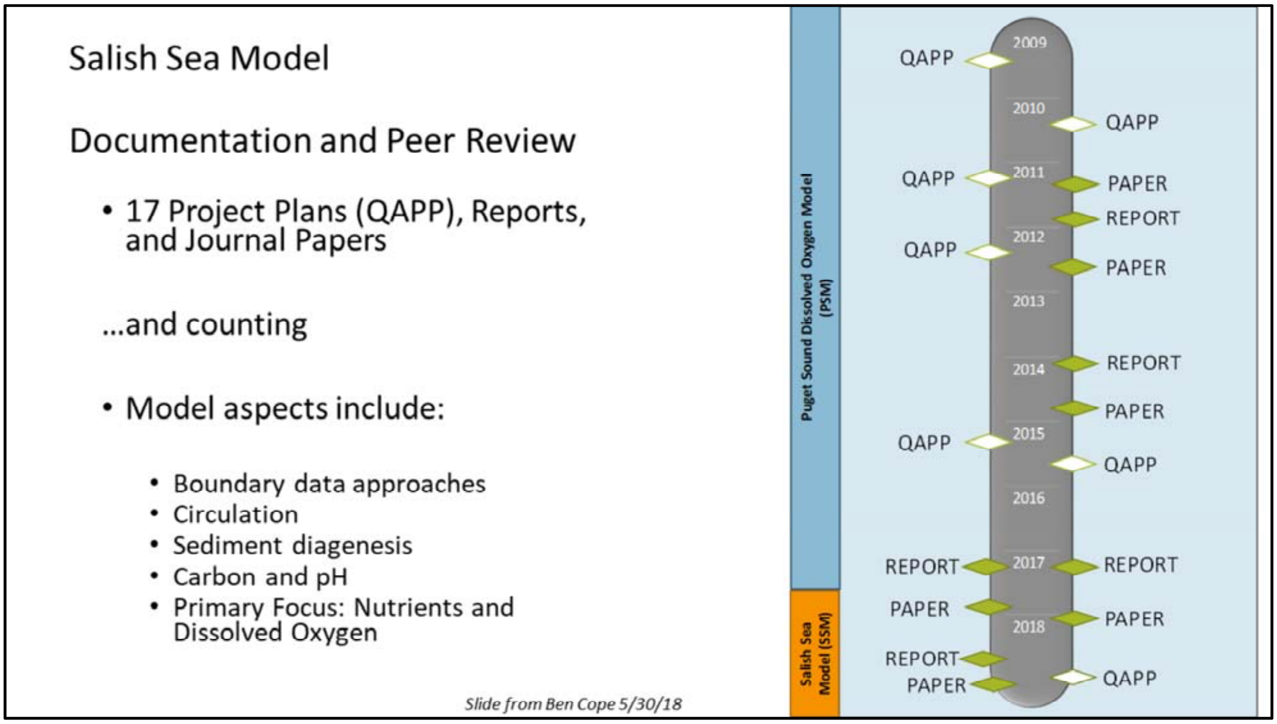
Human nutrient loading will continue growing over time and we will significantly increase our total nitrogen loading to Puget Sound over the next half century if we continue the status quo.

Over that period of time, we will need to continue adapting our infrastructure and capacity to treat that additional wastewater. Several wastewater treatment plants have been forward thinking about this. The LOTT facility in Olympia and Pierce County's Chambers Bay facility have taken this challenge head-on and most every other wastewater treatment plant in the region will continue to grow and face decisions about how to upgrade their facilities.

As facilities make those changes, they give themselves room to grow and significantly reduce their impact on water quality.

Bounding Scenarios: Understanding the significance of human impacts

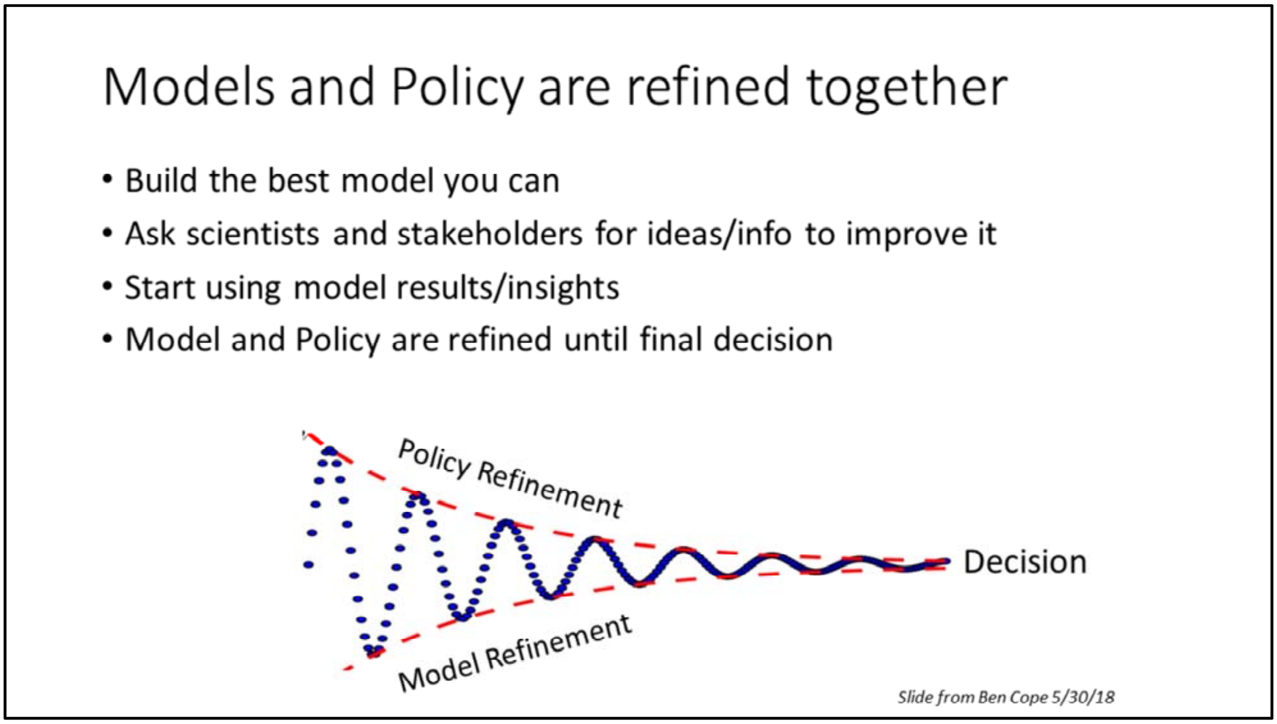
The bounding scenarios are meant as a starting place for us to discuss the marine water quality response to large categories of source reductions. The bounding scenarios are primarily designed to understand the significance of large categories of human sources, like how important are watershed reductions compared to marine source reductions.



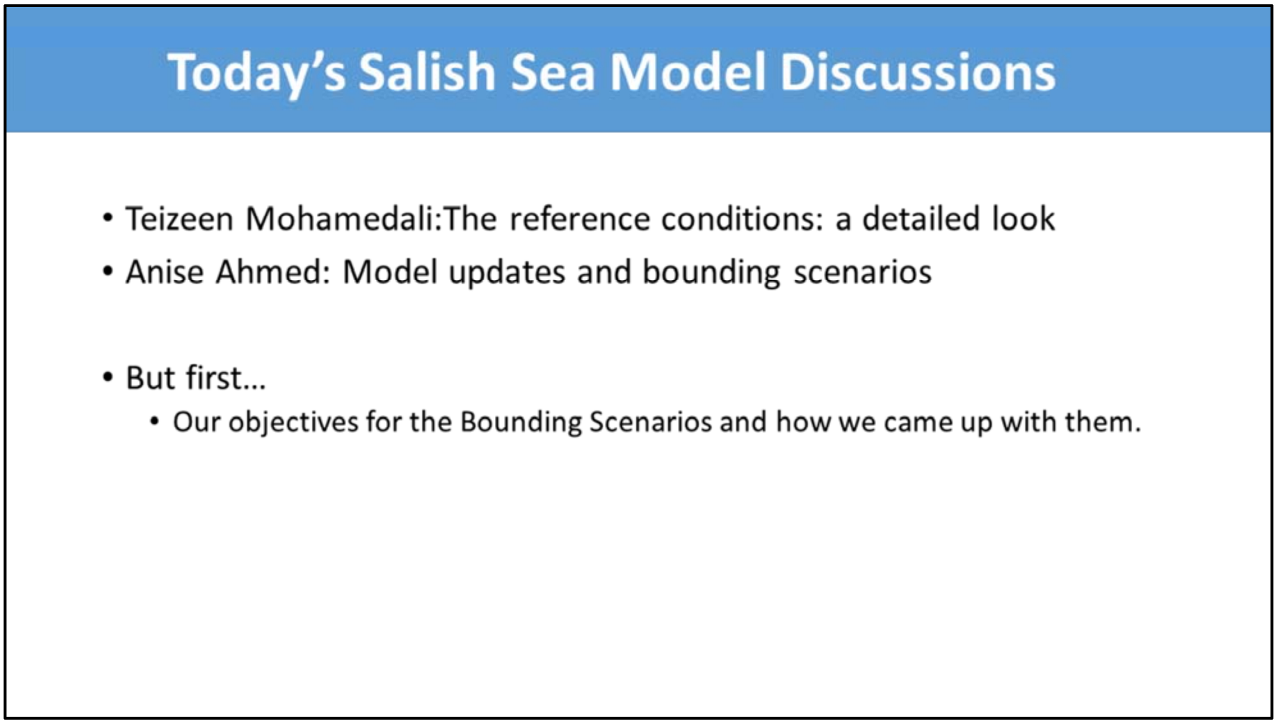
Ben Cope described criteria for a good regulatory model, including: thorough documentation, and peer and public review. The Salish Sea model is very well documented and has been through various reviews at each step of development. This work has been happening for a decade and we now have a good tool that has had a lot of engineers and scientists building it, reviewing it, and improving the model.

We believe the Salish Sea Model is a quality decision-making tool. We are open to continual improvement and we will be discussing that today and in future Forums.

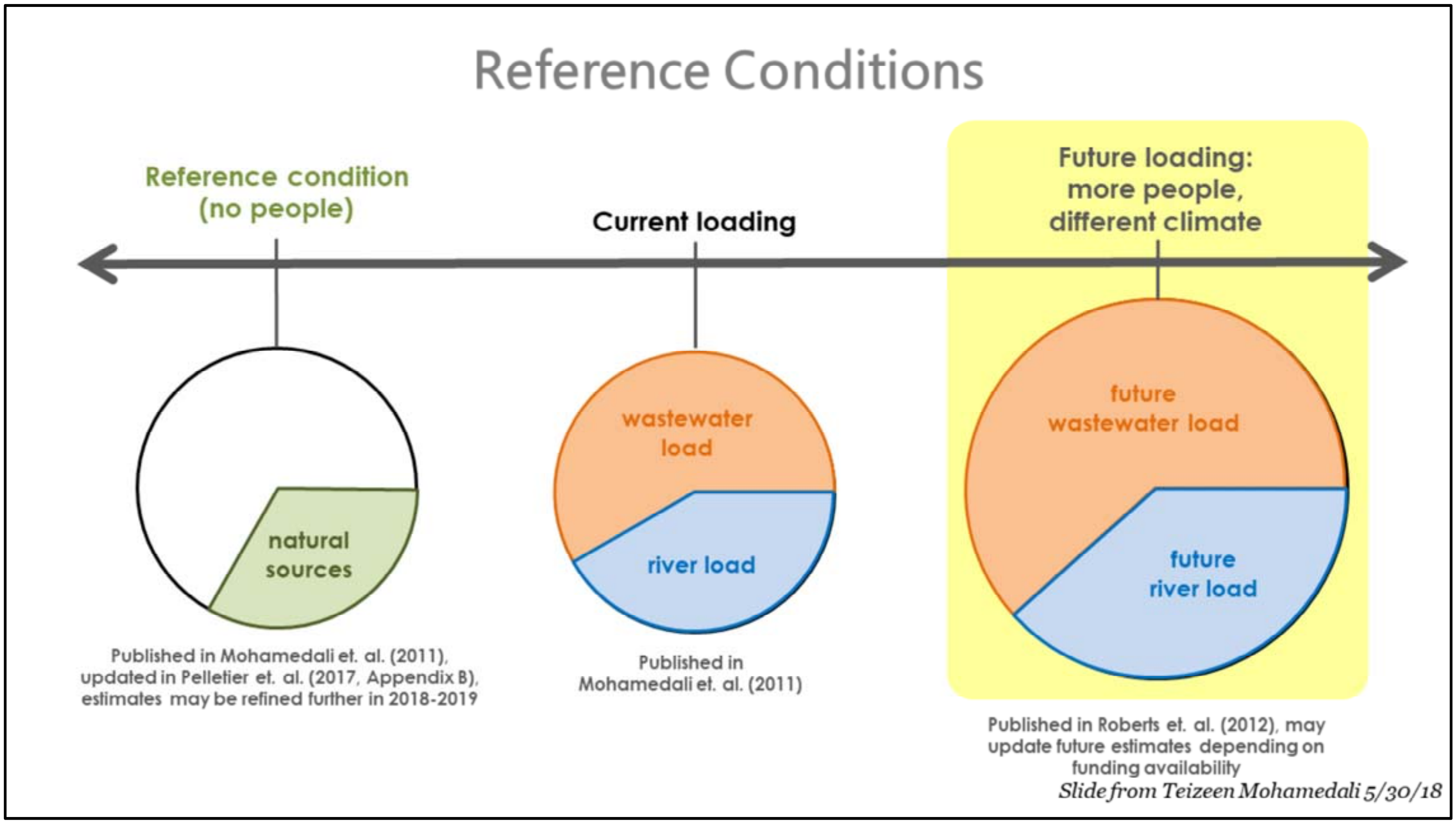
We need the Salish Sea Model, in addition to continued data collection, to understand the spatial and temporal variability of this complex system as well as to understand what we can do to reduce our human impact on marine water quality.



I like this graphic from Ben Cope which shows how modeling informs policy and vice versa, back and forth as we continue to refine each aspect until we reach a final decision. We will be evaluating lots of nutrient reduction scenarios and continually refining them until we find the set of marine and watershed reductions that meet water quality criteria.



Earlier this week, we sent out links to two documents that are meant to describe our approach for using the Salish Sea model in two different phases of modeling. The first phase, we are calling Bounding Scenarios, got started this summer with our modeling team and PNNL. Anise will go into more detail about this today, but I'm going take a few minutes first to describe our objectives for these scenarios and how we came up with them.



Our goal is to make sure that current and future loading does not violate our criteria and that means getting as far to the left on this line so that we are within 0.2mg/L of the reference condition. This includes figuring out how to reduce nitrogen from both marine sources that are primarily wastewater treatment plants and from watersheds draining to Puget Sound. Our earlier findings with the Salish Sea model found that existing loadings are causing violations of DO criteria and as we continue to grow, that will only get worse.

Using the Salish Sea Model is the best way to evaluate and predict what changes to human sources will get us in terms of marine water quality improvement.

How did we come up with the scenarios and how are we using them?

- Scenario objectives
  - High/Low bounds for temporal variability
  - Understand significance between watersheds and marine sources
  - Understand what a focus on marine WWTPs would mean for water quality improvement
- South Puget Sound DO model scenario examples
- Decided by Ecology's internal project steering committee

Read the title

We had modeling time that we needed to use over this summer and to use our resources wisely, we in Ecology's Water Quality Program decided to run some simple, high-level scenarios using the latest version of the model and improvements to inputs so that we can have a starting place for discussions to understand the scope of potential solutions. We also wanted to run the model for a couple different years so that we could begin to understand the effects of inter-annual variability on marine water quality.

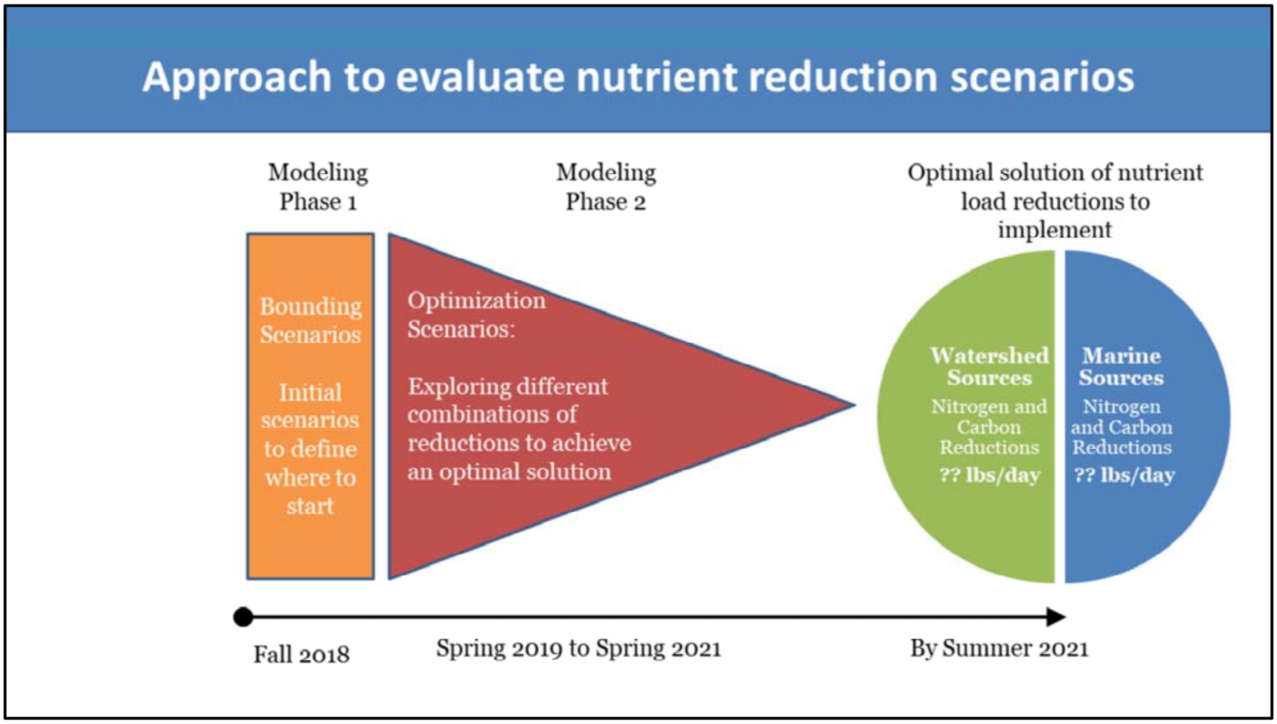
This project has an internal steering committee that includes some of our engineers, scientists, and key decision-makers. We met last winter to talk about what scenarios would provide a good foundation for discussions that will drive the next phase of modeling. We reflected on past scenarios, and some of the big questions we are grappling with, to come up with a group of scenarios that maximized what our modeling team could accomplish in a short period of time.

What scenarios are we testing now?

- Existing conditions
  - 2006 (above average) and 2008, 2014 (average) conditions
- Reference conditions
  - Understand when numeric criteria will not be met "naturally"
  - Calculate the Human DO depletion
- Bounding Scenarios
  - Marine sources vs. Watershed sources
  - How much improvement to expect from marine WWTPs
- Explorations in Parameterization

Anise and Teizeen will cover this in more detail today, but to summarize the scenarios in this first phase of modeling, they include:

- Evaluating existing conditions for years representing average and above average climate and circulation conditions
- Generating reference conditions for these years so that we can understand if Puget Sound meets our DO numeric criteria. This also gives us a way to calculate the human DO depletion part of the criteria
- Comparing the significance of marine sources vs watershed sources as well as better understanding how much improvement we should expect from reductions at wastewater treatment plants discharging directly to marine waters
- And we are also exploring the sensitivity of the model output to changes in some of the assumptions for parameters used in the model. We had questions about whether we are using the appropriate values for rates and other parameters in the model so this will help us understand how much of an impact each of those assumptions have on the model output.



Our overall modeling approach includes two phases. The first phase that we are currently working on includes the bounding scenarios. We will have results to discuss with you all later this fall. That will lead us into phase 2 which will include what we are calling optimization scenarios with the objective to achieve an optimal combination of marine and watershed source reductions.

We will have a Forum or workshop early next year with all of you to discuss what scenarios to model in Phase 2. We have about a two-year budget to accomplish as much modeling as possible. At most we might have four iterations in which we run a set of scenarios and analyze them every 6 months, and then apply what we learn from each iteration to improve on the scenarios we run in the next iteration.

The number of the iterations might change depending on the progress we make, but we will have to be judicious in what we run because we have limited resources and time. During that time period, we also coordinating with Naomi Detenbeck at EPA on improving the SPARROW model to use as a decision support tool for watershed nutrient management scenarios that could achieve the watershed reductions identified with the Salish Sea Model.

Finding the Sweet Spot with Modeling Phase 2

- Compare change within basins
- Which combination of marine and watershed sources meet the water quality target?
  - Different levels of reductions from different sources
  - Annual reductions vs. seasonal reductions (and which seasons?)
  - Where to focus activities
- We might not be able to do everything so which source reduction actions give us the "biggest bang for the buck?"

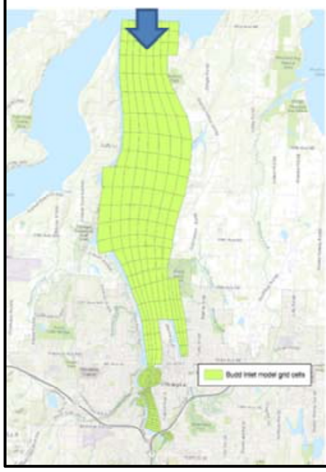
The objective for phase 2 of the Salish Sea modeling effort will be finding the optimal set of marine and watershed reductions that meet our DO criteria and balance a range of factors including: accounting for inter-annual variability and seasonality, constraints for sequencing implementation, affordability, and feasibility.

We might not be able to afford to do everything all at once, so we will have to think about sequencing and how we can reduce sources over time to meet our water quality objectives. For now I'm calling this optimal solution the sweet spot.

Maybe there will be multiple optimal solutions? We will discover that together as we work through this process.

Budd Inlet TMDL Requirement

Nutrient Bubble Allocation for
External Sources to Budd Inlet



Budd Inlet DO TMDL Wasteload Allocation

- External Sources to Budd Inlet must meet bubble allocation
- Verified with the model

The nutrient reductions captured in the Puget Sound Nutrient Management Plan must meet bubble allocation

37

One critical requirement to note is that the optimal solution must also meet the bubble allocation for external sources to Budd Inlet currently being developed in the Budd Inlet DO TMDL. That TMDL will have a bubble wasteload allocation for the water flowing into Budd Inlet that must be met. The bubble allocation is meant to include all of the other human sources in Puget Sound that are external to Budd Inlet, and that wasteload allocation must be met by the final set of reductions that will be in the nutrient management plan.

QUESTIONS?

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