WARMING IMPACTS ON SALMON AND HERRING HAVE WIDESPREAD ECOSYSTEM IMPACTS

Climate change effects in the marine system of Puget Sound

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We examined the impact of future ocean conditions in Puget Sound, an urban estuary in the Pacific Northwest

In Puget Sound, Washington, USA, climate change will reshape the ecosystem through bottom-up processes, affecting the abundance of groups at the base of the food web (i.e. phytoplankton and marine plants), and through top-down processes (i.e. consumer-driven). We link scenarios of warming oceanography to Atlantis simulations that test to what extent 'speeding up' ecosystem-wide anabolic processes (e.g., gains due to higher growth rates) will be balanced by 'speeding up' catabolic processes (e.g., losses due to declines in assimilation rates or increases in predation mortality).

We applied an end-to-end Atlantis model

We used an ecosystem model built in the Atlantis modeling framework to link the physiological effects of warming oceanography to ecosystem-level changes. Atlantis is a deterministic and spatially resolved model that considers ecological processes, fishing activity and hydrodynamics within three-dimensional irregular polygons. The Atlantis model for Puget Sound (AMPS) has 89 polygons that extend over 9652 km^2, uses 74 functional groups and is initialized for 2011.

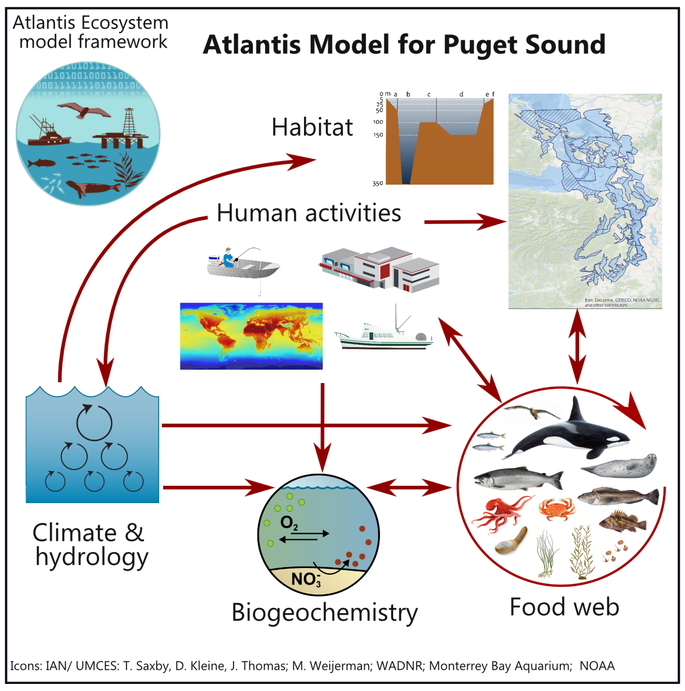


FIGURE 1 - Structure of the Atlantis model for Puget Sound.

We simulated future hydrodynamics using an ensemble approach

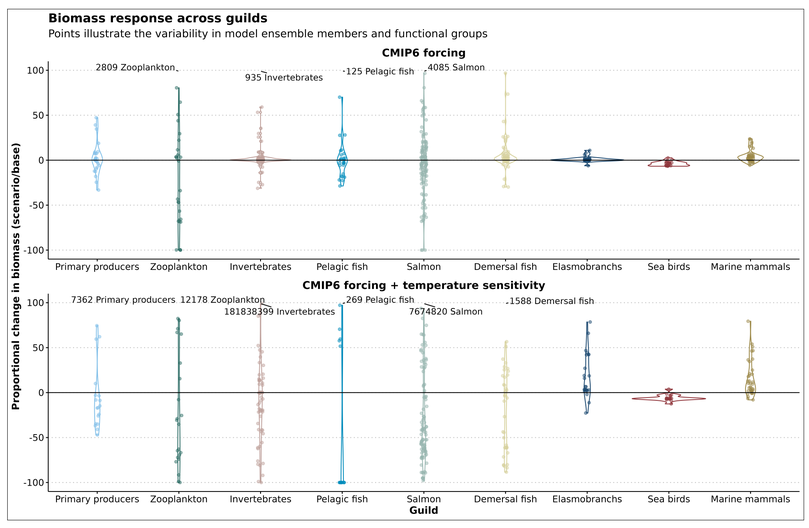
We used a set of eight different AMPS ensemble members that represent parameter combinations that approximate the lower and upper bounds of observed system productivity, and allow examining the impacts of parameter uncertainty. We used anomalies of sea surface temperature and salinity estimated through empirical-downscaling of future CMIP6 projections of model CNRM-CM6-1-HR for horizon 2020-2050, and applied to the Regional Ocean Modeling System (ROMS) time series that forces the Atlantis model, developed by Walker et al. (2022).

We included metabolic effects

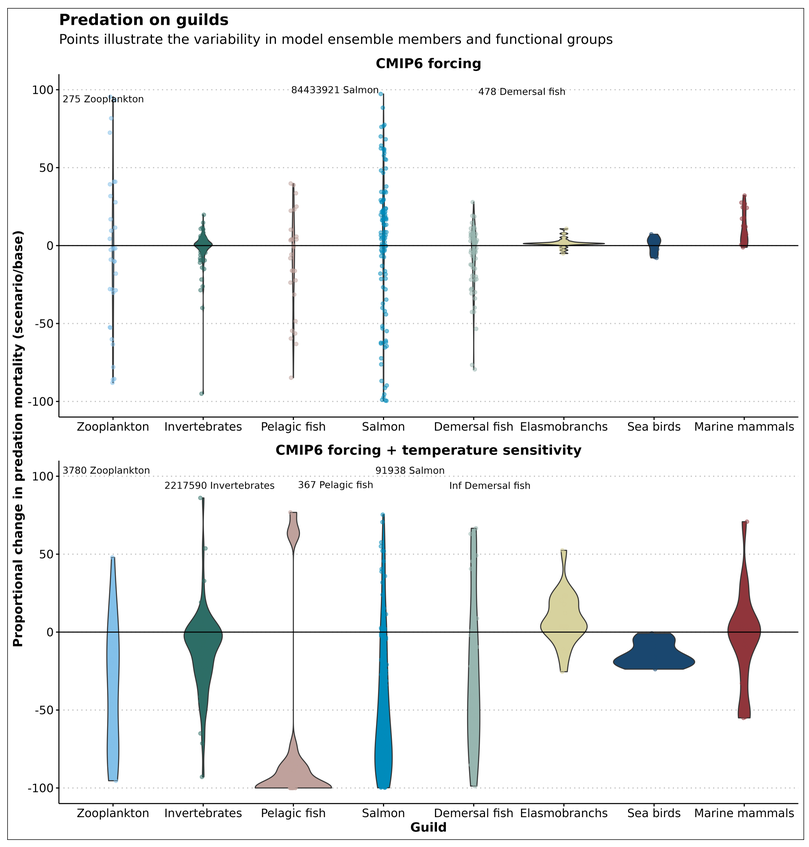
We parametrized temperature sensitivity for Chinook salmon, coho salmon, and Pacific Herring through Q10, the temperature coefficient equal to the rate of change in chemical or biological process when temperature increases by 10 °C. We used a bioenergetics response curve (code courtesy A. Rovellini) that uses a slope, the optimal temperature, and the maximum temperature from empirical data. The slope approximates the Q10 or the rate at which the function increases over relatively low water temperatures. In Atlantis life history attributes affected by temperature include growth rates, assimilation efficiency, vertebrate search volume, clearance and growth rates, linear mortality and quadratic mortality. Other processes affected also temperature, light saturation of primary producers, invertebrate clearance (i.e. feeding), rate of nitrification, and rates of detritus breakdown.

Future hydrodynamic forcing had extensive food web effects

We found both negative and positive effects on primary production and on consumers. Temperature sensitivity increased the range of responses.



Predation at the guild level in CMIP6 forcing alone has a variable response, while predation declines in the combined scenario, especially for salmon and other fish.



Morzaria-Luna et al. 2022. Design and Parameterization of a Spatially Explicit Atlantis Ecosystem Model for Puget Sound. NOAA Technical Memorandum NMFS-NWFSC-177.

Walker et al. 2022. Future temperature and salinity in Puget Sound, Washington State, under CMIP6 climate change scenarios. Journal of Water and Climate Change (2022) 13 (12): 4255–4272