Appendix 1. Model Perturbations and References

|  |  |  |  |
| --- | --- | --- | --- |
| **Drivers** | **Variables** | **Reference** | **Invoked Perturbation** |
| *Environmental* | Sunlight | Littell et al. 2009 | ↑ |
|  | Winter Storms | Littell et al. 2009 | ↑ |
|  | Precipitation | Mauger et al. 2015, Littell et al. 2009 | ↑ |
|  | Upwelling[[1]](#footnote-1) | Mauger et al. 2015 | ↓ |
|  | Stratification[[2]](#footnote-2) | Mauger et al. 2015 | ↑ |
|  | Temperature | Littell et al. 2009, Field et al. 2006, Hollowed et al. 2001 | ↑ |
|  | River Flow | Littell et al. 2009[[3]](#footnote-3) | ↑ |
|  | Turbidity |  | ↓ |
|  | Dissolved Oxygen | Roberts et al. 2014 | ↓ |
| *Production* | Nutrients | Roberts et al. 2014 | ↑ |
|  | Microplankton | Moore et al. 2015 | ↑ |
|  | Microbial Detritivores | PSEMP 2016 | ↑ |
|  | Diatoms | Brandenberger 2008, PSEMP 2016 | ↓ |
| *Foodweb* | Zooplankton[[4]](#footnote-4) |  | ↓ |
|  | Gelatinous Zooplankton | Greene et al. 2015 | ↑ |
|  | Forage Fish | Greene et al. 2015 | ↓ |
|  | Ichthyoplankton | Palsson et al. 1998 | ↓ |
|  | Other Salmon |  | ↑ |
|  | Piscivorous Fish | Palsson et al. 1998 | ↓ |
|  | Piscivorous Birds | Gaydos and Pearson 2011, Anderson et al. 2009 | ↓ |
|  | Marine Mammals | Chasco et al. 2017 | ↑ |
| *Anthropogenic* | Hatcheries | Christie et al. 2012, Waples 1999 | ↑ |
|  | Harvest[[5]](#footnote-5) |  | ↑ |
|  | Habitat Loss | Puget Sound Water Quality Action Team 2002 | ↑ |
|  | CO2 | Feely et al. 2010 | ↑ |
|  | Global Warming | IPCC 2014 | ↑ |
|  | Contaminants | O’Neill et al. 2009, Meador et al. 2006, Crecelius et al. 1995 | ↑ |
|  | Disease |  | ↑ |

Anderson, E.M., Bower, J.L., Nysewander, D.R., Evenson, J.R. and Lovvorn, J.R.  2009.  Changes in avifaunal abundance in a heavily-used wintering and migration site in Puget Sound, Washington during 1966–2007. *Marine Ornithology* 37: 19-27.

Chasco et al. 2017.

Christie, M.R., M.L. Marine, R.A. French, R.S. Waples and M.S. Blouin. 2012. Effective size of a wild salmonid population is greatly reduced by hatchery supplementation. *Heredity* 109: 254-260.

Crecilius, E.A., V.I. Cullinan, L.F. Lefkovitz and C. Peden. 1995. Historical trends in the accumulation of chemicals in Puget Sound. 825-831 In Volume 2, Puget Sound Research '95 Proceedings, Puget Sound Water Quality Authority, Olympia.

Feely, R. A., S. R. Alin, J. Newton, C. L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy. 2010. The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. *Estuarine, Coastal and Shelf Science*, 88, 442-449, doi:10.1016/j.ecss.2010.05.004

Field, D., D. Cayan, and F. Chavez. 2006. Secular warming in the California current and North Pacific. *California Cooperative Oceanic Fisheries Investigations Reports*, 47, 92-108.

Hollowed, A. B., S. R. Hare, and W. S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. *Progress in Oceanography*, 49, 257-282, doi:10.1016/S0079-6611(01)00026-X.

Gaydos, J.K. and S.F. Pearson. 2011. Birds and mammals that depend on the Salish Sea: A

compilation. *Northwest Naturalist*: 92:79–94.

Intergovernmental Panel on Climate Change. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Littell, J.S., M. McGuire Elsner, L.C. Whitely Binder, and A.K. Snover (eds). 2009. *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate.* Climate Impacts Group, University of Washington, Seattle, Washington. Available at: [www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf](http://www.cses.washington.edu/db/pdf/wacciaexecsummary638.pdf)

Mauger, G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover. 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

Meador, J.P., F.C. Sommers, G.M. Ylitalo, C.A. Sloan. 2006. Altered growth and related physiological response in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). *. Can. J. of Fish. and Aqua. Sci.* 63: 2364-2376.

Moore, S.K. et al., 2011. Past trends and future scenarios for environmental conditions favoring the accumulation of paralytic shellfish toxins in Puget Sound shellfish. *Harmful Algae*, 10, 521-529.

Moore, S.K. et al., 2015. Present-day and future climate pathways affecting the harmful algal blooms species *Alexandrium catenella* in Puget Sound, WA, USA. *Harmful Algae*, 48, 1-11. 25

O'Neill, S.M., and West, J.E. 2009. Marine Distribution, Life History Traits, and the Accumulation of Polychlorinated Biphenyls in Chinook Salmon from Puget Sound, Washington*. Transactions of the American Fisheries Society* 138(3): 616-632.

Palsson, W.A., T.J. Northrup, and M.W. Baker. 1998. Puget Sound Groundfish Management Plan. Washington Department of Fish and Wildlife. Olympia, WA.

PSEMP Marine Waters Workgroup. 2016. Puget Sound marine waters: 2015 overview. S. K. Moore, R. Wold, K. Stark, J. Bos, P. Williams, K. Dzinbal, C. Krembs and J. Newton (Eds). URL: www.psp.wa.gov/PSEMP/PSmarinewatersoverview.php.

Puget Sound Water Quality Action Team. 2002. *2002 Puget Sound Update: Eighth Annual Report of the Puget Sound Ambient Monitoring Program*. Puget Sound Water Quality Action Team. Olympia, Washington.

Roberts, M., T. Mohamedali, B. Sackmann, T. Khangaonkar, W. Long. 2014. Puget Sound and the Straits Dissolved Oxygen Assessment Impacts of Current and Future Human Nitrogen Sources and Climate Change through 2070. Washington State Department of Ecology, Publication No. 14-03-007. Olympia, WA.

Waples, R.S. 1999. Dispelling some myths about hatcheries. *Fisheries* 24: 12–21.

1. While impacts to upwelling are unknown, we invoked a decrease in upwelling because it would reduce the delivery of nutrients to Puget Sound and potentially disrupt primary production. [↑](#footnote-ref-1)
2. Decreased mixing as a result of changes in freshwater flow could lead to increased stratification; while the exact response is unknown (see Mauger et al. 2015), we have invoked an increase in stratification because decreased mixing would likely lead to declines in primary productivity. [↑](#footnote-ref-2)
3. River flow is projected to be higher during the winter/spring period of salmon outmigration, but lower in the summers due to decreased precipitation and higher temps. during this season (Littell et al. 2009). [↑](#footnote-ref-3)
4. While it is unknown if total abundance of zooplankton has decreased, there is some indication that the community has shifted. We invoked a decrease in zooplankton to reflect this shift. [↑](#footnote-ref-4)
5. Harvest has decreased over the time period we used to frame this analysis; however, we were interested in the impacts of increased harvest on salmon survival so invoked an increase in harvest as the perturbation [↑](#footnote-ref-5)