



Using the STEPS Framework to Define the Impacts of Air Pollution on Aquatic Final Ecosystem Goods and Services

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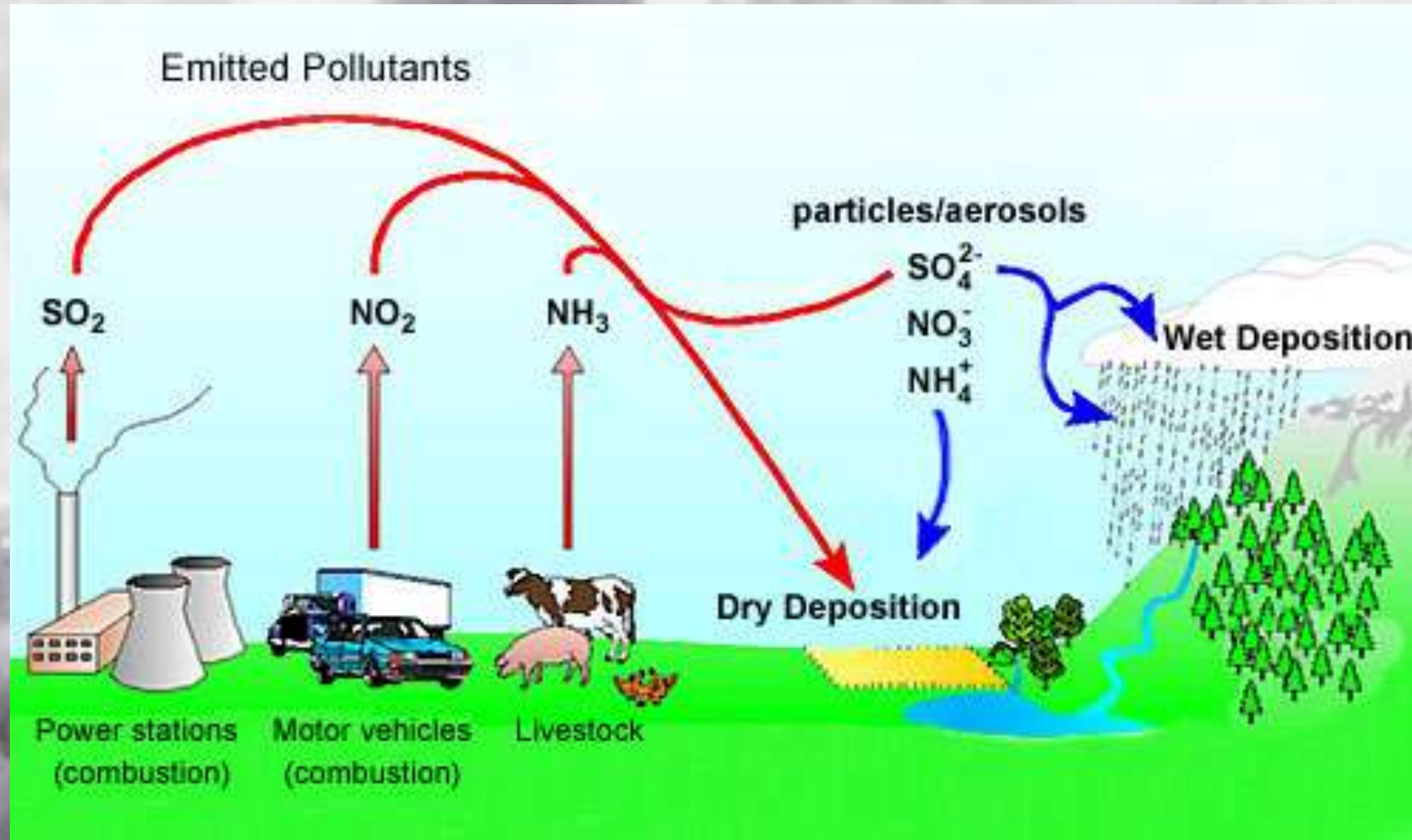
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Presentation Goals

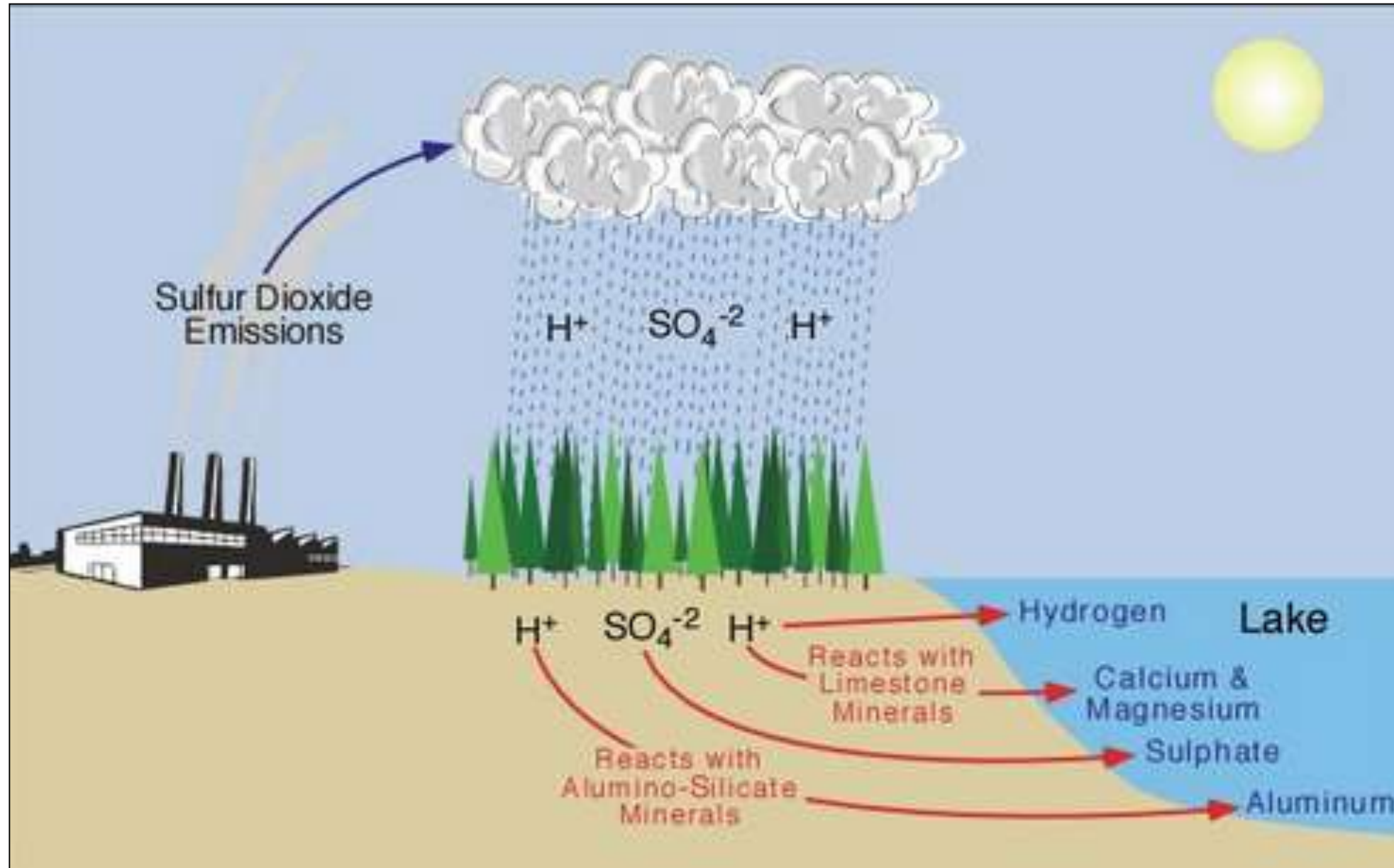
- Provide examples of Ecological Production Functions created using the STEPS Framework
- Explain how air pollution affects ecosystem goods and services



Atmospheric Deposition of Sulfur and Nitrogen



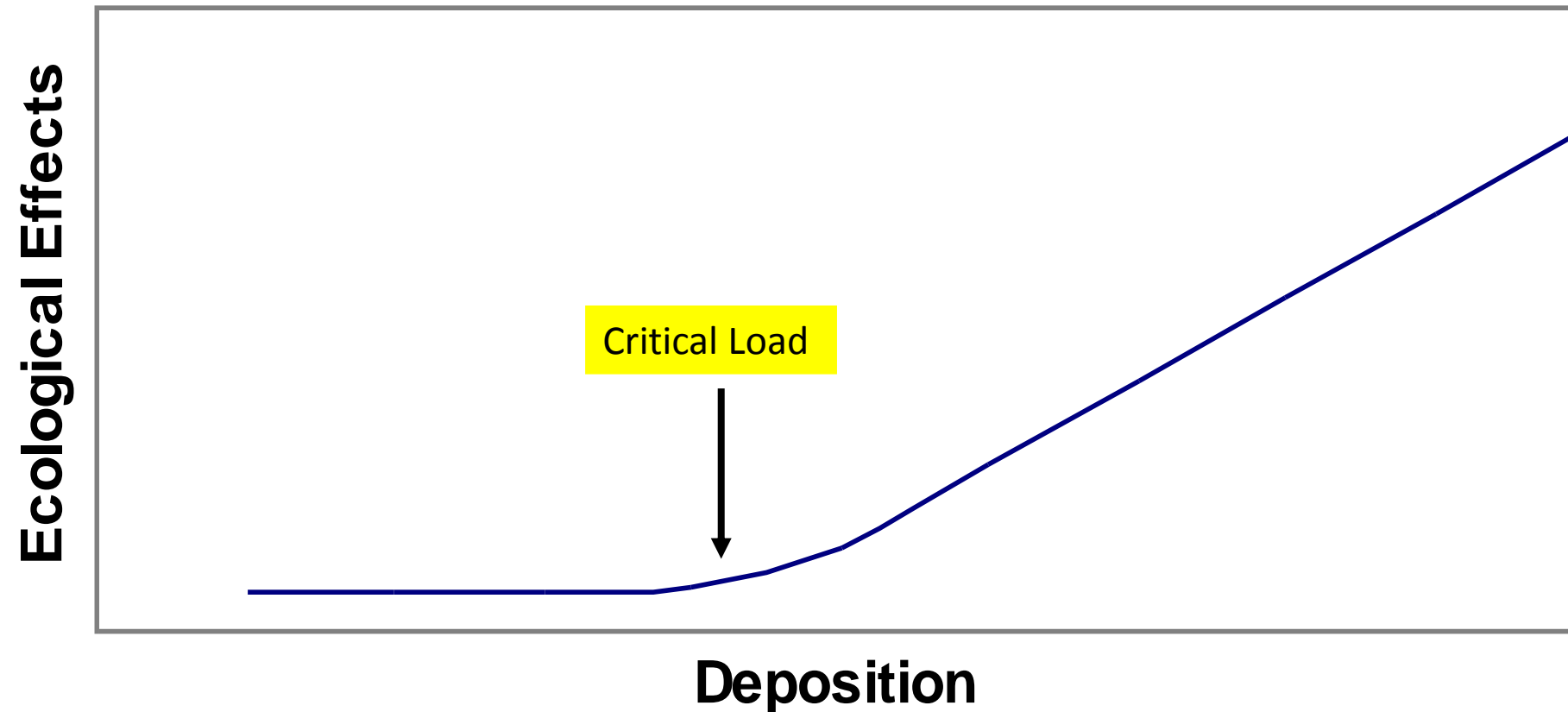
Deposition leads to Eutrophication and Acidification



Four Modes of Ecosystem Response to Atmospheric Deposition

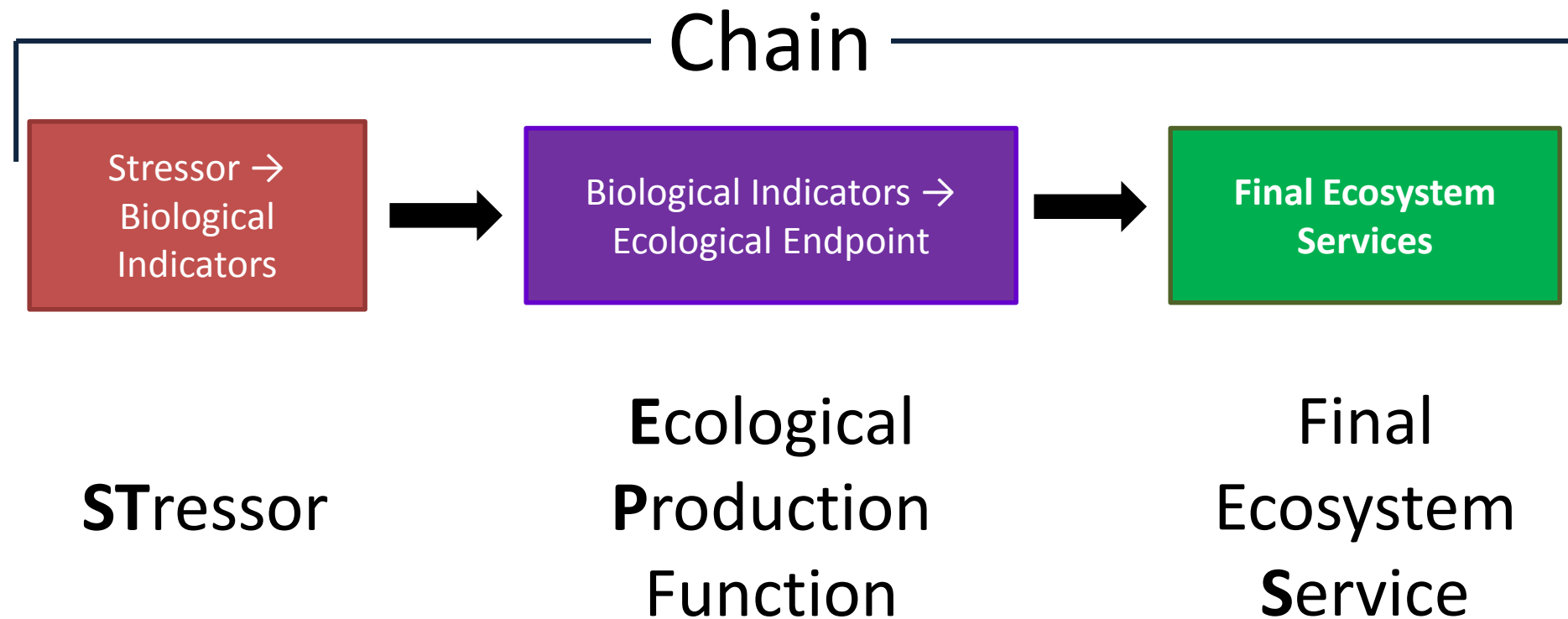
Acidification (eastern US)		Eutrophication (western US)	
Aquatic			
			
Terrestrial			
			

Critical load is the level of atmospheric deposition below which no harmful ecological effects occur for an ecosystem



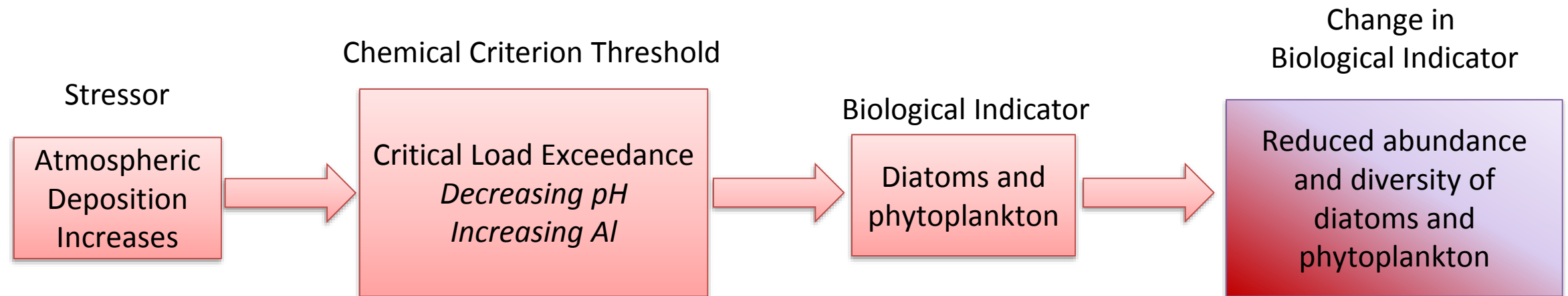
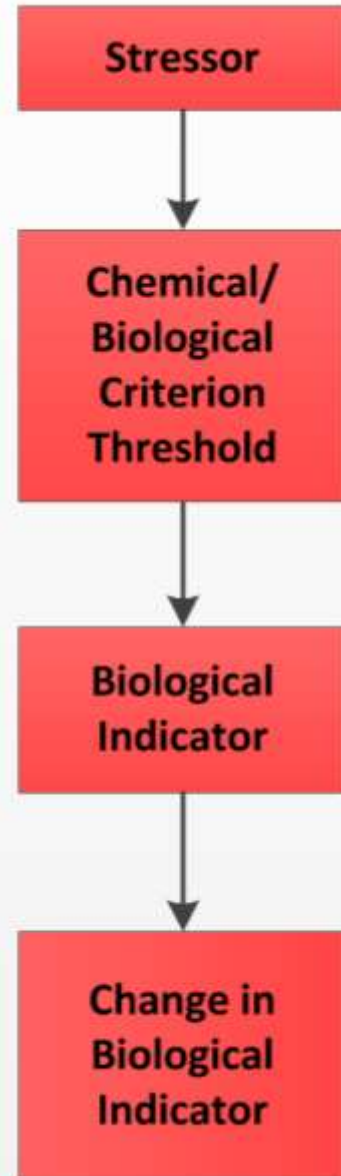


STEPS Framework

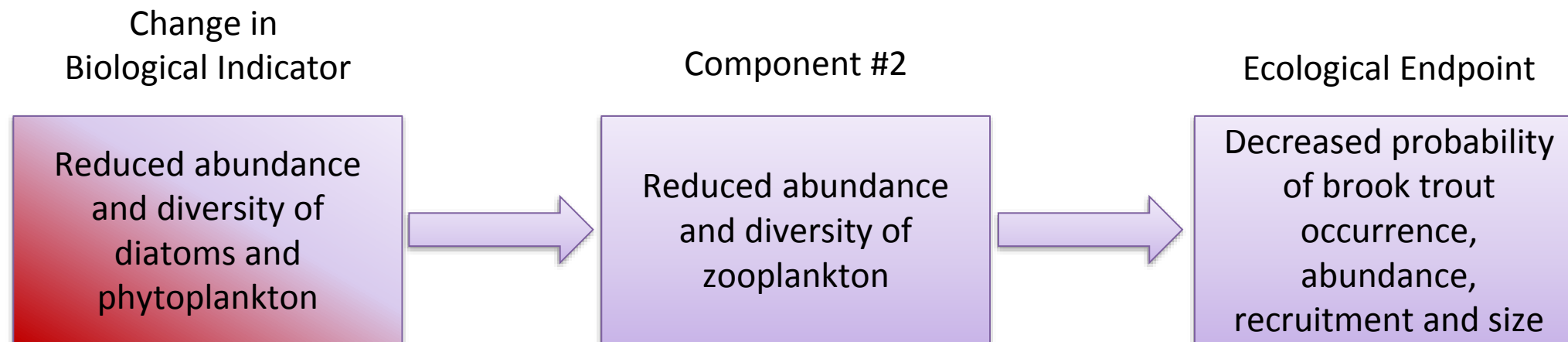
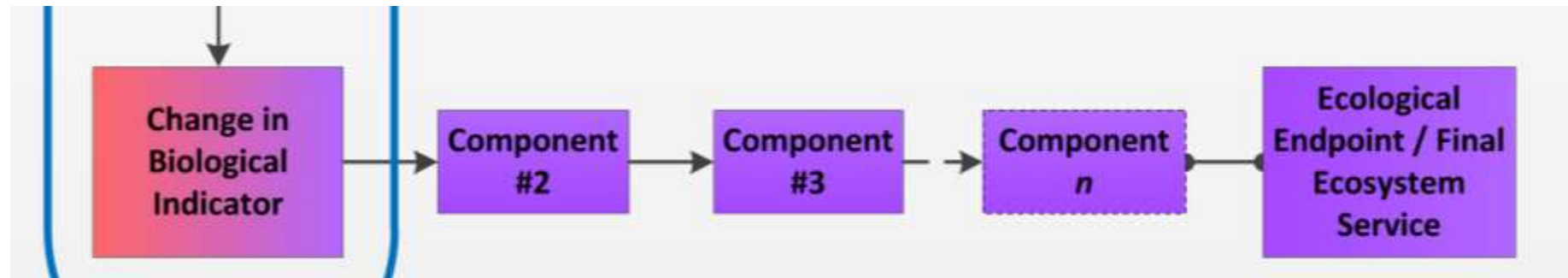




Stressor Module

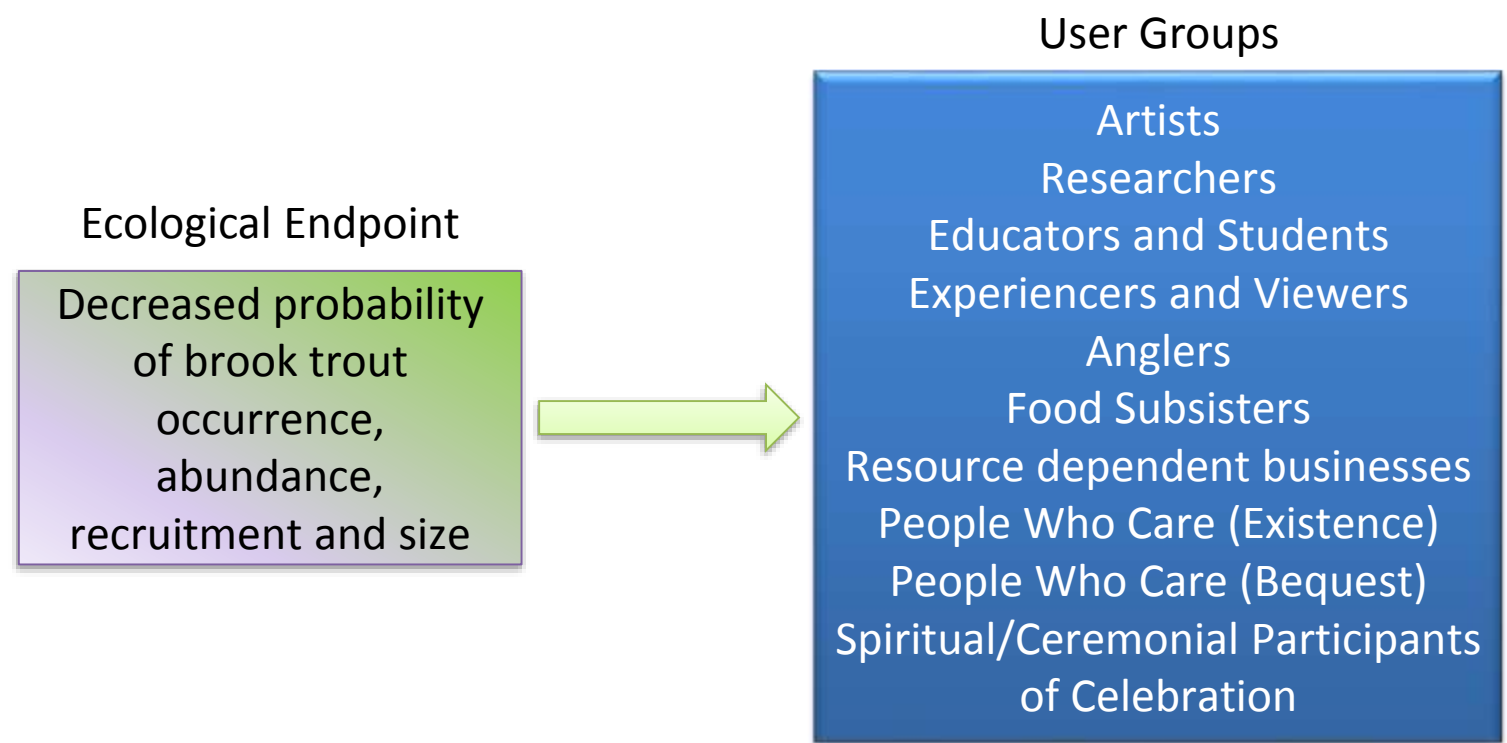
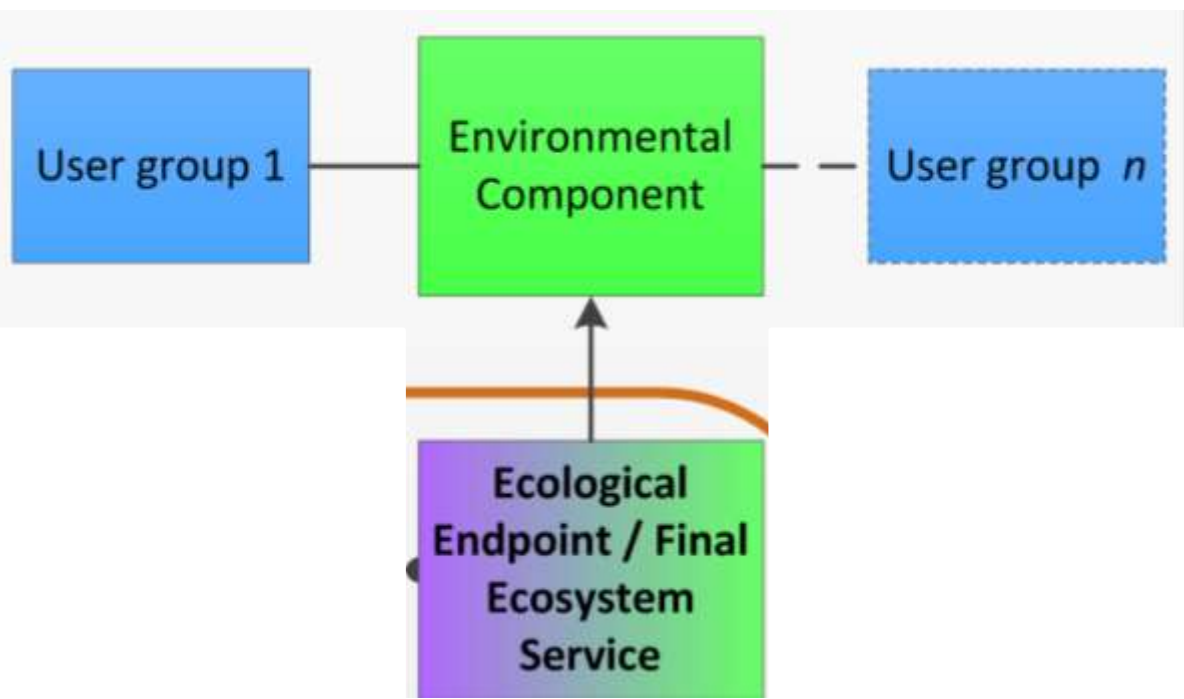


Ecological Production Function Module



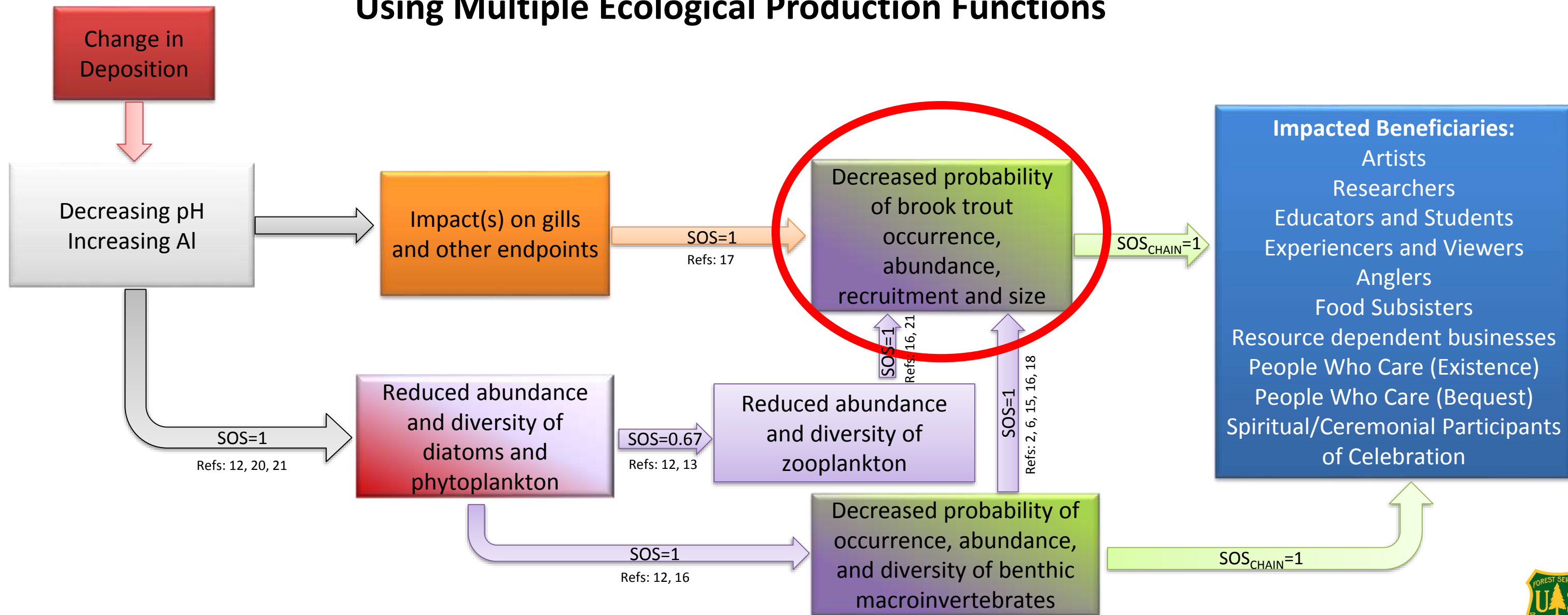


Final Ecosystem Services Module

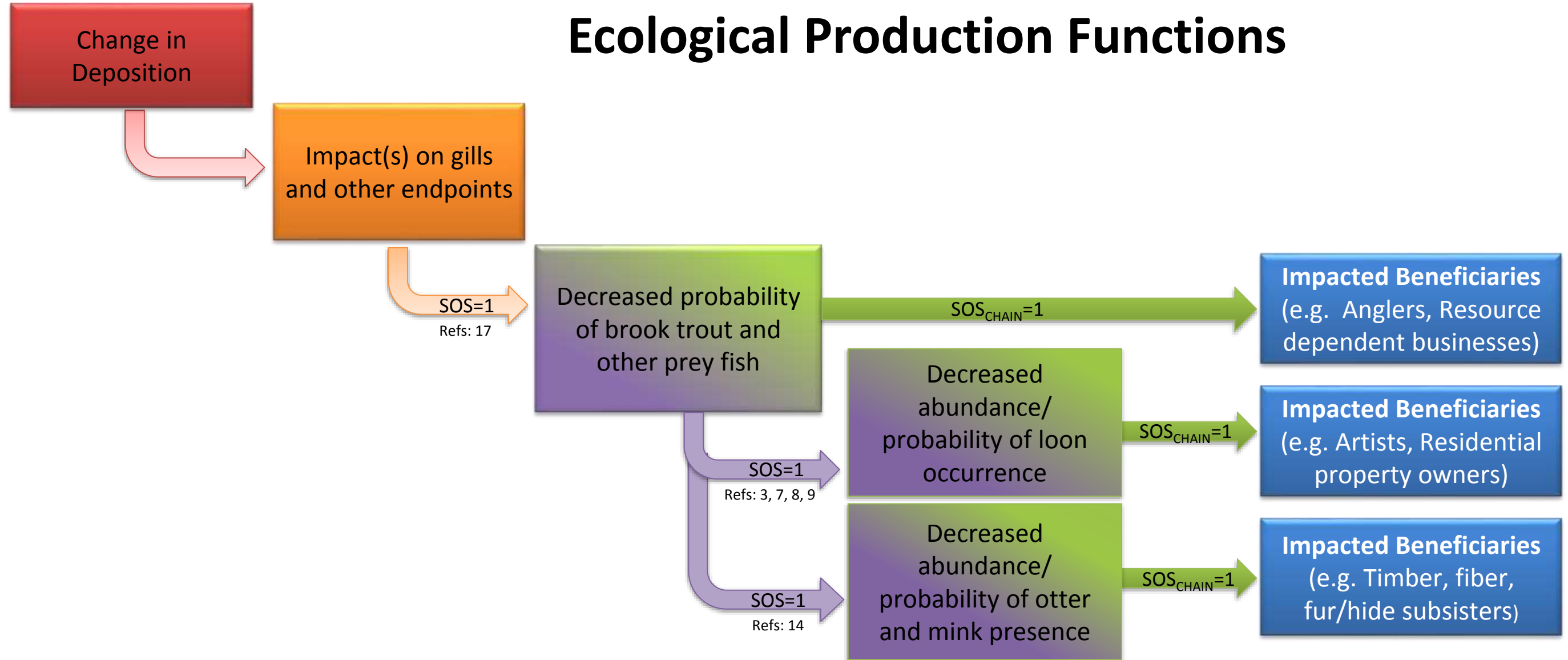


The Impact of Deposition on Brook Trout Beneficiaries

Using Multiple Ecological Production Functions

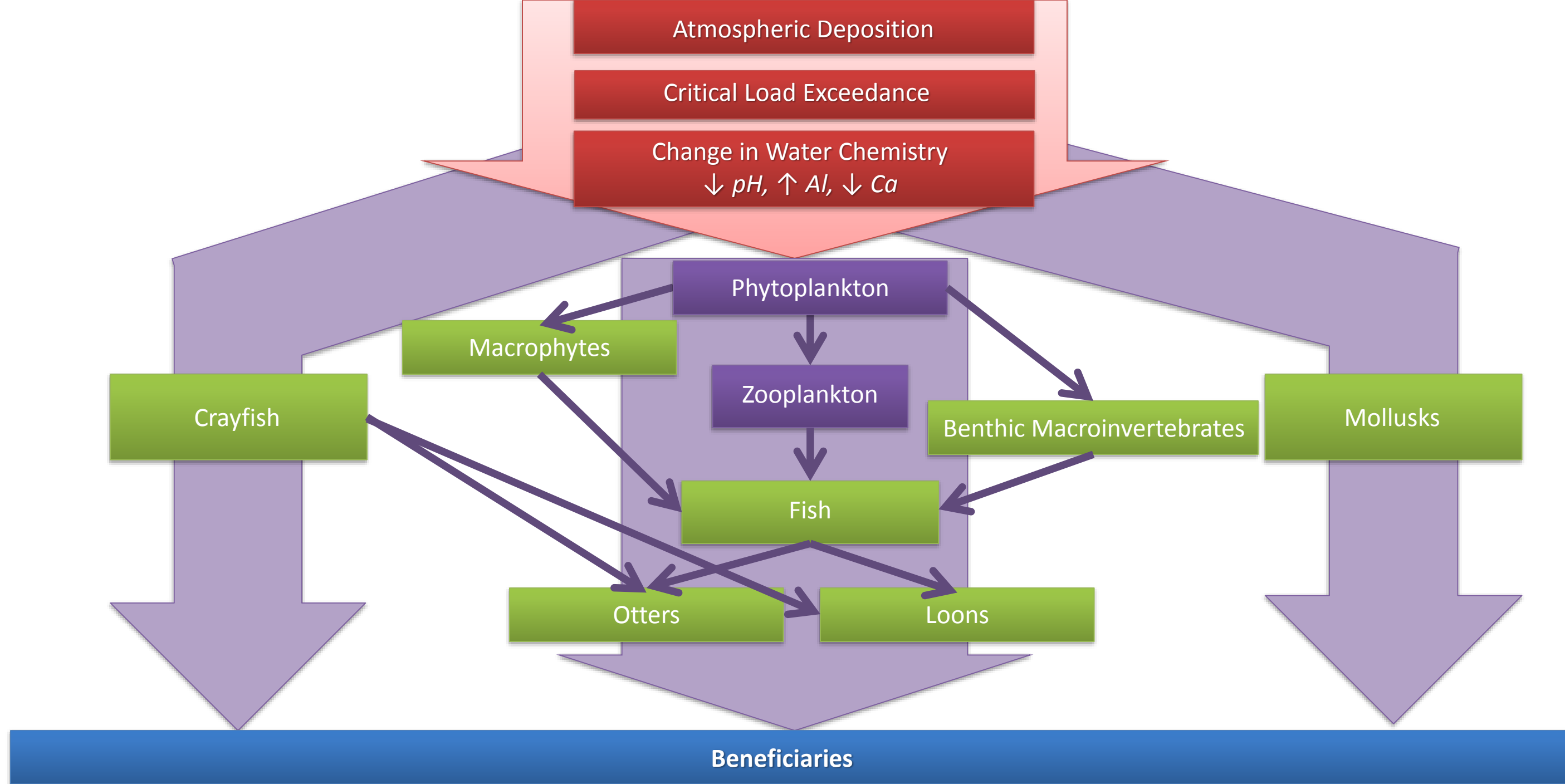


Adding Ecological Endpoints to Create Additional Ecological Production Functions



Aquatic Acidification References	
1	Baker, J.P., D.P. Bernard, S.W. Christensen, and M.J. Sale. 1990. Biological Effects of Changes in Surface Water Acid-Base Chemistry. State of Science/Technology Report 13. National Acid Precipitation Assessment Program, Washington DC.
2	Baldigo, B.P., G.B. Lawrence, R.W. Bode, H.A. Simonin, K.M. Roy, and A.J. Smith. 2009. Impacts of acidification on macroinvertebrate communities in streams of the western Adirondack Mountains, New York, USA. Ecol. Indicat. 9: 226-239.
3	Biodiversity Research Institute http://www.briloon.org/
4	Bulger, A.J., B.J. Cosby, C.A. Dolloff, K.N. Eshleman, J.R. Webb, and J.N. Galloway. 1999. SNP:FISH, Shenandoah National Park: Fish in Sensitive Habitats. Project Final Report to National Park Service. University of Virginia, Charlottesville, VA.
5	Bulger, A.J., C.A. Dolloff, B.J. Cosby, K.N. Eshleman, J.R. Webb, and J.N. Galloway. 1995. The "Shenandoah National Park: Fish in Sensitive Habitats" (SNP: FISH) project. an integrated assessment of fish community responses to stream acidification. Water, Air, and Soil Pollution 85: 309-314.
6	Cosby, B.J., J.R. Webb, J.N. Galloway, and F.A. Deviney. 2006. Acidic Deposition Impacts on Natural Resources in Shenandoah National Park. NPS/NER/NRTR-2006/066. U.S. Department of the Interior, National Park Service, Northeast Region, Philadelphia, PA. NPS/NER/NRTR-2006/066
7	Diamond, A.W. 1989. Impacts of acid rain on aquatic birds. Environmental Monitoring and Assessment 12(3): 245-254.
8	Doka, S.E., D.K. Mcnicol, M.L. Mallory, I. Wong, C.K. Minns, and N.D. Yan. 2003. Assessing Potential for Recovery of Biotic Richness and Indicator Species due to Changes in Acidic Deposition and Lake pH in Five Areas of Southeastern Canada. Environmental Monitoring and Assessment 88: 53–101.
9	Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. Bioscience 51: 180-198.
10	Durocher, P.P., W.C. Provine, and J.E. Kraai. 1984. Relationship between Abundance of Largemouth Bass and Submerged Vegetation in Texas Reservoirs. North American Journal of Fisheries Management 4(1): 84-88.
11	France, R.L. 1981. Response of the crayfish <i>Orconectes virilis</i> to experimental acidification of a lake with special reference to the importance of calcium, In: C.R. Goldman (Ed.), Freshwater Crayfish V. Papers from the Fifth International Symposium on Freshwater Crayfish (pp. 98-111). Avi Publishing Company, Inc., Davis, California.
12	Geelen, J.F.M, and R.S.E.W. Leuven. 1986. Impact of acidification on phytoplankton and zooplankton communities. Experientia 42: 486-494.
13	Kelble, C. Plankton type affects food webs. In Tropical Connections: South Florida's Marine Environment, W.L. Kruczynski and P.J. Fletcher (eds.). IAN Press, University of Maryland Center for Environmental Science, Cambridge, MD, 125 (2012).
14	Mason, C.F., and S.M. MacDonald. 1989. Acidification and otter (<i>Lutra lutra</i>) distribution in Scotland. Water, Air, and Soil Pollution 43(3): 365-374.
15	Moeykens, M.D. and J.R. Voshell. 2002. Studies of Benthic Macroinvertebrates for the Shenandoah National Park Long-Term Ecological Monitoring System: Statistical Analysis of LTEMs Aquatic Dataset from 1986 to 2000 on Water Chemistry, Habitat and Macroinvertebrates. Report to Shenandoah National Park from the Dept. of Entomology. Virginia Polytechnic and State University, Blacksburg, VA.
16	Økland, J. and K.A. Økland. 1986. The effects of acid deposition on benthic animals in lakes and streams. Experientia, 42(5): 471.
17	Sayer, M.D.J., J.P. Reader, and T.R.K. Dalziel. 1993. Freshwater acidification: effects on the early life stages of fish. Reviews in Fish Biology and Fisheries 3(2): 95-132.
18	Sullivan, T.J., B.J. Cosby, J.A. Laurence, R.L. Dennis, K. Savig, J.R. Webb, A.J. Bulger, M. Scruggs, C. Gordon, J. Ray, H. Lee, W.E. Hogsett, H. Wayne, D. Miller, and J.S. Kern. 2003. Assessment of Air Quality and Related Values in Shenandoah National Park. NPS/NERCHAL/NRTR-03/090. U.S. Department of the Interior, National Park Service, Northeast Region.
19	Sullivan, T.J., C.T. Driscoll, B.J. Cosby, I.J. Fernandez, A.T. Herlihy, J. Zhai, R. Stemberger, K.U. Snyder, J.W. Sutherland, S.A. Nierzwicki-Bauer, C.W. Boylen, T.C. McDonnell, and N.A. Nowicki. 2006. Assessment of the Extent to Which Intensively-Studied Lakes Are Representative of the Adirondack Mountain Region. Final Report 06-17. New York State Energy Research and Development Authority, Albany, NY.
20	Sullivan, T.J., D.F. Charles, J.P. Smol, B.F. Cumming, A.R. Selle, D.R. Thomas, J.A. Bernert, and S.S. Dixit. 1990. Quantification of changes in lakewater chemistry in response to acidic deposition. Nature 345: 54-58.
21	Sutherland, J.W., F.W. Acker, J.A. Bloomfield, C.W. Boylen, D.F. Charles, R.A. Daniels, L.W. Eichler, J.L. Farrell, R.S. Feranec, M.P. Hare, S.L. Kanfoush, R.J. Preall, S.O. Quinn, H.C. Rowell, W.F. Schoch, W.H. Shaw, C.A. Siegfried, T.J. Sullivan, D.A. Winkler, and S.A. Nierzwicki-Bauer. 2015. Brooktrout Lake Case Study: Biotic Recovery from Acid Deposition 20 Years after the 1990 Clean Air Act Amendments. Environ. Sci. Technol. 49(5): 2665-2674.
22	Wiley, M.J., R.W. Gorden, S.W. Waite, and T. Powless. 1984. The Relationship between Aquatic Macrophytes and Sport Fish Production in Illinois Ponds: A Simple Model. North American Journal of Fisheries Management 4(1): 111-119.
23	Delibes, M. and I. Adrian. 1987. Effects of crayfish introduction on Otter <i>Lutra lutra</i> food in the Doñana National Park, SW Spain. Biological Conservation 42(2): 153-159.
24	Dekar, M.P., D.D. Magoulick, J. Beringer. 2010. Bioenergetics assessment of fish and crayfish consumption by river otter (<i>Lontra canadensis</i>): integrating prey availability, diet, and field metabolic rate. 67(9): 1439-1448.





We Love Our Loons!



Acidification cancels Christmas



Next Steps

- Air pollution harms ecosystem goods and services through four response modes:
 - Aquatic acidification
 - Terrestrial acidification
 - Aquatic eutrophication
 - Terrestrial eutrophication
- Ecosphere special issue currently under review!



Questions?

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