

2021 Lake/Reservoir Nutrient Criteria Recommendations - Exploratory Examples

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Office of Science and Technology

2022 Nutrients Roundtable with State and Tribal Environmental Programs

Outline

- Overview - 2021 Published 304(a) Numeric Nutrient Criteria (NNC) to Protect Lakes and Reservoirs from Nutrient Pollution
- Exploratory Case Studies for the PNW

2021 Lake/Reservoir NNC Overview

- [In 2021 EPA published 304\(a\) recommended criteria for chlorophyll *a*, total nitrogen and total phosphorus](#) to protect aquatic life, recreation, and drinking water designated uses in lakes and reservoirs, to be identified using a suite of stressor-response models
- Draft FAQs under development
- 3 models to identify chlorophyll *a* endpoints protective of uses (aquatic life, human health recreation and drinking water)
 - Hypoxia (aquatic life) - <https://nsteps.epa.gov/apps/chl-hypoxia/> for stratified waters with cold or cool water species; stratification dynamics, elevation, DOC, and refugia
 - Zooplankton (aquatic life)- <https://nsteps.epa.gov/apps/chl-zooplankton/> depth-dependent
 - Microcystins (human health)- <https://nsteps.epa.gov/apps/chl-microcystin/> probability of exceedance choice
- Chlorophyll *a* endpoints then used to identify TN and TP criteria values using a separate set of models. Chlorophyll *a*, TN and TP criteria are the outputs.
 - Nutrient models - <https://nsteps.epa.gov/apps/tp-tn-chl/>
- 304(a) are for the Continental U.S. and exclude AK* and HI

*AK –similar modeling approach could be developed

*Oligotrophic waters– water clarity (not in these models)
identified as likely more appropriate endpoint*

Zooplankton model- background

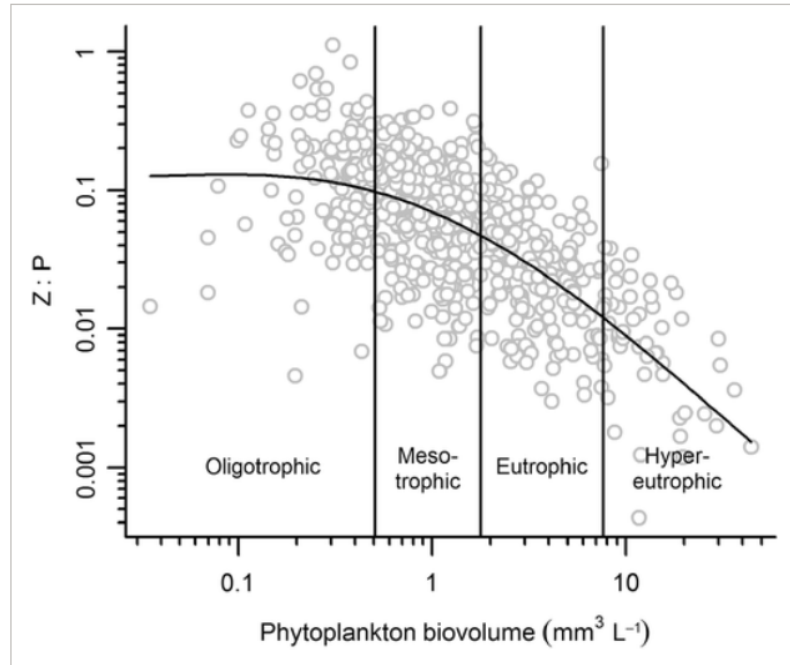


Figure 6

[Open in figure viewer](#)

[PowerPoint](#)

Zooplankton to phytoplankton biomass ratio ($Z:P$) vs. phytoplankton biovolume. Solid line: fitted relationship, open circles: estimated seasonal mean $Z:P$ at different sites. Trophic states as labeled.

...at low levels of phytoplankton biovolume, $\log(Z:P)$ is nearly constant. As phytoplankton biomass increases, $\log(Z:P)$ decreases, eventually approaching a line with a slope equal to negative $\log(P)$. For reference, boundaries between different trophic states are noted with vertical lines.

Pollard and Yuan, 2018: <https://aslopubs.onlinelibrary.wiley.com/doi/10.1002/lno.10955>

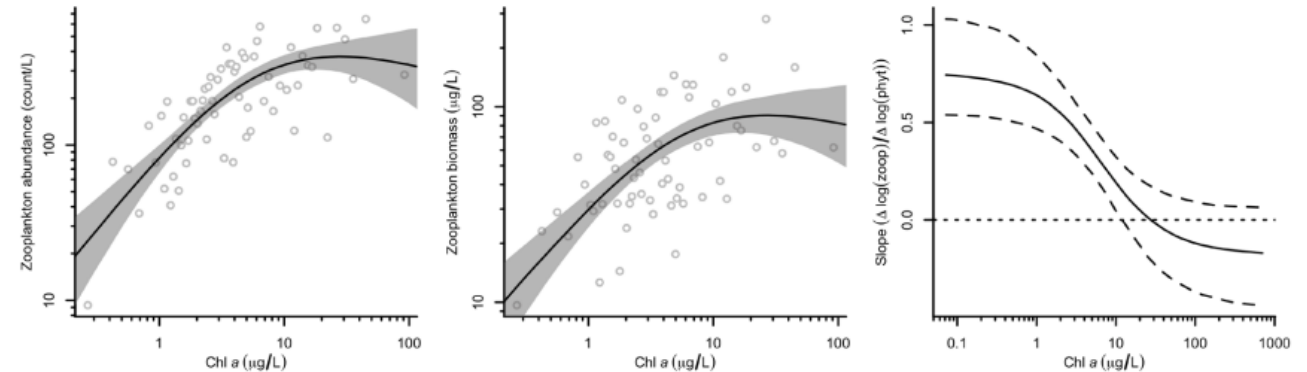


Figure 6. Estimated relationships between zooplankton and Chl a for lakes > 8 m deep. *Left panel*: Chl a vs. zooplankton abundance; *middle panel*: Chl a vs. zooplankton biomass; *right panel*: Chl a vs. slope of the relationship between zooplankton biomass and Chl a . *Solid lines*: mean relationships; *shaded areas (left and middle panels)*: 90% credible intervals (bounded by the 5th and 95th percentiles of the distribution of possible mean relationships); *dashed lines (right panel)*: 90% credible interval; *open circles (left and middle panels)*: average of five samples nearest the indicated Chl a concentration; *dotted horizontal line (right panel)*: one example value of threshold for deriving a Chl a criterion.

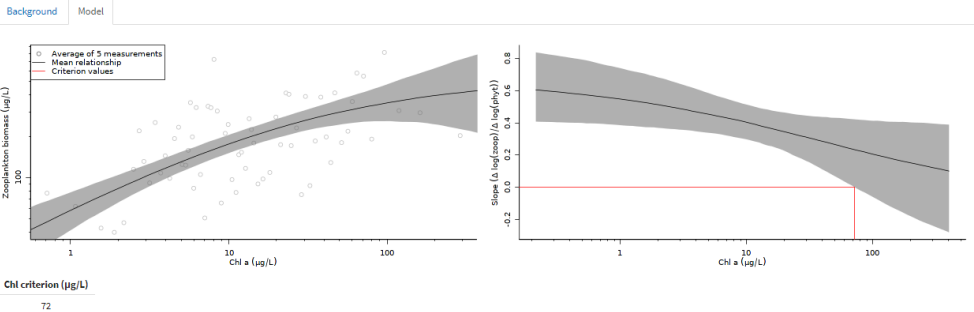
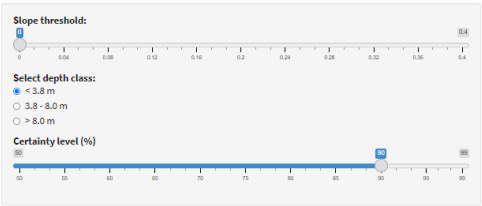
<https://www.epa.gov/system/files/documents/2021-08/nutrient-lakes-reservoirs-report-final.pdf>

Zooplankton model- example effect of slope choice on chlorophyll *a* criteria values, for shallowest depth range

Related Topics: [Environmental Topics](#)

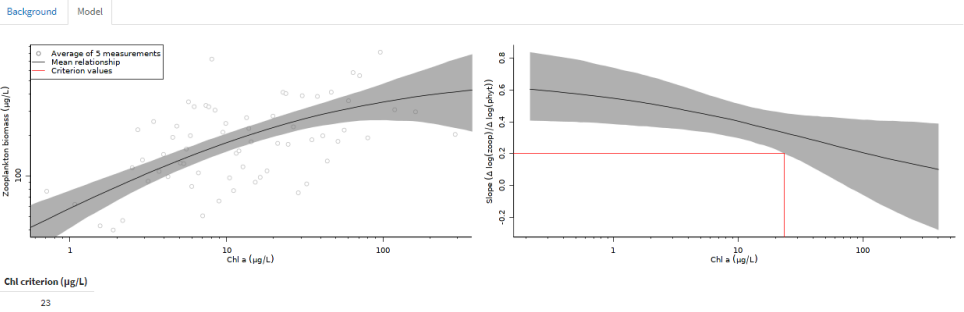
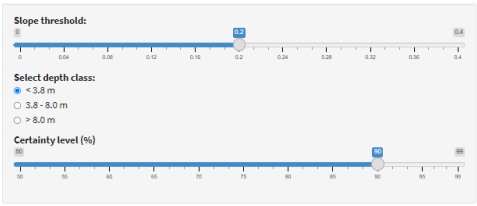
[Contact Us](#)

Chlorophyll criteria based on zooplankton



Slope =0; 72 mcg/L Chla

Chlorophyll criteria based on zooplankton

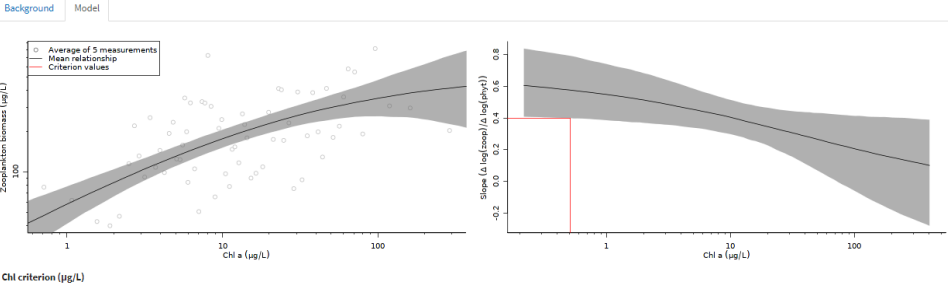
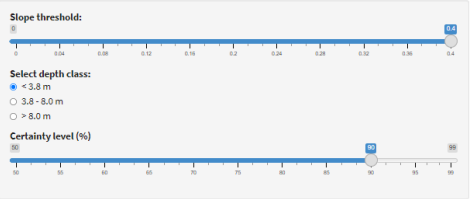


Slope =0.2; 23 mcg/L Chla

Related Topics: [Environmental Topics](#)

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Chlorophyll criteria based on zooplankton



Slope =0.4; 1 mcg/L Chla
(lowest value allowed)

Microcystins model background

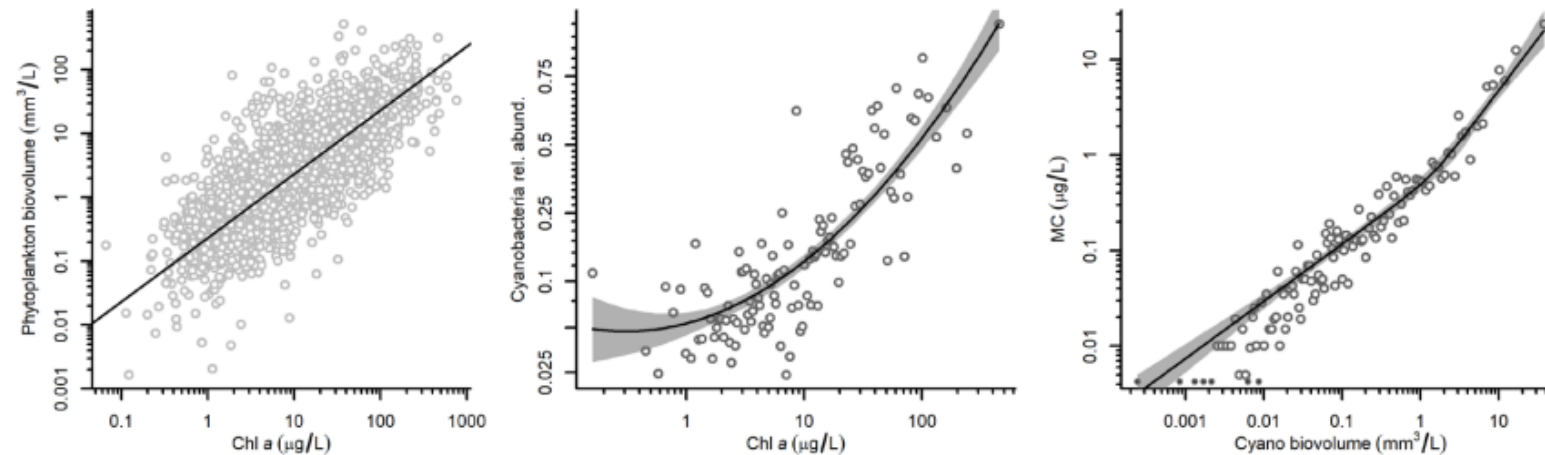
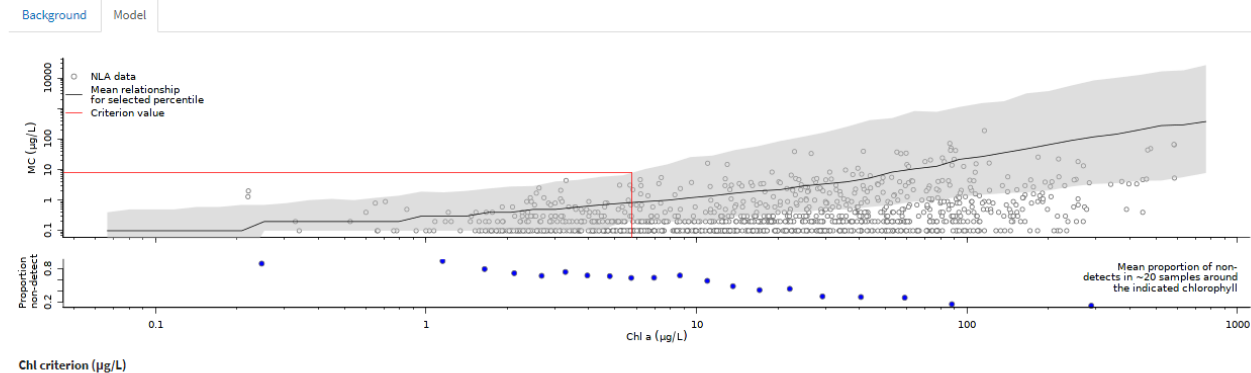
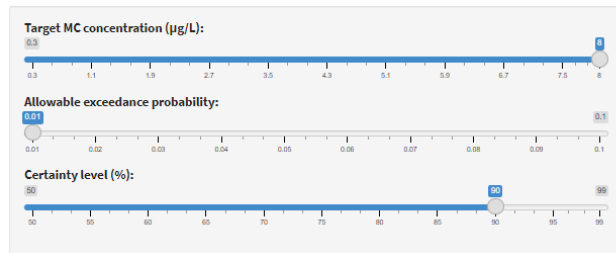


Figure 21. Modeled relationships for the microcystin model. *Left panel*: relationship between Chl *a* and phytoplankton biovolume; *open circles*: observed measurements of Chl *a* and phytoplankton biovolume; *solid line*: has a slope of 1. *Middle panel*: relationship between Chl *a* and cyanobacterial relative biovolume; *open circles*: average cyanobacterial relative biovolume in ~20 samples at the indicated Chl *a* concentration; *solid line*: estimated mean relationship; *gray shading*: 5th and 95th percentiles of the distribution of possible mean relationships (i.e., the 90% credible interval); *vertical axis*: has been logit-transformed. *Right panel*: relationship between cyanobacterial biovolume and microcystin; *open circles*: average microcystin in ~20 samples at the indicated cyanobacterial biovolume; *solid line*: estimated mean relationship; *gray shading*: 90% credible intervals about the mean relationship; *small filled circles*: Chl *a* bins in which microcystin in all samples was zero.

Microcystins- model- example effect of exceedance probability for 8 mcg/L microcystins magnitude

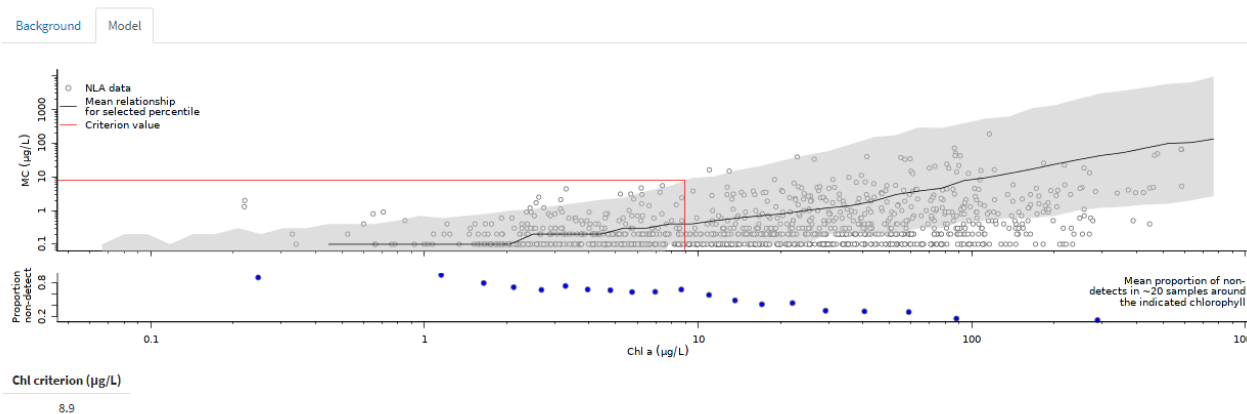
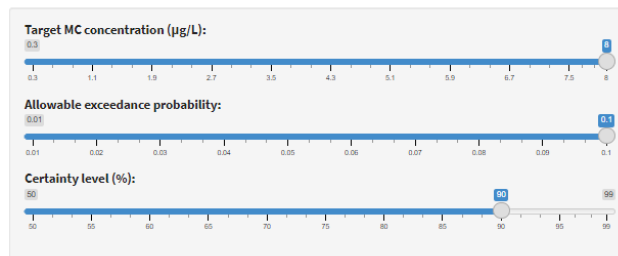
Chlorophyll – Microcystin Model



Probability 1%
exceedance=
5.7 mcg/L Chla

Related Topics: [Environmental Topics](#)

Chlorophyll – Microcystin Model



Probability 10%
exceedance=
8.9 mcg/L Chla

Exploratory Examples for the PNW

• Lake 1

- Ecoregion: Oregon Coast Range
- Natural lake state – mesotrophic, now eutrophic
- Depth- 3m maximum
- Cold water fish existing/designated use
- Recreational water; **is not*** a drinking water source
- No DOC data available; no zoo
- Not stratified

• Lake 2

- Ecoregion: Puget Sound Lowlands
- Natural lake state mesotrophic, now upper meso
- Depth- 30m maximum
- Cold water fish existing/designated use (rainbow trout)
- Recreational water; **is not*** a drinking water source
- Long term DOC data available; zoo
- Seasonally stratifies

• Lake 3

- Ecoregion: Snake River Plain
- Reservoir– oligotrophic**/mesotrophic borderline
- Depth – 20m maximum
- Cold water fish existing/designated use (whitefish)
- Recreational water; **is a drinking water source**
- No DOC data available; no zoo
- Seasonally stratifies

*if designated and microcystins are or could be an issue, consider applying drinking water value; **for oligotrophic waters– water clarity (not in these models) identified as likely more appropriate endpoint and would require a different approach⁸

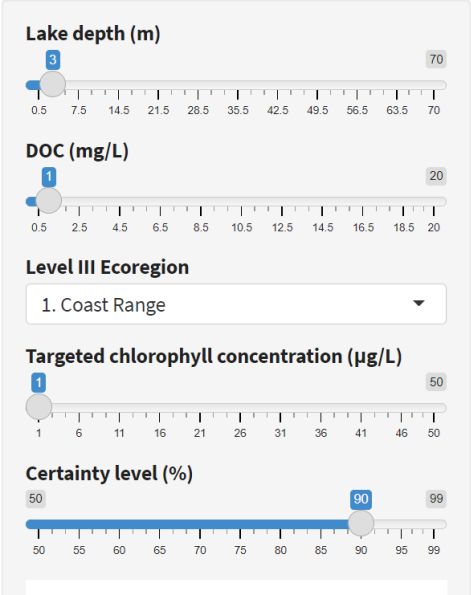
Lake 1- Oregon Coast Range

- Example Decisions
 - Models – Zoo; Microcystins; Nutrients
 - Zoo
 - Slope factor – 0.4*
 - Depth- 3 m
 - Microcystins
 - Recreational values- 8 mcg/L
 - Exceedance probability - 0.01
 - Nutrients
 - DOC- 1 mg/L (low end ecoregional value in NLA dataset for this ecoregion and depth)
 - Limiting Relationship
 - CL- 90% used for all models

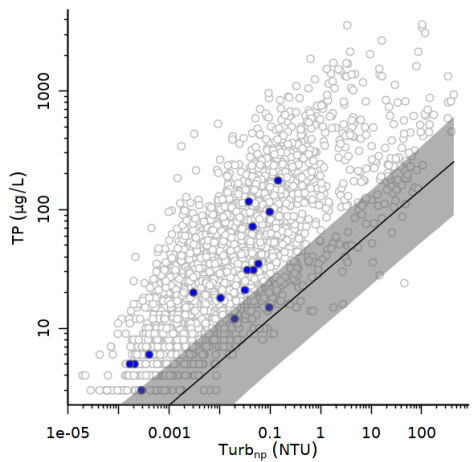
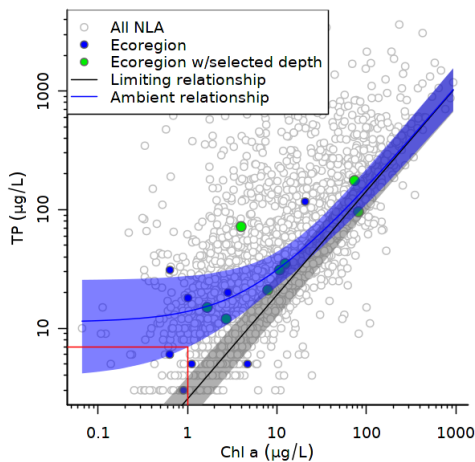
Examples only; rationale (scientifically defensible/level of protection) needed for identification of decisions
- Outcomes matrix- Seasonal Average Values
 - Chlorophyll *a* (Chla)
 - Zoo- 1 mcg/L Chla
 - Microcystins- 5.7 mcg/L Chla
 - Nutrients model using 1 mcg/L Chla
 - TN: 57 mcg/L
 - TP: 7 mcg/L
 - Nutrients model using 5.7 mcg/L Chla
 - TN: 110 mcg/L
 - TP: 17 mcg/L

*chosen to include a safety factor given lack of data, but see slides 4 and 5 for more background on zoo slope threshold

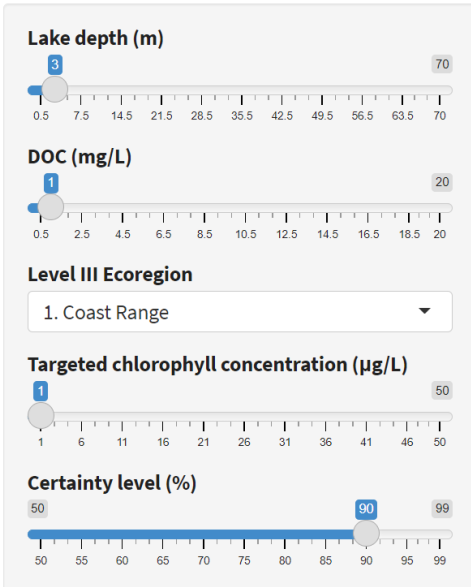
Nutrient - Chlorophyll Models



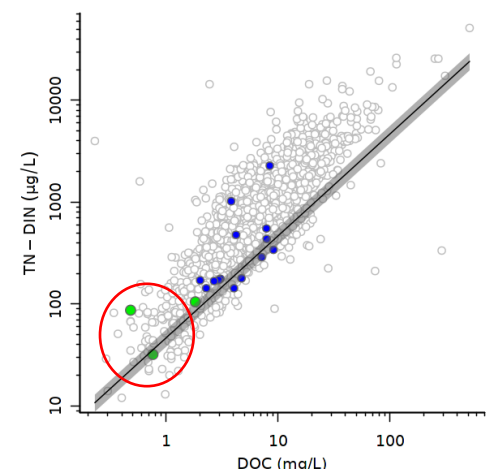
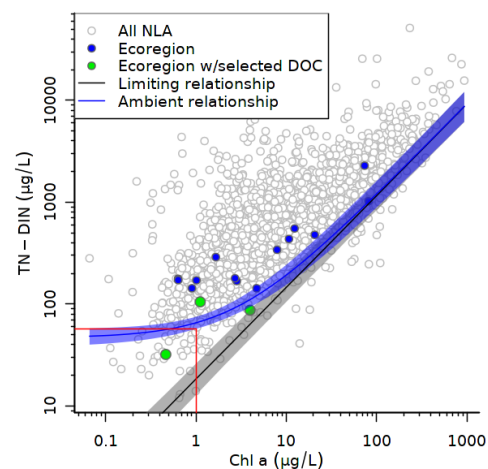
Background Phosphorus Nitrogen Candidate criteria



Nutrient - Chlorophyll Models



Background Phosphorus Nitrogen Candidate criteria



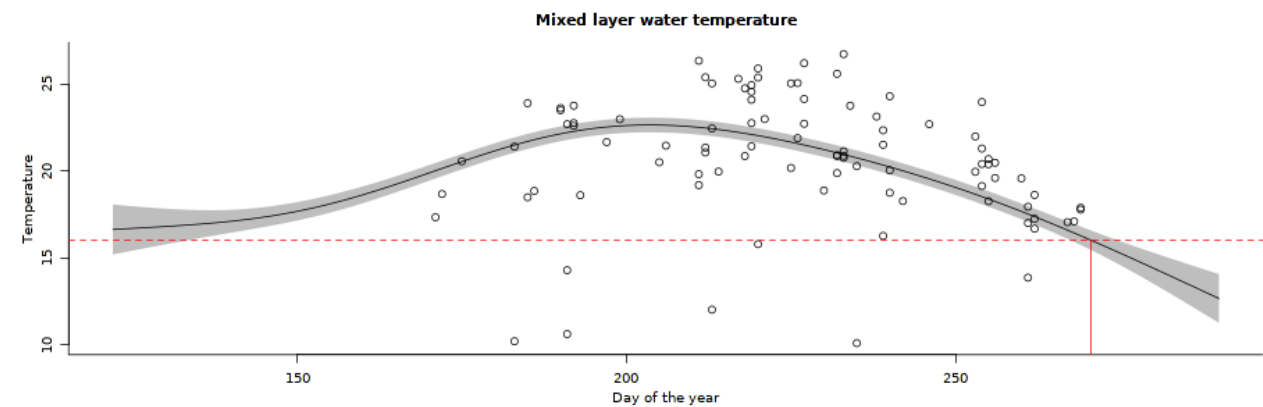
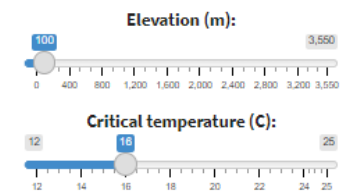
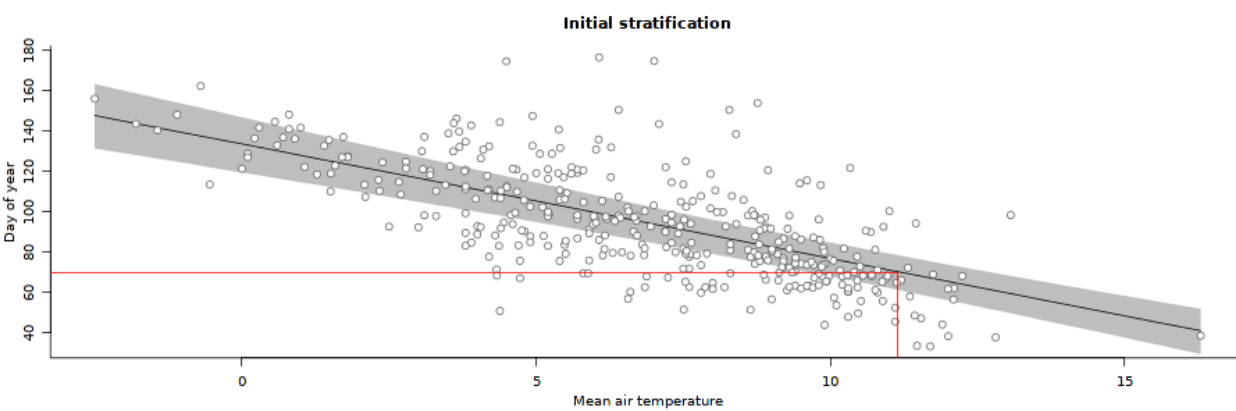
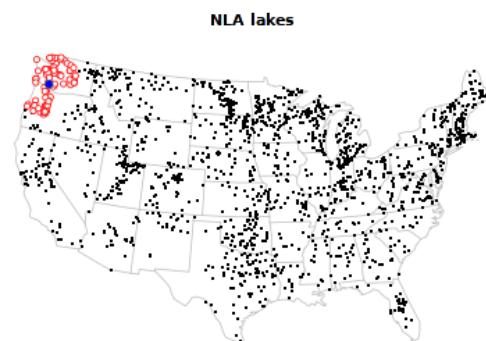
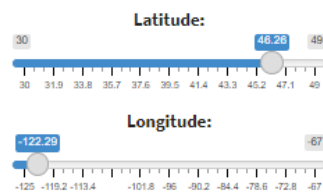
Lake 2- Puget Lowland

- Decisions

- Models – Zoo; Microcystins; Hypoxia; Nutrients
- Zoo
 - Slope factor – 0.2 (long term average)
 - Depth- 30 m
- Microcystins
 - Recreational values- 8 mcg/L
 - Exceedance probability- 0.01
- Hypoxia
 - Stratification dynamics information available
 - Refugia depth and temperature threshold based upon data on ALU/fishery
- Nutrients
 - DOC 3.4 mg/L (long term average)
 - Limiting or Ambient (Ambient)
- CL- 90% used for all models

- Outcomes matrix- Seasonal Average Values

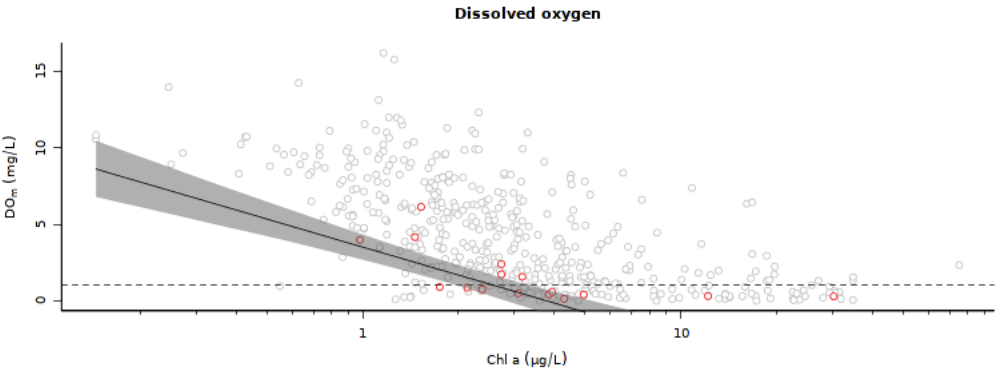
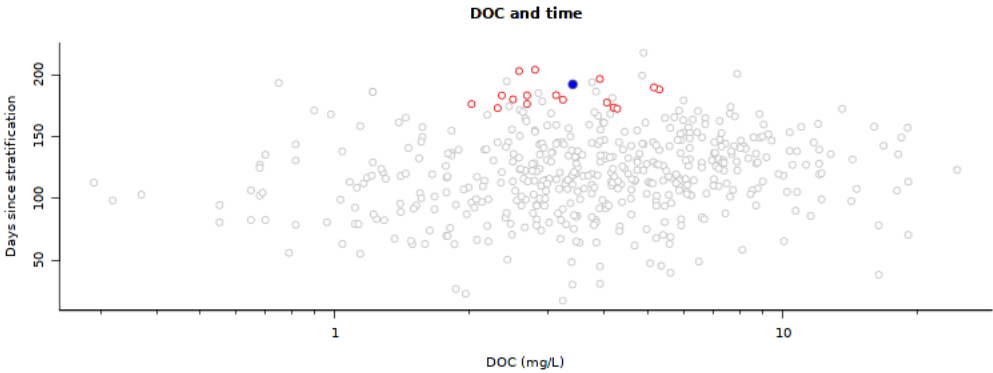
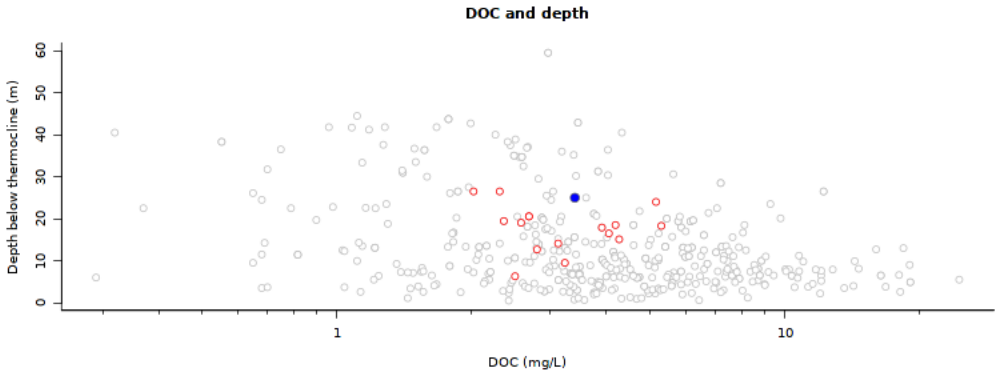
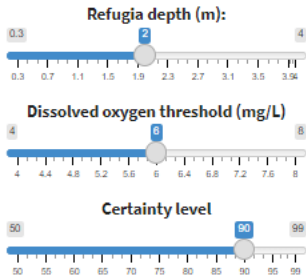
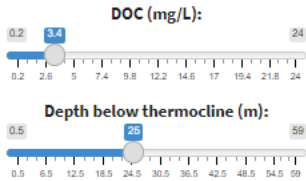
- Chlorophyll *a* (Chla)
 - Zoo – 4 mcg/L Chla
 - Hypoxia- 2 mcg/L Chla
 - Microcystins- 5.7 mcg/L Chla
- Nutrients model using 2 mcg/L Chla
 - TN: 210 mcg/L
 - TP: 6 mcg/L



	Mean day	SE
Initial stratification	70.2	5.3
Temperature release	270.6	1.7

Hypoxia Model

[Background information](#) [Critical time window](#) [Chlorophyll criteria](#)



Chl criterion (µg/L)

2.0

Nutrient - Chlorophyll Models

Lake depth (m)
0.5 70
0.5 7.5 14.5 21.5 28.5 35.5 42.5 49.5 56.5 63.5 70

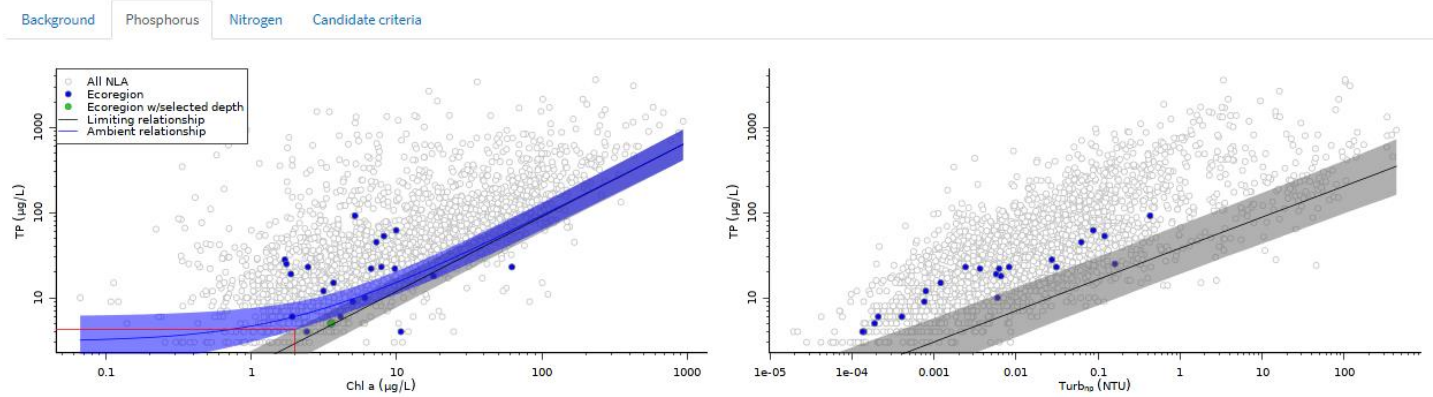
DOC (mg/L)
0.5 20
0.5 2.5 4.5 6.5 8.5 10.5 12.5 14.5 16.5 18.5 20

Level III Ecoregion
2. Puget Lowland

Targeted chlorophyll concentration (µg/L)
1 50
1 6 11 16 21 26 31 36 41 46 50

Certainty level (%)
50 99
50 55 60 65 70 75 80 85 90 95 99



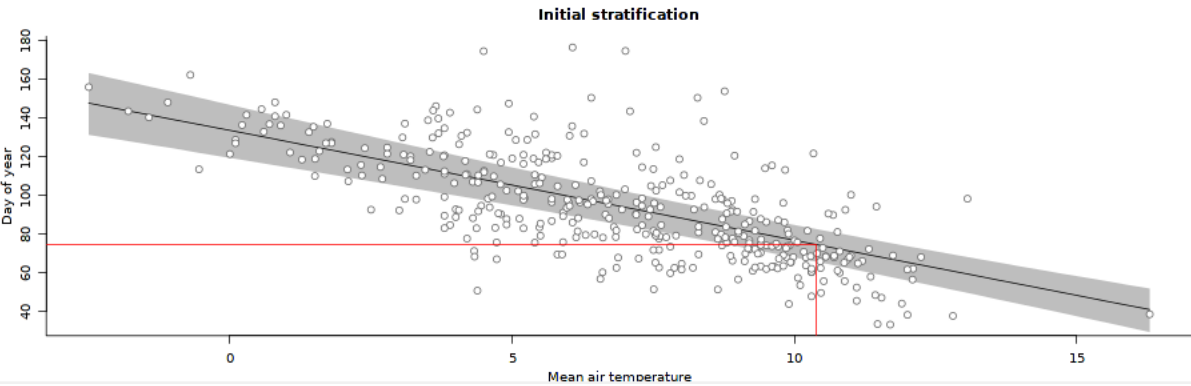
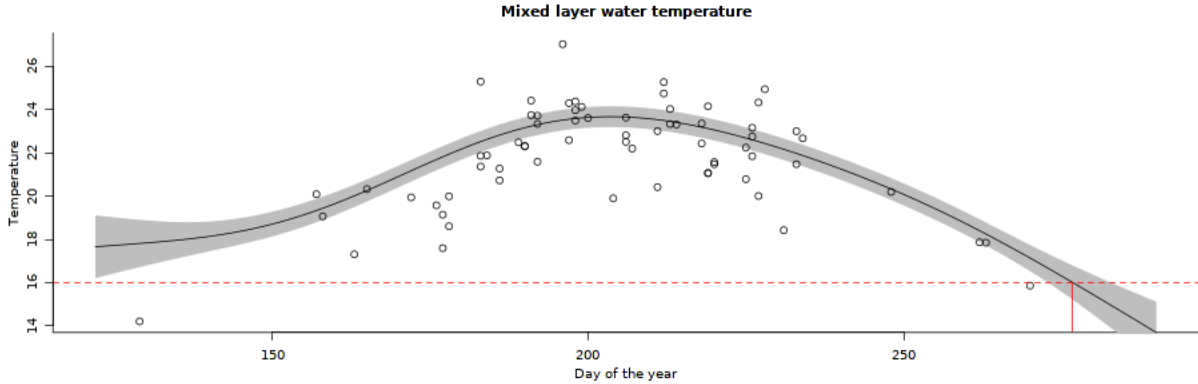
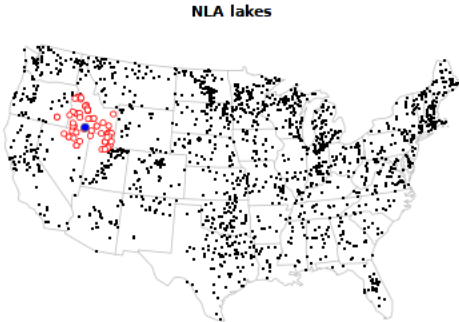
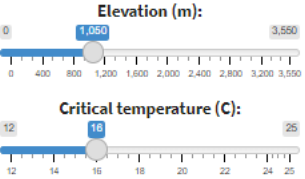
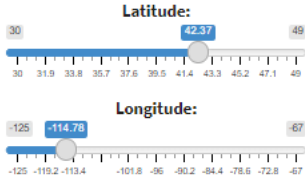


Lake 3- Snake River Plain

- Decisions
 - Models – Zoo; Microcystins; Hypoxia; Nutrients
 - Zoo
 - Slope factor – 0.4
 - Depth – 20 m
 - Microcystins
 - Recreational 8 ug/L and drinking water values 0.3 mcg/L
 - Exceedance probability; 0.01 for rec, 0.10 for drinking water (otherwise no valid data)
 - Hypoxia
 - Stratification dynamics information available
 - Refugia depth and temperature threshold based upon data from fishery
 - DOC 3 mg/L based on lowest part of NLA ecoregional distribution
 - Nutrients
 - DOC
 - Limiting or S-R
 - CL- 90% used for all models
- Outcomes matrix- Seasonal Average Values
 - Chlorophyll a (Chla)
 - Zoo – 1 mcg/L
 - Hypoxia – 1.4 mcg/L
 - Microcystins Rec- 5.7 mcg/L
 - Microcystins DW – 0.3 mcg/L
 - Nutrients model using 0.3 mcg/L Chla (lowest of modeled values, rounded up to 1 mcg/L, lowest value that can be entered)
 - TN: 200 mcg/L
 - TP: 5 mcg/L

Hypoxia Model

Background information Critical time window Chlorophyll criteria

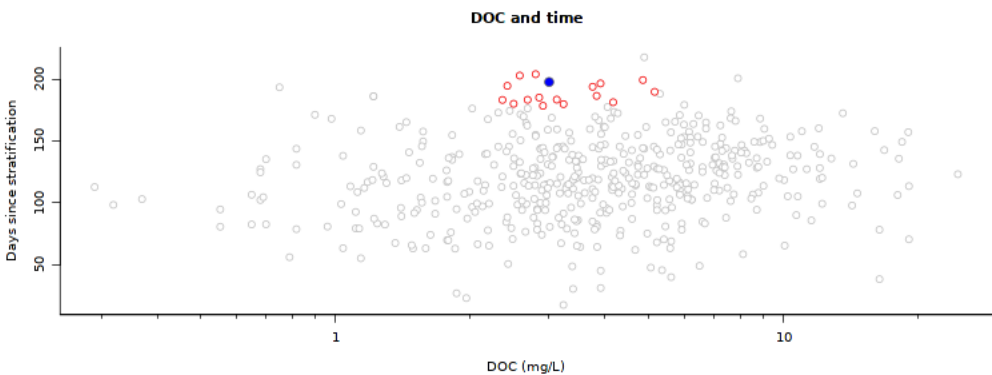
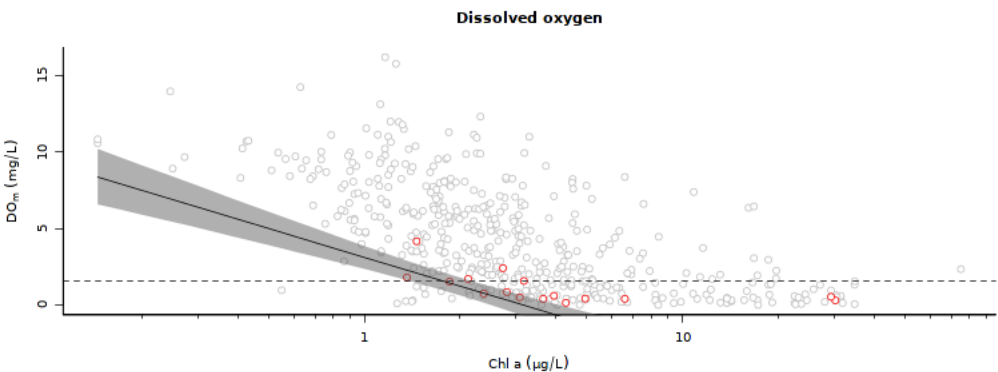
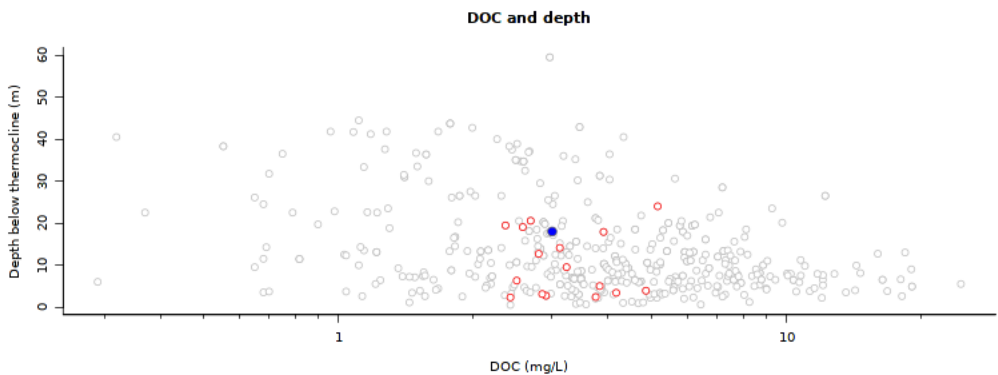
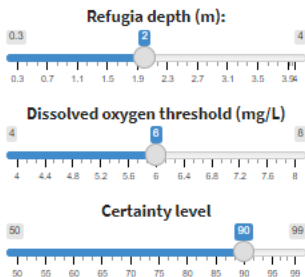
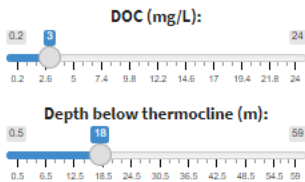


	Mean day	SE
Initial stratification	74.5	5.3
Temperature release	276.8	2.4

Hypoxia Model

[Background information](#) [Critical time window](#)

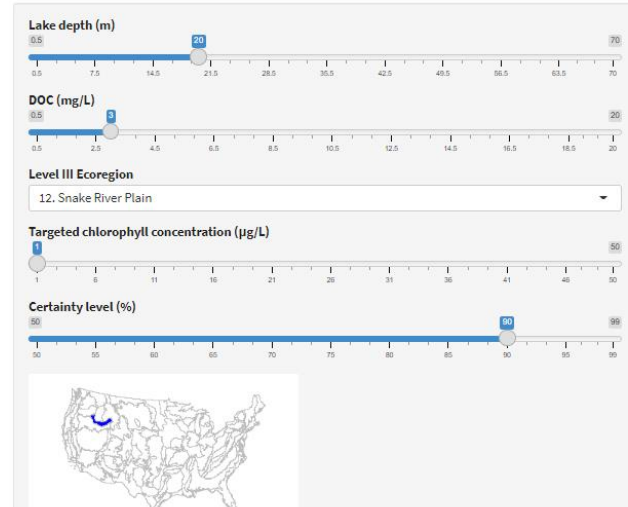
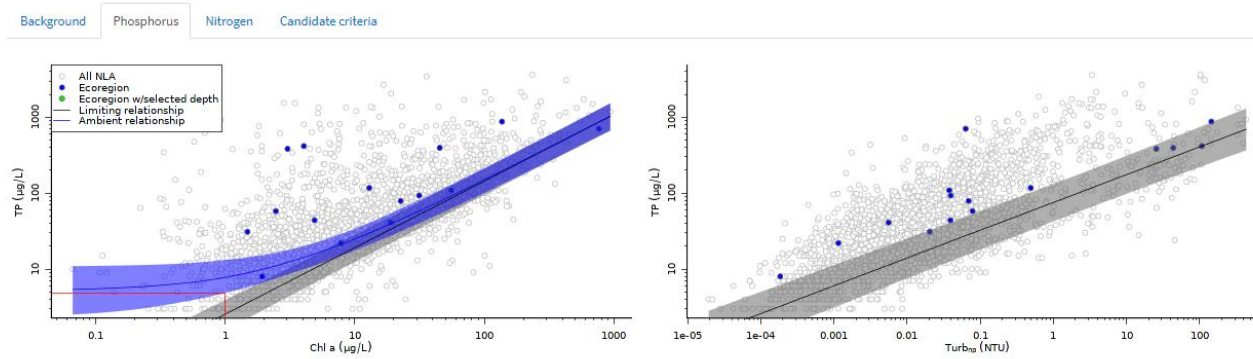
Chlorophyll criteria



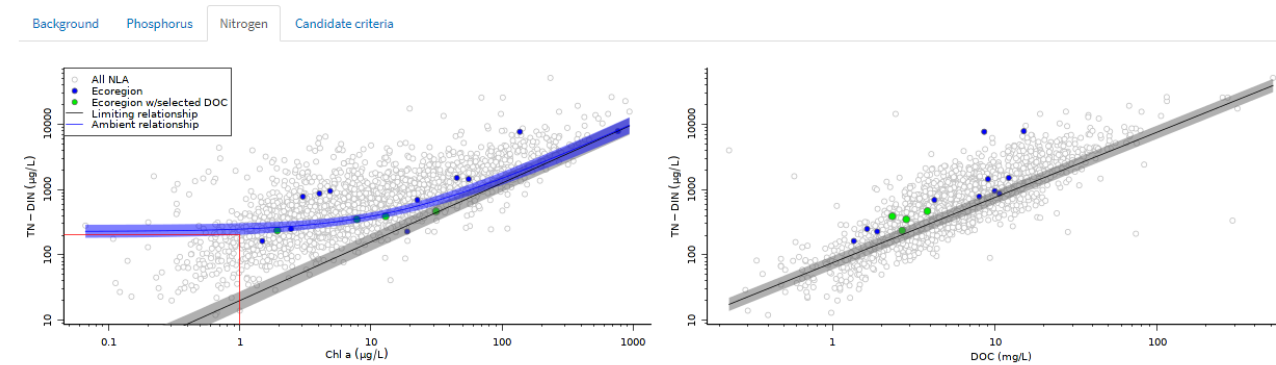
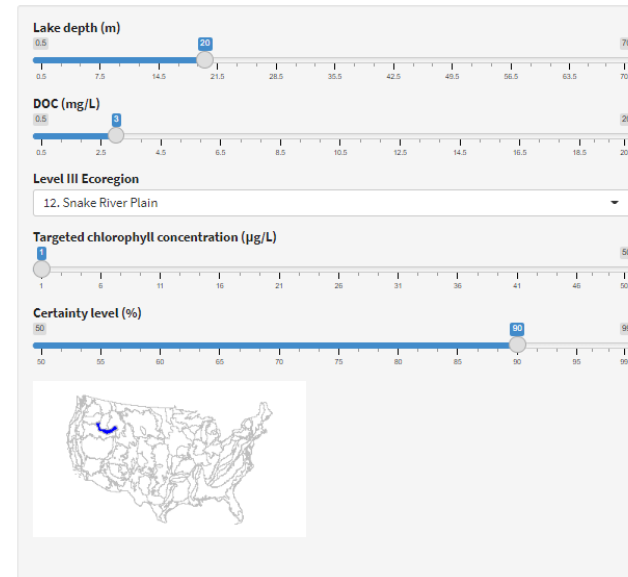
Chl criterion (µg/L)

1.4

Nutrient - Chlorophyll Models

Related Topics: [Environmental Topics](#)[Contact Us](#)

Nutrient - Chlorophyll Models



A Note About the Need for Dual Control of N and P



United States
Environmental Protection
Agency

Office of Water EPA - 820-S-15-001

MC 4304T

February 2015

Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria

Summary

Nutrient pollution resulting from excess nitrogen (N) and phosphorus (P) is a leading cause of degradation of U.S. water quality. The scientific literature provides many examples that illustrate the effects of both N and P on instream and downstream water quality in streams, lakes, estuaries, and coastal systems. Development of numeric nutrient criteria for both N and P can be an effective tool to protect designated uses in the nation's waters. The purpose of this fact sheet is

water quality standards and are an effective tool for preventing nutrient pollution, for example, in helping to derive numeric limits in discharge permits. Development of numeric nutrient criteria is one aspect of a coordinated and comprehensive approach to nutrient management [7]. EPA has published several guidance documents to assist states and authorized tribes in deriving numeric nutrient criteria for both N and P to protect aquatic systems [8, 9, 10, 11, 12].

Main points

- Trophic status can vary in space and time
- N and P in excess typically result in the highest rates of primary production
- Cyanobacteria dominance can be supported by N and/or P in excess
- Downstream protection typically requires control of both N and P

https://www.epa.gov/sites/production/files/documents/nandp_factsheet.pdf

Other considerations

- Can include a frequency of exceedance (e.g., to account for interannual variability)
- For criteria magnitude, duration, frequency and certainty, consider risk tolerance for a given outcome (e.g., microcystins criteria recommendations; aquatic life criteria/use target for response of interest)
- Seasonal calculation should be based on site or ecoregion-specific growing season
- Ecoregional criteria possible, with conservative assumptions, but note depth ranges and other aspects in protecting all waters and uses to which the criteria will apply. Subcategories may be preferred.
- For state or tribal data to be included in the models, N-STEPs support would be necessary.

Contact

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- Lester Yuan Environmental Engineer, EPA's Office of Science and Technology, yuan.lester@epa.gov 2021 Lake/Reservoir Criteria Recommendations POC