

Appendix A

Annotated Literature

Citation Title:

Surface waters

Authors

Baron, J.

Source

Biogeochemistry of a Subalpine Ecosystem

Annotation:

Another N critical load paper. Generally redundant with other studies so far.

Abstract:

SUMMARY Chapter is specific to surface waters of the Loch Vale Watershed. Strong seasonal difference is as or more important than spatial differences between alpine and subalpine lakes.

Stressor/Response/Threshold Info

Year

1992

Volume

Pages

142-186

Location

Reviewer Comments:

Edited By: kristen

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Document Type

Peer review status

Keywords

Regions

Study Design

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load

Authors

Baron, J.

Year

2006

Source

Ecological Applications

Volume Pages Location

16 433-439

Annotation:

Reinforces studies suggesting influence of atmospheric N enrichment on east divide lake systems, increased eutrophic diatoms, increased chlorophyll, increased NO₃ concentrations.

Reviewer Comments:

Abstract:

Using an estimated background nitrogen (N) deposition value of 0.5 kg N_{ha}-1yr-1 in 1900, and a 19-year record of measured values from Loch Vale (Colorado, USA; NADP site CO98), I reconstructed an N-deposition history using exponential equations that correlated well with EPA-reported NO_x emissions from Colorado and from the sum of emissions of 11 western states. The mean wet N-deposition values for the period 1950–1964 was ;1.5 kg N_{ha}-1yr-1 , corresponding to the reported time of alteration of diatom assemblages attributed to N deposition in alpine lakes in Rocky Mountain National Park (USA). This value becomes the critical load defining the threshold for ecological change from eutrophication. Thus if an N-deposition threshold for ecological change can be identified, and the date at which that threshold was crossed is known, hindcasting can derive the amount of atmospheric deposition at the time of change, at least for alpine lakes. Independent support for the technique and the deposition amount comes from experimental studies, ecosystem modeling, and paleolimnological records from northern Wyoming (USA).

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Keywords

Regions

Rocky Mountains

Study Design

Paleolimnological reconstruction

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Ecosystem Responses to Nitrogen Deposition in the Colorado Front Range

Authors

Baron, J.S.; Rueth, H.M.; Wolfe, A.M.; Nydick, K.R.; Allstott, E.J.; Minear, J.T.; Moraska, B.

Year

2000

Source

Ecosystems

Volume Pages Location

3 352-368

Annotation:

RMNP study lakes are generally sensitive lakes with low TP and elevated NO₃ from atmospheric N.

Reviewer Comments:

Abstract:

We asked whether 3–5 kg N y⁻¹ atmospheric N deposition was sufficient to have influenced natural, otherwise undisturbed, terrestrial and aquatic ecosystems of the Colorado Front Range by comparing ecosystem processes and properties east and west of the Continental Divide. The eastern side receives elevated N deposition from urban, agricultural, and industrial sources, compared with 1–2 kg N y⁻¹ on the western side. Foliage of east side old-growth Englemann spruce forests have significantly lower C:N and lignin:N ratios and greater N:Mg and N:P ratios. Soil % N is higher, and C:N ratios lower in the east side stands, and potential net N mineralization rates are greater. Lake NO₃ concentrations are significantly higher in eastern lakes than western lakes. Two east side lakes studied paleolimnologically revealed rapid changes in diatom community composition and increased biovolumes and cell concentrations. The diatom flora is now representative of increased disturbance or eutrophication. Sediment nitrogen isotopic ratios have become progressively lighter over the past 50 years, coincident with the change in algal flora, possibly from an influx of isotopically light N volatilized from agricultural fields and feedlots. Seventy-five percent of the increased east side soil N pool can be accounted for by increased N deposition commensurate with human settlement. Nitrogen emissions from fixed, mobile, and agricultural sources have increased dramatically since approximately 1950 to the east of the Colorado Front Range, as they have in many parts of the world. Our findings indicate even slight increases in atmospheric deposition lead to measurable changes in ecosystem properties.

Stressor/Response/Threshold Info

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Keywords

alpine

Regions

Rocky Mountains

diatoms

nitrogen

paleolimnology

Rocky Mountains

subalpine forests

Study Design

Waterbody Types

Paleolimnological reconstruction

lake

reservoir

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Atmospheric nitrogen deposition has caused nitrogen enrichment and eutrophication of lakes in the northern hemisphere

Authors

Bergstrom, A.-K.; Jansson, M.

Year

2006

Source

Global Change Biology

Volume Pages Location

12 635-643

Annotation:

Atmospheric N enrichment globally eutrophying lakes, especially oligotrophic lakes, suggests more N limitation, and may explain P effects.

Reviewer Comments:

Abstract:

We compiled chemical data and phytoplankton biomass (PB) data (chlorophyll a) from unproductive lakes in 42 different regions in Europe and North America, and compared these data to inorganic nitrogen (N) deposition over these regions. We demonstrate that increased deposition of inorganic N over large areas of Europe and North America has caused elevated concentrations of inorganic N in lakes. In addition, the unproductive lakes in high N deposition areas had clearly higher PB relative to the total phosphorus (P) concentrations illustrating that the elevated inorganic N concentrations has resulted in eutrophication and increased biomass of phytoplankton. The eutrophication caused by inorganic N deposition indicates that PB yield in a majority of lakes in the northern hemisphere is (was) limited by N in their natural state. We, therefore, suggest that P limitation largely concerns lakes where the balance between N and P has been changed because of increased anthropogenic input of N.

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Document Type

Keywords

chlorophyll

deposition

eutrophication
limitation

nitrogen
northern lakes

nutrient

phosphorus
phytoplankton

Study Design

Field experiment

Peer review status

Regions

Europe

North America

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Diatom-inference models for surface-water temperature and salinity developed from a 57-lake calibration set from the Sierra Nevada, California, USA

Authors

Bloom, A.M.; Moser, K.A.; Porinchu, D.F.; MacDonald, G.M.

Year

2003

Source

Journal of Paleolimnology

Volume Pages

29 235-255

Location

Annotation:

Salinity model, not really relevant.

Reviewer Comments:

Abstract:

Physical, chemical, and biological data were collected from a suite of 57 lakes that span an elevational gradient of 1360 m (2115 to 3475 m a.s.l.) in the eastern Sierra Nevada, California, USA as part of a multiproxy study aimed at developing transfer functions from which to infer past drought events. Multivariate statistical techniques, including canonical correspondence analysis (CCA), were used to determine the main environmental variables influencing diatom distributions in the study lakes. Lakewater depth, surface-water temperature, salinity, total Kjeldahl nitrogen, and total phosphorus were important variables in explaining variance in the diatom distributions. Weighted-averaging (WA) and weighted-averaging partial least squares (WA-PLS) were used to develop diatom-based surface-water temperature and salinity inference models. The two best diatom-inference models for surface-water temperature were developed using simple WA and inverse deshrinking. One model 2 covered a larger surface-water temperature gradient (13.7 8C) and performed slightly poorer (r 5 0.72, RMSE 5 1.4 8C, RMSEP 5 2.1 8C) than a second model, which covered a smaller gradient (9.5 8C) and performed jack 2 slightly better (r 5 0.89, RMSE 5 0.7 8C, RMSEP 5 1.5 8C). The best diatom-inference model for salinity jack 2 21 was developed using WA-PLS with three components (r 5 0.96, RMSE 5 4.06 mg L , RMSEP 5 11.13 mg jack 21 L). These are presently the only diatom-based inference models for surface-water temperature and salinity developed for the southwestern United States. Application of these models to fossil-diatom assemblages preserved in Sierra Nevada lake sediments offers great potential for reconstructing a high-resolution time-series of Holocene and late Pleistocene climate and drought for California.

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Keywords

alpine
California

Regions

North America

diatoms

drought
inference models

paleolimnology
salinity

Sierra Nevada

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

The effects of atmospheric nitrogen deposition in the Rocky Mountains of Colorado and southern Wyoming, USA—a critical review

Authors

Burns, D.A.

Year

2004

Source

Environmental Pollution

Volume Pages

127 257-269

Location

Annotation:

Questions extent of atmospheric N in front range systems.

Long-term core data do support N enrichment, but recent surface water NO₃ may not. NO₃ concentration east of divide are greater than west.

Abstract:

The Rocky Mountains of Colorado and southern Wyoming receive atmospheric nitrogen (N) deposition that ranges from 2 to 7 kg ha⁻¹ yr⁻¹, and some previous research indicates pronounced ecosystem effects at the highest rates of deposition. This paper provides a critical review of previously published studies on the effects of atmospheric N deposition in the region. Plant community changes have been demonstrated through N fertilization studies, however, N limitation is still widely reported in alpine tundra and subalpine forests of the Front Range, and sensitivity to changes in snowcover alone indicate the importance of climate sensitivity in these ecosystems. Retention of N in atmospheric wet deposition is <50% in some watersheds east of the Continental Divide, which reflects low biomass and a short growing season relative to the timing and N load in deposition. Regional upward temporal trends in surface water NO₃ concentrations have not been demonstrated, and future trend analyses must consider the role of climate as well as N deposition. Relatively high rates of atmospheric N deposition east of the Divide may have altered nutrient limitation of phytoplankton, species composition of diatoms, and amphibian populations, but most of these effects have been inconclusive to date, and additional studies are needed to confirm hypothesized cause and effect relations. Projected future population growth and energy use in Colorado and the west increase the likelihood that the subtle effects of atmospheric N deposition now evident in the Front Range will become more pronounced and widespread in the future.

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Document Type

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Keywords

atmospheric nitrogen deposition

Colorado

lake chemistry
nitrogen saturation

Rocky Mountains

Study Design

Review

Regions

Rocky Mountains

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Prediction of total phosphorus concentrations, chlorophyll-a, and Secchi depths in natural and artificial lakes

Authors

Canfield, D.E., Jr.; Bachmann, R.W.

Year

1981

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages

38 414-423

Location

Annotation:

Equations for predicting TP in lakes and reservoirs based on P loading rate, depth, and hydraulic flushing rate. Can then be tied to Chl and Secchi depth. More noise in reservoir relationships.

Reviewer Comments:

Abstract:

SUMMARY A model for prediction of total P was developed and tested using data on 704 natural and artificial lakes including 626 lakes in the EPA National Eutrophication Survey. The model yields unbiased estimates of P concentrations over a wide range of lake types and has a 95% confidence interval of 31-288% of the calculated total P concentration. Other models are less precise.

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Keywords

eutrophication

lake trophic state

phosphorus models

Regions

North America

Study Design

Modeling

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

[A Trophic State Index for Lakes](#)

Authors

Carlson, R.E.

Source

Limnology and Oceanography

Annotation:

Original TSI paper. Lays out basis for TSI and relative linkage to trophic state.

Abstract:

A numerical trophic state index for lakes has been developed that incorporates most lakes in a ascale of 0 to 100. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including Secchi disk transparency, cholorophyll, and total phosphorus.

Stressor/Response/Threshold Info**Year**

1977

Volume

22

Pages

361-369

Location**Reviewer Comments:**

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Document Type**Peer review status****Keywords**

algal biomass

chlorophyll

Secchi depth

total phosphorus

Regions

North America

Study Design

Index

Waterbody Types

lake

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Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

[More complications in the chlorophyll-Secchi disk relationship](#)

Authors

Carlson, R.E.

Source

Limnology and Oceanography

Annotation:

TSI based on Secchi is robust in non-algal turbidity if Chl measured as well.

Abstract:**Year**

1980

Volume

25

Pages

379-382

Location**Reviewer Comments:**

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Document Type**Peer review status****Keywords****Regions****Study Design**

Review

Waterbody Types**Projects**

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Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Changes in the chemistry of lakes and precipitation in high-elevation national parks in the western United States, 1985–1999

Authors

Clow, D.W.; Sickman, J.O.; Striegl, R.G.; Krabbenhoft, D.P.; Elliott, J.G.; Dornblaser, M.; R, D.A.; Campbell, D.H.

Year

2003

Source

Water Resources Research

Volume Pages Location

39 1171-1184

Annotation:

1999 resampled 69 EPA Western Lakes 85 lakes from 1985. Generally similar NO₃ or slightly lower, generally higher TP.

Reviewer Comments:

Abstract:

[1] High-elevation lakes in the western United States are sensitive to atmospheric deposition of sulfur and nitrogen due to fast hydrologic flushing rates, short growing seasons, an abundance of exposed bedrock, and a lack of well-developed soils. This sensitivity is reflected in the dilute chemistry of the lakes, which was documented in the U.S. Environmental Protection Agency's Western Lake Survey of 1985. Sixty-nine lakes in seven national parks sampled during the 1985 survey were resampled during fall 1999 to investigate possible decadal-scale changes in lake chemistry. In most lakes, SO₄ concentrations were slightly lower in 1999 than in 1985, consistent with a regional decrease in precipitation SO₄ concentrations and in SO₂ emissions in the western United States. Nitrate concentrations also tended to be slightly lower in 1999 than in 1985, in contrast with generally stable or increasing inorganic N deposition in the west. Differences in alkalinity were variable among parks but were relatively consistent within each park. Possible effects of annual and seasonal-scale variations in precipitation amount on lake chemistry were evaluated based on climate data available for the parks and an analysis of climatic effects at two research watersheds with long-term records. Results suggest that rain prior to sampling in 1985 may have caused elevated NO₃ in some lakes due to direct runoff of precipitation and flushing of NO₃ from alpine soils, which may explain some of the decrease in NO₃ concentrations observed in survey lakes.

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Keywords

alpine

Regions

North America

atmospheric deposition

emissions

lake chemistry

talus

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Three Lakes Clean Lakes Watershed Assessment Draft Report

Authors

Hydrosphere Resource Consultants

Year

2003

Source

Volume **Pages** **Location**
64 pp

Annotation:

3 Lakes reservoirs in Colorado along continental divide. All mesotrophic. N and P limited. TP 7-11 ug/L, TN 195-210 ug/L, Chl a 4-7 ug/L.

Reviewer Comments:

Abstract:

A study was conducted to assess the water-quality of the Three Lakes and surrounding area. Water-quality data were collected over a 24 month period and used to develop and calibrate a watershed model and an integrated, time-varying lake / reservoir water-quality model. A nutrient loading and trophic state analysis was also conducted. Additional modeling runs were made using hydrology from a ten-year period in the 1970's and 1980's to assess how the system would react under different hydrologic conditions. One ten-year run assumed existing demands and the other assumed future projected full-use demand conditions.

According to the data used in this analysis, the following key points were made:

- The water-quality of each of the Three Lakes is very similar even though the morphometry (physical structure) and residence times (the amount of time the water "resides" in the system) significantly differ. This is a result of the tightly integrated manner in which the system is operated.
 - Each of the Three Lakes are in a mesotrophic or moderately-nourished trophic state.
 - Although predominantly nitrogen limited, the lakes are probably limited by both nitrogen and phosphorus for portions of the year.
 - Precipitation is a significant source of nutrients to the system.
 - The more developed sub-watersheds contribute a disproportionate amount of nutrients to the system (Stillwater, Windy Gap, Willow Creek).
 - Model output shows the Three Lakes remaining in a mesotrophic state under each of the ten-year runs.
- The study was somewhat limited by high detection limits for nitrate, ammonium, and ortho-phosphate and by few data points for the Windy Gap and Willow Creek inflows.

Recommendations include:

- Continued and improved implementation of construction and recreation related Best Management Practices (BMPs);
- Implementation of additional stormwater water-quality control measures;
- Conducting a septic system survey and replacing poorly operating systems;
- A survey of user perceptions and the development of a site-specific waterquality index;
- More frequent and expanded monitoring for the Willow Creek and Windy Gap sub-watersheds;
- Modeling of the Willow Creek and Windy Gap sub-watersheds, including point source impacts;
- Use of analytic methods with lower detection limits for ortho-phosphate, ammonium, and nitrate; and
- The watershed and lake / reservoir models should be run under a variety of conditions to estimate resultant water-

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Keywords

nutrient loading

watershed model

Regions

Rocky Mountains

Study Design

Field experiment

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Stressor/Response/Threshold Info

Annotated Literature

quality.

Citation Title:

[Hypolimnetic Oxygen Deficits: Their Prediction and Interpretation](#)

Authors

Cornett, R.J.; Rigler, F.H.

Year

1979

Source

Science

Volume Pages

205 580-581

Location

Edited By: kristen

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Annotation:

Areal hypolimnetic oxygen demand not reliable predictor of trophic state without hypolimnetic morphometry data.

Reviewer Comments:

Keywords

hypolimnion

Regions

lake trophic state

oxygen

phosphorus

Abstract:

Rates of hypolimnetic oxygen depletion can be predicted from a knowledge of a lake's phosphorus retention, the average hypolimnetic temperature, and the mean thickness of the hypolimnion. Areal oxygen deficits cannot be used to index lake trophic status because areal calculations do not eliminate the influence of hypolimnetic morphometry.

Study Design

Modeling

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Inferring sedimentary chlorophyll concentrations with reflectance spectroscopy: a novel approach to reconstructing historical changes in the trophic status of mountain lakes

Authors

Das, B.; Vinebrooke, R.D.; Sanchez-Azofeifa, A.; Rivard, B.; Wolfe, A.P.

Year

2005

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

62 1067-1078

Annotation:

RMNP lakes ranging in NO₃: 0.08-1.0 mg/L, NH₄: 15-33 ug/L, TP: 3-11 ug/L. All lakes exhibit large post 1950s chlorophyll a increases.

Reviewer Comments:

Abstract:

Reflectance spectroscopy has made it possible to rapidly and nondestructively assess the chlorophyll content of plants and natural waters. However, to date this approach has not been applied to chlorophyll and chlorophyll derivatives preserved in lake sediments. Here, we explore the relationships between visible-near-infrared spectral properties of lake sediments and measured pigment concentrations for lakes that have been exposed recently to anthropogenic nitrogen deposition. Down-core decreases in pigment concentrations and changes in reflectance properties effectively chronicle increases in whole-lake primary production since 1950. Specifically, reflectance spectra of sediments from four alpine lakes in Rocky Mountain National Park (Colorado Front Range, USA) preserve salient troughs near 675 nm that covary in magnitude with concentrations of chlorophyll a and associated pheopigments. The area of the trough in reflectance between 600 and 760 nm best explains the sum of total chlorophyll a and its derivatives ($r^2 = 0.82$, $n = 23$, $P < 0.01$). This result suggests that chlorophyll a preserved in lake sediments can be remotely sensed using a simple index derived from reflectance spectroscopy, thus providing a new paleolimnological strategy for rapid exploratory assessments of changing lake trophic status.

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Document Type

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Keywords

alpine

Regions

Rocky Mountains

chlorophyll

primary production
reflectance

Rocky Mountains
sediment

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

[A simple method for predicting the capacity of a lake for development based on lake trophic status](#)

Authors

Dillon, P.J.; Rigler, F.H.

Year

1975

Source

Journal of Fisheries Research Board of Canada

Volume Pages Location

32 1519-1531

Annotation:

Classic on predicting effects of development on lake productivity. More people, more P, more chlorophyll.

Reviewer Comments:**Abstract:**

SUMMARY General technique presented for calculating the capacity of a lake for development based on quantifiable relationships between nutrient inputs and water quality parameters reflecting lake and geological formations prevalent in a lake's drainage basin.

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Document Type**Peer review status****Keywords**

development

Regions

North America

nutrient
phosphorus

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Seasonal uptake and regeneration of inorganic nitrogen and phosphorus in a large oligotrophic lake: size-fractionation and antibiotic treatment

Authors

Dodds, W.K.; Prisco, J.C.; Ellis, B.K.

Source

Journal of Plankton Research

Annotation:

N and P both limit large glacial oligotrophic Flathead Lake. Responds to both N and P. Both limit production.

Abstract:

Uptake and regeneration of inorganic N and P in oligotrophic Flathead Lake (Montana) were measured with ^{13}N and ^{32}P incorporation and dilution experiments, six times over a seasonal cycle. The annual mean molar N:P uptake ratio at ambient concentrations was 13.9 (range = 4.8-34.2); uptake of nitrate, ammonium and phosphate were always below saturation indicating both N and P deficiency. Organisms $>280\ \mu\text{m}$ were responsible for 0-60% of ammonium and 0-40% of phosphate regeneration, 40-100% of the ammonium and 34-98% of phosphate regeneration occurred in the $<3\ \mu\text{m}$ fraction. The $<3\ \mu\text{m}$ fraction accounted for 7-70% of the ammonium and 6-64% of the phosphate uptake. Results from antibiotic treatments indicated that both prokaryotic and eukaryotic ammonium uptake was important, and that eukaryotes accounted for 53-98% of the ammonium regeneration. During thermal stratification, heterotrophic ammonium and phosphate regeneration by organisms $<3\ \mu\text{m}$ supplied much of the inorganic N and P in the epilimnion. Estimated rates of allochthonous and diffusive (i.e. 'new') ammonium, nitrate and phosphate input were $<5\%$ of biotic regeneration. These results suggest that (i) both N and P dynamics should be considered when examining nutrient regulation of primary productivity of oligotrophic lakes, (ii) bacteria probably compete with phytoplankton for both ammonium and phosphate, (iii) biotic regeneration is the main source of nutrients to the epilimnion during stratification, and (iv) crustacean zooplankton were relatively unimportant sources of regenerated ammonium and phosphate.

Stressor/Response/Threshold Info

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Document Type

Keywords

phosphate

Study Design

Field experiment

Peer review status

Regions

North America

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Interactive effects of temperature and nutrient limitation on the response of alpine phytoplankton growth to ultraviolet radiation

Authors

Doyle, S.A.; Saros, J.E.; Williamson, C.E

Year

2005

Source

Limnology and Oceanography

Volume Pages Location

50 1362-1367

Annotation:

Beartooth lake nutrient addition. Oligotrophic lake. UV exposure may influence N enrichment responses being observed. Nutrients definitely stimulate algae in these lakes.

Reviewer Comments:

Abstract:

We performed bag-enclosure experiments for 7 d in a lake in the Beartooth Mountains (in Montana and Wyoming) using natural phytoplankton assemblages. Ultraviolet radiation (UVR) (exposed or blocked), temperature (68C and 148C), and nutrients (nitrogen, phosphorus, and nitrogen plus phosphorus) were manipulated in a factorial design to determine how these factors interact to affect phytoplankton growth. Four major phytoplankton taxa (two diatoms, one chrysophyte, and one dinoflagellate) were found in the water samples across all treatments. Greater growth rates were observed at the higher temperature for all taxa, except the chrysophyte. UVR depressed the growth rates of all phytoplankton at 68C regardless of nutrient conditions. In contrast, at 148C, a negative effect of UVR was not observed for any species in the absence of nutrient additions; only with the addition of nutrients did UVR exposure depress the growth of one diatom species and the dinoflagellate. Our results suggest that in alpine lakes, the effects of UVR exposure on phytoplankton depend on temperature and nutrient availability, indicating that climate change and enhanced atmospheric nitrogen deposition are likely to alter UV-temperature-nutrient relationships of plankton in high-UV systems.

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Document Type

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Keywords

nutrient

phytoplankton

UVR

Regions

North America

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

[Trophic state evaluation for selected lakes in Grand Teton National Park](#)

Authors

Dustin, J.S.; Miller, A.W.

Year

2001

Source

Journal of the American Water Resources Association

Volume Pages Location

37 887-898

Annotation:

Survey of trophic state (3 approaches) of Grand Teton lakes: Alpine and Moraine lakes - oligo-meso; Colter Bay and Valley lakes - meso. Geologic drivers/differences.

Reviewer Comments:

Abstract:

Increased visitation at Grand Teton National Park (GTNP) has raised concerns about impacts on surface water in the park. The purposes of this study are to perform a benchmark trophic state survey for comparison to future evaluations and to identify possible areas of concern. Four watershed regions based on geographic and geologic features were delineated for study. Six Alpine lakes, six Moraine lakes, three Valley lakes, and two Colter Bay lakes are evaluated. Lakes were sampled for total phosphorus (TP), chlorophyll-a, and transparency. The water quality, as defined by trophic state, in the park is generally good. Oligotrophic to mesotrophic conditions were found in the Alpine and Moraine lakes and mesotrophic to eutrophic conditions were found in the Colter Bay and Valley lakes. High inflow TP concentrations in the park's northeast side may be due to the presence of natural geologic phosphate from the Phosphoria Formation.

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Keywords

chlorophyll

eutrophication

lake trophic state
phosphorus

Secchi depth

Regions

North America

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Phosphorus and nitrogen limitation of phytoplankton growth in the freshwaters of North America: A review and critique of experimental enrichments.

Authors

Elser, J.J.; Marzolf, E.R.; Goldman, C.R.

Year

1990

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

47 1468-1477

Annotation:

N limitation much more common than perceived, co-limitation most common.

Reviewer Comments:

Abstract:

While phosphorus is generally considered to be the primary nutrient limiting algal growth in lakes, limitation of algal growth by nitrogen has been observed in freshwater. It is also commonly observed that the most pronounced phytoplankton responses to enrichment occur when both N and P are added together. This led us to re-evaluate nitrogen's status as a secondary nutrient in freshwater through a systematic literature search. In our survey of enrichment bioassays, we found considerable deficiencies in the degree to which investigators have applied sufficient replication, performed and reported statistical tests, and assessed seasonal and spatial differences in algal nutrient limitation. Given these limitations, however, we found that combined N + P enrichment enhanced algal growth much more frequently and more substantially than did addition of N or P singly. On average, the frequency and degree of algal response did not differ for P vs. N enrichment. From our review of whole-lake fertilizations, we concluded that the roles of N and P in constraining algal growth at the whole-lake scale have not been completely separated. We suggest that greater attention should be given to both P and N in the future.

Stressor/Response/Threshold Info

Edited By: kristen

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Document Type

Peer review status

Keywords

algae

nitrogen

phosphorus

phytoplankton

Regions

North America

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Compound-specific stable isotopes of organic compounds from lake sediments track recent environmental changes in an alpine ecosystem, Rocky Mountain National Park, Colorado

Authors

Enders, S.K.; Pagani, M.; Pantoja, S.; Baron, J.S.; Wolfe, A.P.; Pedentchouk, N.; Nunez, L.

Year

2008

Source

Limnology and Oceanography

Volume Pages Location

53 1468-1478

Annotation:

Sky pond in RMNP; NO₃ 240 ug/L, NH₄ 37 ug/L, TP 3 ug/L. Isotope analysis indicate greater rates of primary production due to N deposition and N enrichment.

Reviewer Comments:

Abstract:

Compound-specific nitrogen, carbon, and hydrogen isotope records from sediments of Sky Pond, an alpine lake in Rocky Mountain National Park (Colorado, United States of America), were used to evaluate factors contributing to changes in diatom assemblages and bulk organic nitrogen isotope records identified in lake sediments across Colorado, Wyoming, and southern Montana. Nitrogen isotopic records of purified algal chlorins indicate a substantial shift in nitrogen cycling in the region over the past similar to 60 yr. Temporal changes in the growth characteristics of algae, captured in carbon isotope records in and around Sky Pond, as well as a -60% excursion in the hydrogen isotope composition of algal-derived palmitic acid, are coincident with changes in nitrogen cycling. The confluence of these trends is attributed to an increase in biologically available nitrogenous compounds caused by an expansion of anthropogenic influences and temporal changes in catchment hydrology and nutrient delivery associated with meltwater

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Document Type

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Keywords

alpine

Regions

Rocky Mountains

diatoms

nitrogen

sediment

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Recent environmental changes inferred from the sediments of small lakes in Yellowstone's northern range

Authors

Engstrom, D.R.; Whitlock, C.; Fritz, S.C.; Wright, H.E.,

Year

1991

Source

Journal of Paleolimnology

Volume Pages

5 139-174

Location

Annotation:

8 small, shallow northern Yellowstone range lakes; TP > 30 ug/L; meso to eutrophic naturally. Have shown fluctuations in nutrients, but generally similar trophic state over last 300 years.

Reviewer Comments:

Abstract:

Recent sediments of eight small lakes in the northern winter range of Yellowstone National Park were cored to examine stratigraphic records of past changes in limnology and local environment that might be attributed to grazing and other activities of elk, bison, and other large ungulates. Cores of undisturbed sediment were analyzed at close intervals to depths covering the last 100-150 years according to chronologies established by lead-210 dating. Pollen analyses were made to show change in regional vegetation, and diatom and geochemical analyses were made to reveal possible limnological changes resulting from soil erosion and nutrient input from the lake catchments.

Variations in sedimentary components prior to establishment of the Park in 1872 indicate some natural variability in environmental factors e.g., erosional inputs in landslide areas west of Gardiner. All lakes had abundant nutrient inputs. After the Park was founded, fire suppression may have been responsible for small increases in pollen percentages of various conifers and *Artemisia tridentata* (big sagebrush) at different times in different lakes. Perceptible decreases in pollen of willow, aspen, alder, and birch at different times may reflect local ungulate browsing, although drier climatic conditions may have been a factor as well.

The most striking manifestation of accelerated erosion in a catchment was found at a lake located beside a road constructed in the 1930s. In contrast to changes at this site, the record of erosion at other lakes is hardly perceptible. Changes in sediment-accumulation rates seen at most sites result from redistribution of sediment within the lake after initial

deposition. In the century following Park establishment, the abundance of planktonic diatoms relative to benthic taxa varies among lakes and may reflect differential nutrient inputs or changes in lake level. Four of the five lakes analyzed for diatoms show in the last few decades an increase in planktonic relative to benthic species, implying elevated nutrient inputs. The recent flora, however, is similar to that in pre-Park levels which suggests that these lakes have not been perturbed outside their normal range. Increased nutrient supply in recent decades for at least two of the lakes is supported by the geochemical data, which show an increase in biogenic silica and in organic matter.

As a whole, our investigation of the sedimentary record does not support the hypothesis that ungulate grazing has had a strong direct or indirect effect on the vegetation and soil stability in the lake catchments or on the water quality of the

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Document Type

Keywords

diatom stratigraphy

elk populations

erosion rates

paleoecology

paleolimnology

pollen analysis

range management

sediment

Study Design

Paleolimnological

reconstruction

Peer review status

Regions

Yellowstone National Park

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Effects of nutrient enrichment on phytoplankton in an alpine lake, Colorado, USA

Authors

Gardner, E.M.; McKnight, D.M.; Lewis, W.M.; Miller, M.P.

Year

2008

Source

Arctic, Antarctic, and Alpine Research

Volume Pages Location

40 55-64

Annotation:

Green Lake, CO in N shadow of Denver: NO3 620-1150 ug/L; SRP 2-5 ug/L; Enrichment experiments indicate P limitation, perhaps induced by atmospheric N enrichment

Reviewer Comments:

Abstract:

Deposition of atmospheric nitrogen from urban and agricultural sources has caused surface water nitrate concentrations to increase in the Front Range of the Colorado Rocky Mountains. To investigate the effects of sustained increases in nitrate concentrations on phytoplankton dynamics in an alpine lake, we conducted nutrient enrichment experiments in mesocosms amended with nitrate, phosphate, and phosphate plus nitrate on four dates in July and August 2002. During this period, phytoplankton species composition shifted as diatoms decreased in abundance. Phytoplankton chlorophyll a increased in the phosphate and phosphate plus nitrate enrichments, but did not increase in the nitrate only enrichments. Analysis of the phytoplankton community using Principal Component Analysis showed that 34% of the variance was accounted for by the primary axis, which was associated with different time periods, and 21% of the variance was explained by the secondary axis, which was associated with treatments. The response to phosphorus enrichment was taxon-specific, and the two chlorophyte species which became more abundant, *Chlamydomonas* sp. and *Scenedesmus* sp., were strongly weighted on the secondary axis. These results indicate that the productivity of this phytoplankton community is phosphorus-limited throughout the summer. Therefore, additional inputs of nitrogen are not expected to directly alter the productivity of the phytoplankton community.

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Keywords

atmospheric nitrogen

Regions

Rocky Mountains

chlorophyll

concentrations

nitrate

phosphate

phytoplankton

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Method for Determining Minimum Pool Requirements to Maintain and Enhance Salmonid Fisheries in Small Wyoming Reservoirs

Edited By: kristen

On: 6/12/2009

Entered By: kristen

On: 6/12/2009

Authors

Guenther, P.M.; Hubert, W.A.

Year

1993

Source

Environmental Management

Volume Pages

17 645-653

Location

Document Type

Peer review status

Annotation:

Mean winter DO < 7 has dramatic increase in winterkill risk in small WY reservoirs.

Reviewer Comments:

Keywords

minimum pool

Regions

Wyoming

Salmonidae

trout

water level

Abstract:

Methods for determination of minimum pool levels in reservoirs that consider sport fishery values are being sought by managers. We developed a technique for assessing the effects of incremental changes in minimum pool levels on potential salmonid abundance in small (<100 surface hectares at full pool) reservoirs in Wyoming managed for irrigation and municipal water supplies. The method has two components, One component is used to determine the minimum pool level needed to eliminate the risk of overwinter loss of salmonids due to low dissolved oxygen concentrations. The other component predicts the potential biomass of salmonids in reservoirs as a function of water depth and total dissolved solids concentration of the reservoir water. Application of the method is demonstrated for two reservoirs in Wyoming.

Study Design

Methods

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Phytoplankton community response to reservoir aging, 1968-92

Authors

Holz, J.C.; Hoagland, K.D.; Spawn, R.L.; Popp, A.; Andersen, J.L.

Year

1997

Source

Hydrobiologia

Volume Pages

346 183-192

Location

Annotation:

Not really relevant. Response of agricultural reservoir through time. Nutrients decrease, sediments increase through time. Chlorophyll intermedia. But all value still high.

Reviewer Comments:

Abstract:

The effects of reservoir aging on the phytoplankton community of a midwestern U.S. reservoir constructed in 1965 (Pawnee Reservoir) were studied by comparing algal biovolume and species composition from April 1992 through November 1992 to surveys conducted in 1968-73 and 1990. Mean summer total phosphorus, nitrate-nitrogen, Secchi disk depth, total suspended solids, chlorophyll a, and phytoplankton species composition data characterized Pawnee Reservoir during 1968-69 as a high nutrient, relatively clear water environment. Phytoplankton biomass was relatively low, consisting mainly of cyanophytes and non-flagellated chlorophytes. During 1970-73, water clarity was poor, total suspended solids were high, and total phosphorus was lower, but was still greater than 100 $\mu\text{g l}^{-1}$. The 1970-73 phytoplankton biomass was high and was dominated by cyanophytes. Mean summer total phosphorus remained > 100 $\mu\text{g l}^{-1}$, water clarity remained poor, but phytoplankton biomass decreased significantly during 1990-92. The dramatic drop in chlorophyll a and low mean volatile suspended solids indicated that inorganic suspended sediments, rather than phytoplankton, accounted for the majority of the turbidity in 1990-92. In addition to lower phytoplankton biomass, community composition shifted away from buoyancy-regulating cyanophytes toward flagellated chlorophytes. These data suggest that as reservoirs located in agricultural watersheds age, (1) inorganic suspended sediments have a significant effect on the light environment as well as phytoplankton biomass and species composition, (2) the control of phytoplankton biomass and species composition shifts away from nutrients to light and suspended sediments, and (3) there is a 1-2 year lag in the response of phytoplankton biomass to maximum nutrient loading during the trophic upsurge period. Thus, sedimentation has been shown to be a primary determinant of plankton and benthic macroinvertebrate community composition as Pawnee Reservoir aged.

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Document Type

Peer review status

Keywords

eutrophication
phytoplankton
reservoir aging
sedimentation
turbidity

Regions

Pawnee Reservoir

Study Design

Survey

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Responses of phytoplankton to varied resource availability in large lakes of the Greater Yellowstone Ecosystem

Authors

Interlandi, S.J.; Kilham, S.S.; Theriot, E.C.

Source

Limnology and Oceanography

Annotation:

Jackson, Yellowstone and Lewis Lakes. NO₃/NO₂ < 23 ug/L, SRP 14 ug/L. N and P and N and P limitation observed.

Abstract:

We assessed phytoplankton dynamics in three lakes in the Greater Yellowstone Ecosystem to better understand the connections between changing environmental conditions and aquatic communities. This work primarily describes the connections between resource availability and phytoplankton seasonal succession in these lakes. We hypothesized that algal species efficient at utilizing a given resource (including N, P, Si, and light) would be correlated with low relative concentrations of those resources. The lakes generally exhibited moderate resource limitation, which is characteristic of lakes in subalpine and subarctic regions. Although in proximity, the lakes all exhibited different resource relationships: Lewis Lake was most P limited, Jackson Lake was most N limited, and Yellowstone Lake exhibited a moderate degree of N limitation along with periodic Si limitation. Mixing depths and light penetration were also variable among lakes. In 1996, spring diatom biomass was dominated by *Stephanodiscus minutulus*, *Asterionella formosa*, *Aulacoseira subarctica*, and *Synedra* sp. Relative abundances and dominance varied among the lakes. *A. formosa* and *Synedra* sp. abundances were positively correlated with total N:total P (TN:TP) levels in an analysis of data from all three lakes. *A. subarctica* was negatively correlated with TN:TP and all light: nutrient ratios. Species exhibiting late season maxima included *Cyclotella bodanica*, *Fragilaria crotonensis*, and *Stephanodiscus niagarae*. *C. bodanica* abundances corresponded to high-light/low-N situations, whereas *S. niagarae* maxima were found in high-TN: TP/low-light conditions. *F. crotonensis* abundances were most strongly positively correlated with total Si:TP and TN:TP. Environmental correlations were generally in good agreement with the measured physiological requirements of these species. Additionally, local population maxima of major species of diatoms never coincided.

Stressor/Response/Threshold Info

Year

1999

Volume Pages

44 668-682

Location

Reviewer Comments:

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Document Type

Keywords

algae

light

nitrogen
phosphorus

phytoplankton
silicon

subalpine

subarctic

total nitrogen

total phosphorus

Study Design

Field experiment

Peer review status

Regions

Yellowstone National Park

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Limnology Of Missouri Reservoirs: An Analysis of Regional Patterns

Authors

Jones, J.R.; Knowlton, M.F.

Year

1993

Source

Lake and Reservoir Management

Volume Pages Location

8 17-30

Annotation:

Study of regional reservoirs. Most are eutrophic, then meso, then oligo, then hyper. Reservoirs are somewhat unique, and vary in trophic state. Turbidity matters.

Reviewer Comments:

Abstract:

Data from 94 Missouri reservoirs demonstrated a large interregional variation in total phosphorus (TP), total nitrogen (TN), algal chlorophyll (Chl), and suspended solids among the four physiographic provinces with numerous reservoirs. The interprovincial pattern for nutrients, algal biomass, and mineral turbidity was Ozark Highlands < Ozark Border Glacial Plains < Osage Plains corresponding to an interregional gradient between forest and agriculture as the dominant land cover. On the basis of TP most Missouri reservoirs were eutrophic (61%) or mesotrophic (21%) with few hypereutrophic (7%) or oligotrophic (1.1%). Statewide, water clarity was low (median Secchi depth 1.0 m) and more strongly related to non-volatile suspended solids (NVSS, RP = 0.80) than algal Chl (RP = 0.30). Summer mean values showed a curvilinear relation between Chl and TP (log₁₀ transformed) reaching an asymptote above 150 µg/L TPIL - a range where most reservoirs have high NVSS and low TN:TP. Nitrogen limitation, light limitation, or binding of phosphorus by non-algal suspended material may explain reduced Chl:TP ratios in turbid reservoirs. Survey data, however, do not distinguish the roles of differing limiting nutrients and light limitation in reservoirs with > 10 mg NVSS/L. Conventional lake management scenarios based on phosphorus control seem appropriate for Missouri reservoirs of low to moderate turbidity.

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Keywords

chlorophyll

limnology

nutrient

transparency

Regions

Missouri

Study Design

Survey

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Land use change and nitrogen enrichment of a Rocky Mountain watershed

Authors

Kaushal, S.S.; Lewis, W.M.; McCutchan, J.H.

Year

2006

Source

Ecological Applications

Volume Pages Location

16 299-312

Annotation:

N loads from development have increased in Lake Dillon watershed. Minimum NO₃ in lake has increased from below detection to > 80 ug/L; mean from ~60 in 1990 to >100 ug/L in 10 years.

Reviewer Comments:

Abstract:

Headwater ecosystems may have a limited threshold for retaining and removing nutrients delivered by certain types of land use. Nitrogen enrichment was studied in a Rocky Mountain watershed undergoing rapid expansion of population and residential development. Study sites were located along a 30-km transect from the headwaters of the Blue River to Lake Dillon, a major source of drinking water for Denver, Colorado. Ground water in residential areas with septic systems showed high concentrations of nitrate-N (4.96 +/- 1.22 mg/L, mean +/- SE), and approximately 40% of wells contained nitrate with delta N-15 values in the range of wastewater. Concentrations of dissolved inorganic nitrogen (DIN) in tributaries with residential development peaked during spring snowmelt as concentrations of DIN declined to below detection limits in undeveloped tributaries. Annual export of dissolved organic nitrogen (DON) was considerably lower in residential streams, suggesting a change in forms of N with development. The seasonal delta N-15 of algae in residential streams was intermediate between baseline values from undeveloped streams and stream algae grown on wastewater. Between 19% and 23% of the annual N export from developed tributaries was derived from septic systems, as estimated from the delta N-15 of algae. This range was similar to the amount of N export above background determined independently from mass-balance estimates. From a watershed perspective, total loading of N to the Blue River catchment from septic and municipal wastewater (2 kg.ha⁻¹.yr⁻¹) is currently less than the amount from background atmospheric sources (3 kg.ha⁻¹.yr⁻¹). Nonetheless, nitrate-N concentrations exceeded limits for safe drinking water in some groundwater wells (10 mg/L), residential streams showed elevated seasonal patterns of nitrate-N concentration and ratios of DIN to total dissolved phosphorus, and seasonal minimum concentrations of nitrate-N in Lake Dillon have increased exponentially to 80 mu g/L over the last decade from an initial value near zero. Results suggest that isotopic ratios in autotrophs can be used to detect and quantify increases in N enrichment associated with land use change. The biotic capacity of headwater ecosystems to assimilate increases in inorganic N from residential development may be insufficient to prevent nitrogen enrichment over considerable distances and multiple aquatic ecosystems downstream.

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Keywords

algae

Regions

Rocky Mountains

land use

nitrogen enrichment

nitrogen isotopes

wastewater

Study Design

Field experiment

Waterbody Types

stream

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Reservoir Nutrient Dynamics

Authors

Kennedy, R.H.; Walker, W.W.

Source

Reservoir Limnology: Ecological Perspectives

Annotation:

General review of reservoir nutrient cycling.

Abstract:

SUMMARY Evaluate relative importance of various processes affecting nutrient distribution and availability in reservoirs - including: nutrient loading (external & internal), sedimentation, flow, mixing, and discharge. Intent of this chapter is to explore relations between these processes and nutrient conditions in reservoir ecosystems.

Stressor/Response/Threshold Info**Year**

1990

Volume**Pages**

109-131

Location**Reviewer Comments:**

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On: 6/22/2009

Document Type**Peer review status****Keywords**

discharge

flow

mixing

nutrient loading

sedimentation

Study Design

Review

Regions

N/A

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Nutrient Criteria: Considerations for Corps of Engineers Reservoirs

Authors

Kennedy, R.H.

Year

2000

Source

U.S. Army Research and Development Center, ERDC
WQTN-AM-08

Volume Pages Location

22 pp.

Annotation:

Important factors to consider in setting reservoir criteria.
Classification by various factors, use of WQ models to
establish reference,

Reviewer Comments:

Abstract:

This technical note describes requirements recently established by the U.S. Environmental Protection Agency (EPA) to determine nutrient criteria for lakes and reservoirs. The technical note also examines proposed methodological approaches, and discusses their relevance to Corps of Engineers water quality and environmental management activities.

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Document Type

Peer review status

Keywords

nutrient criteria

Regions

US

Study Design

Review

Waterbody Types

lake
reservoir

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

[Nutrient addition experiments in a nitrogen-limited high plains reservoir where nitrogen-fixing algae seldom bloom](#)

Authors

Knowlton, M.F.; Jones, J.R.

Source

Journal of Freshwater Ecology

Annotation:

Cherry Creek Reservoir, eutrophic. TP ~ 40 ug/L, TN 600-800 ug/L, Chl a 7-22 ug/L. Very large late summer cyano blooms. Propose P recycling and N fixation. Was

N limited pre-bloom and N and P limited during bloom.

Abstract:

Cherry Creek Lake in Colorado is a shallow flood control reservoir that exhibits infrequent blooms of nitrogen-fixing cyanobacteria one of which occurred in summer 1992. In nutrient addition experiments run before and during the bloom, added nitrogen significantly stimulated algal growth. The magnitude of the N-effect was much greater in the pre-bloom experiments in which added phosphorus had no effect. During the bloom, added P had small but significant effects on growth indicating concurrent P and N limitation. Monitoring data suggest that phytoplankton is usually N-limited in the lake, but, for unknown reasons, bloom of N-fixing algae are rare.

Stressor/Response/Threshold Info

Year

1996

Volume Pages

11 123-130

Location

Reviewer Comments:

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Document Type

Peer review status

Keywords

algae

bloom

nitrogen

phosphorus

phytoplankton

Regions

Colorado

Study Design

Field experiment

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

The Impact of Uncertainties in Hydrologic Measurement on Phosphorus Budgets and Empirical Models for Two Colorado Reservoirs

Authors

LaBaugh, J.W.; Winter, T.C.

Year

1984

Source

Limnology and Oceanography

Volume Pages Location

29 322-339

Annotation:

Gross and Williams Fork Reservoirs in CO. P and water budgets. TP 5-17 ug/L, Chl a 0.5-3.5, SD 2-5m

Reviewer Comments:

Abstract:

Water budgets and related chemical budgets of aquatic ecosystems commonly are interpreted without reference to uncertainties resulting from error of measurement. The importance of such uncertainties in the use and interpretation of the phosphorus budgets of two Colorado reservoirs was determined. Water budgets were calculated from data from on-site measurement of precipitation, evaporation, reservoir stage, outflow, and inflow from the major river of each reservoir. Direction of groundwater flow was determined with existing well information and seepage meters. Contributions of ungauged watershed and groundwater were estimated from the residual of measured water budget terms. Less than 25% of both water and phosphorus input to Gross Reservoir remained as a residual term: the contribution of errors in budget measurement to empirical model uncertainty was <13%. In Williams Fork Reservoir, <20% of the water and >45% of the phosphorus input was calculated as residual: errors in budget measurement contributed almost 50% to empirical model uncertainty. Measured concentrations of total phosphorus in each reservoir in both years were within the confidence limits of empirical model predictions. However, the confidence limits of those models were too large to produce accurate predictions, especially for the Williams Fork Reservoir. Attempts to predict the effect of changes in water or phosphorus budgets on reservoir concentrations of total phosphorus and chlorophyll

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Document Type

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Keywords

chlorophyll

Regions

Colorado

empirical model
phosphorus budget
total phosphorus

Study Design

Field experiment

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Environmental characteristics and benthic invertebrate assemblages in Colorado mountain lakes

Authors

Lafrancois, B.M.; Carlisle, D.M.; Nydick, K.R.; Johnson, B.M.; Baron, J.S.

Year

2003

Source

Western North American Naturalist

Volume Pages

63 137-154

Location

Annotation:

Front Range lakes. Lake NO3 unrelated to lake benthic macroinvertebrates. TP < 10 ug/L, NO3 0-1.24 mg/L.

Reviewer Comments:

Abstract:

Twenty-two high-elevation lakes (>3000 in) in Rocky Mountain National Park and Indian Peaks Wilderness Area, Colorado, were surveyed during summer 1998 to explore relationships among benthic invertebrates, water chemistry (particularly nitrate concentrations), and other environmental variables. Water samples were collected from the deepest portion of each lake and analyzed for ions and other water chemistry parameters. Benthic invertebrates were collected from the littoral zone using both a sweep net and Hess sampler. Physical and geographical measurements were derived from maps. Relationships among benthic invertebrate assemblages and environmental variables were examined using canonical correspondence analysis, and the importance of sampling methodology and taxonomic resolution on these relationships was evaluated. Choice of sampling methodology strongly influenced the outcome of statistical analyses, whereas taxonomic resolution did not. Presence/absence of benthic invertebrate taxa among the study lakes was best explained by elevation and presence of fish. Relative abundance and density of benthic invertebrate taxa were more strongly influenced by sampling date and water chemistry. Nitrate (NO₃⁻) concentration, potentially on the rise due to regional nitrogen deposition, was unrelated to benthic invertebrate distribution regardless of sampling method or

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Document Type

Peer review status

Keywords

biomonitoring

Regions

Colorado

CCA sampling

macroinvertebrates

mountain lakes

taxonomic resolution

water quality

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Influence of nitrogen on phytoplankton biomass and community composition in fifteen Snowy Range lakes (Wyoming, USA)

Authors

Lafrancois, B.M.; Nydick, K.R.; Caruso, B.

Year

2003

Source

Arctic Antarctic and Alpine Research

Volume Pages Location

35 499-508

Annotation:

15 Snowy Range lakes: Mean DIN 29 ug/L, NO3 11 ug/L, TP 30 ug/L, SRP 4 ug/L, Chl a 6 ug/L; N and N+P limitation. High ambient P and low N, make these lakes more susceptible. More N would favor cyanos too.

Reviewer Comments:

Abstract:

Nitrogen (N) deposition has been implicated in changes in surface water chemistry and algal composition in several dilute mountain lakes of the western United States. Lakes of the Snowy Range (Medicine Bow National Forest, Wyoming) appear to have low nitrate concentrations currently, and 2 Snowy Range lakes showed strong eutrophication responses to N or N + phosphorus (P) additions in previous enclosure experiments. In this study, we explored the regional extent of phytoplankton N limitation by examining a nutrient ratio index (dissolved inorganic nitrogen:total phosphorus) and phytoplankton species-environment relationships across 15 Snowy Range lakes. Based on this index, we estimate that phytoplankton biomass in the study lakes is largely N limited or N + P colimited. In addition, redundancy analysis demonstrated strong relationships between phytoplankton species composition and N gradients, with chrysophyte taxa favored in low-N lakes and cyanophytes and chlorophytes favored in higher-N lakes. We conclude that both phytoplankton biomass and community structure are sensitive indicators of N gradients in lakes of the Snowy Range, and that eutrophication responses to future increases in N loading could be widespread in these and other low-N lakes.

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Document Type

Peer review status

Keywords

algal composition

eutrophication

mountain lakes

nitrate

phytoplankton

total phosphorus

Regions

Snowy Range, WY

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Cumulative effects of nutrients and pH on the plankton of two mountain lakes

Authors

Lafrancois, B.M.; Nydick, K.R.; Johnson, B.M.; Baron, J.S.

Year

2004

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

61 1153-1165

Annotation:

Same as Nydick et al. study lakes - one in RMNP (high N), one in Snowy Range (low N). Low N lakes (WY) respond to N increases, High N to N and P and especially

Reviewer Comments:

Abstract:

We conducted enclosure experiments to examine the cumulative effects of nutrient enrichment and acidification on the plankton of two mountain lakes with differing nutrient conditions. The low-nitrate lake responded to N, N plus acid, and N plus acid plus P additions, showing four- to seven-fold increases in chlorophyll a, increased photosynthetic rate, compositional shifts toward large chlorophytes, and decreased zooplankton biomass. The high-nitrate lake responded minimally to either N or P alone but responded strongly to combined additions of N plus acid plus P, showing eightfold increases in chlorophyll a, increased cell density and photosynthetic rates, and compositional shifts toward chlorophytes and the dinoflagellate *Gymnodinium*. In both study lakes, changes in chlorophyll a were linked to addition of limiting nutrients regardless of pH, whereas shifts in phytoplankton species composition were apparently affected by both nutrient conditions and acidity. The most striking changes in species composition and biomass occurred in combined N plus acid plus P treatments, indicating that continued nutrient enrichment may interact with acidification to produce marked changes in the plankton of mountain lakes.

Stressor/Response/Threshold Info

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Document Type

Peer review status

Keywords

acidification

Regions

Colorado Front Range

chlorophyll

nutrient enrichment

pH

phytoplankton

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Effects of upstream lakes and nutrient limitation on periphytic biomass and nitrogen fixation in oligotrophic, subalpine streams

Authors

Marcarelli, A.M.; Wurtsbaugh, W.A.

Year

2007

Source

Freshwater Biology

Volume Pages Location

52 2211-2225

Annotation:

Lake inlet streams in Northern Rockies (Sawtooth): NO₃ 2-167 ug/L, TN 33-290 ug/L, TP 6-20 ug/L. Oligotrophic systems.

Reviewer Comments:

Abstract:

1. We conducted bioassays of nutrient limitation to understand how macronutrients and the position of streams relative to lakes control nitrogen (N-2) fixation and periphytic biomass in three oligotrophic Rocky Mountain catchments. We measured periphytic chlorophyll-a (chl-a) and nitrogen-fixation responses to nitrogen (N) and phosphorus (P) additions using nutrient-diffusing substrata at 19 stream study sites, located above and below lakes within the study catchments. 2. We found that periphytic chl-a was significantly co-limited by N and P at 13 of the 19 sites, with sole limitation by P observed at another four sites, and no nutrient response at the final two sites. On average, the addition of N, P and N + P stimulated chl-a 35%, 114% and 700% above control values respectively. The addition of P alone stimulated nitrogen fixation by 2500% at five of the 19 sites. The addition of N, either with or without simultaneous P addition, suppressed nitrogen fixation by 73% at nine of the 19 sites. 3. Lake outlet streams were warmer and had higher dissolved organic carbon concentrations than inlet streams and those further upstream, but position relative to lakes did not affect chl-a and nitrogen fixation in the absence of nutrient additions. Chl-a response to nutrient additions did not change along the length of the study streams, but nitrogen fixation was suppressed more strongly by N, and stimulated more strongly by P, at lower altitude sites. The responses of chl-a and nitrogen fixation to nutrients were not affected by location relative to lakes. Some variation in responses to nutrients could be explained by nitrate and/or total N concentration. 4. Periphytic chl-a and nitrogen fixation were affected by nutrient supply, but responses to nutrients were independent of stream position in the landscape relative to lakes. Understanding interactions between nutrient supply, nitrogen fixation and chl-a may help predict periphytic responses to future perturbations of oligotrophic streams, such as the deposition of

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Keywords

bioassay

nitrogen fixation

nutrient limitation

oligotrophic

Regions

Rocky Mountains

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Phytoplankton nutrient limitation in Colorado mountain lakes

Authors

Morris, D.P.; Lewis, W.M., Jr.

Source

Freshwater Biology

Annotation:

Compared nutrient limitation in 8 Rocky Mountain Lakes in CO. SRP 0-7.5 ug/L, TP 2-16 ug/L, DIN 3-270 ug/L, Chl a 0-12 ug/L. All are ranges not means. Lakes show both N and P limitation, but more N.

Abstract:

1. Limiting nutrients for phytoplankton were studied experimentally in eight mountain lakes of central Colorado between May and November of 1984.
2. Five categories of phytoplankton limitation were identified: no limitation, N limitation, P limitation, concurrent limitation (stimulation only by simultaneous additions of N and P), and reciprocal limitation (stimulation by addition of either N or P). The phytoplankton communities of three lakes were primarily N-limited, one was primarily phosphorus-limited, and four showed primarily combined limitation (concurrent or reciprocal). Switching between categories of limitation was also observed within lakes. Nitrogen was the most frequently limiting nutrient; N, either alone or in combination with P, accounted for 79% of all observed instances of limitation.
3. Nine indices were tested for effectiveness in predicting phytoplankton limitation by N and P. The best indices for discriminating all limitations were ratios of dissolved inorganic N: total P (84% accuracy) and dissolved inorganic N:total dissolved P (80% accuracy). The effectiveness of these indices may be explained by the degree to which they represent N and P fractions actually available to the phytoplankton.

Stressor/Response/Threshold Info

Year

1988

Volume Pages Location

20 315-327

Reviewer Comments:

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Document Type

Peer review status

Keywords

mountain lakes

nitrogen

phytoplankton

Regions

Colorado

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Nutrient limitation of bacterioplankton growth in Lake Dillon, Colorado

Authors

Morris, D.P.; Lewis, W.M., Jr.

Source

Limnology and Oceanography

Annotation:

Lake Dillon (CO reservoir), mesotrophic TP 2-10ug/L, NO3 1-200 ug/L. Bacterioplankton are P limited, not DOC limited!

Abstract:

Bacterioplankton biomass, production, and growth rate were measured over a 2-yr period in Lake Dillon, a mesotrophic Colorado reservoir. In addition, a multivariate statistical analysis and nutrient addition experiments were used to analyze the regulation of bacterioplankton growth in situ. Biomass ranged between 170 (winter) and 2,200 mg C m⁻³ (summer); production ranged from 10 (winter) to 625 mg C m⁻³ d⁻¹ (summer); annual bacterioplankton production was 47 g C m⁻² yr⁻¹ in 1987 and 67 in 1988. Population growth rates ranged between 0.001 and 0.08 1 h⁻¹. Growth rates in the epilimnion were substantially below estimated potential rates, suggesting severe nutrient limitation during the period of stratification. Population growth rates were highly correlated with P concentrations but not with dissolved organic C concentrations. Bacterioplankton growth in the summer epilimnion responded strongly to the addition of P alone or in combination with N or labile organic C. The field data show that bacterioplankton are frequently without sufficient nutrients to sustain maximum growth; the experimental and statistical analyses indicate that P, rather than organic C, is the critical nutrient for bacterioplankton growth in this lake.

Stressor/Response/Threshold Info

Year

1992

Volume Pages Location

37 1179-1192

Reviewer Comments:

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Document Type

Peer review status

Keywords

bacterioplankton

Regions

Colorado

mesotrophic

multivariate

nutrient limitation

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Evaluating regional patterns in nitrate sources to watersheds in national parks of the Rocky Mountains using nitrate isotopes

Authors

Nanus, L.; Williams, M.W.; Campbell, D.H.; Elliott, E.M.; Kendall, C.

Year

2008

Source

Environmental Science & Technology

Volume Pages Location

42 6487-6493

Annotation:

50+ Lakes sampled from Glacier to Great Sand Dunes; Gradient in NO₃ concentrations from Southern (Higher) to Northern Rockies (Lower) - may be due to differences in atmospheric loading and nitrification.

Reviewer Comments:

Abstract:

In the Rocky Mountains, there is uncertainty about the source areas and emission types that contribute to nitrate (NO₃) deposition, which can adversely affect sensitive aquatic habitats of high-elevation watersheds. Regional patterns in NO₃ deposition sources were evaluated using NO₃ isotopes in five National Parks, including 37 lakes and 7 precipitation sites. Results indicate that lake NO₃ ranged from detection limit to 38 μ eq/L, delta O-18 (NO₃) ranged from -5.7 to +21.3 parts per thousand, and delta N-15 (NO₃) ranged from -6.6 to +4.6 parts per thousand. delta O-18 (NO₃) in precipitation ranged from +71 to +78 parts per thousand. delta N-15 (NO₃) in precipitation and lakes overlap; however delta N-15 (NO₃) in precipitation is more depleted than delta N-15 (NO₃) in lakes, ranging from -5.5 to -2.0 parts per thousand. delta N-15 (NO₃) values are significantly related ($p < 0.05$) to wet deposition of inorganic N, sulfate, and acidity, suggesting that spatial variability of delta N-15 (NO₃) over the Rocky Mountains may be related to source areas of these solutes. Regional patterns show that NO₃ and delta N-15 (NO₃) are more enriched in lakes and precipitation from the southern Rockies and at higher elevations compared to the northern Rockies. The correspondence of high NO₃ and enriched delta N-15 (NO₃) in precipitation with high NO₃ and enriched delta N-15 (NO₃) in lakes, suggests that deposition of inorganic N in wetfall may affect the amount of NO₃ in lakes through a combination of direct and indirect processes such as

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Keywords

acidity

deposition

high elevation

inorganic N

nitrate

sulfate

Regions

Rocky Mountains

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

[NO3 uptake in shallow, oligotrophic, mountain lakes: the influence of elevated NO3 concentrations](#)

Authors

Nydick, K.R.; Lafrancois, B.M.; Baron, J.S.

Year

2004

Source

Journal of the North American Benthological Society

Volume Pages Location

23 397-415

Annotation:

N and P additions in RMNP (high N) vs Snowy Range lake (low N). Snowy range lake: NO3 <3 ug/L, NH4 5-10 ug/L, TP 22-26 ug/L, SRP 4-5 ug/L, Chl a 1.7-2.8 ug/L.

Reviewer Comments:

N stimulated algae in Snowy Range. Needed N and P in RMNP. Benthic algae very important too.

Abstract:

Nutrient enrichment experiments were conducted in 1.2-m deep enclosures in 2 shallow, oligotrophic, mountain lakes. N-15-NO3 isotope tracer was used to compare the importance of phytoplankton and benthic compartments (epilithon, surface sediment [epipelon], and subsurface sediment) for NO3 uptake under high and low NO3 conditions. NO3 uptake approached saturation in the high-N lake, but not in the low-N lake. The capacity of phytoplankton and benthic compartments to take up NO3 differed among treatments and between lakes, and depended on water-column nutrient conditions and the history of NO3 availability. Phytoplankton productivity responded strongly to addition of limiting nutrients, and NO3 uptake was related to phytoplankton biomass and photosynthesis. However, more NO3 usually was taken up by benthic compartments (57-92% combined) than by phytoplankton, even though the response of benthic algal biomass to nutrient additions was less pronounced than that of phytoplankton and benthic NO3 uptake was unrelated to benthic algal biomass. In the low-N lake where NO3 uptake was unsaturated, C content or % was related to NO3 uptake in benthic substrates, suggesting that heterotrophic bacterial processes could be important in benthic NO3 uptake. These results suggest that phytoplankton are most sensitive to nutrient additions, but benthic processes are important for NO3 uptake in shallow, oligotrophic lakes.

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Keywords

15N isotope tracer

Regions

Rocky Mountains

benthic

mountain lakes

NO3 uptake

nutrient enrichment

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Lake-specific responses to elevated atmospheric nitrogen deposition in the Colorado Rocky Mountains, USA

Authors

Nydick, K.R.; Lafrancois, B.M.; Baron, J.S.; Johnson, B.M.

Year

2003

Source

Hydrobiologia

Volume Pages

510 103-114

Location

Annotation:

3 lakes around RMNP. Mean NO₃ 5-224 ug/L, NH₄ 13-25 ug/L; PO₄ 3-8 ug/L, TP 9 ug/L, Chla 1.4-1.7. P and N both limiting, although P more so in these atmospherically N influenced lakes.

Reviewer Comments:

Abstract:

We explored variability among subalpine lakes sharing very similar climate and atmospheric conditions, but differing in watershed characteristics, hydrology, and food web structure. Special attention was given to nitrogen (N) dynamics because the study area receives some of the highest levels of atmospheric N deposition in the Rocky Mountains. We asked if the effect of regional N deposition would be manifested uniformly among neighboring lakes both in terms of ambient conditions and responses to greater nutrient inputs. Catchment vegetation appeared to be the main determinant of ambient nitrate (NO₃), phosphate (PO₄), and dissolved organic carbon (DOC) concentrations, although in-lake differences in recycling produced variable and contrasting NH₄ levels. Phytoplankton chlorophyll a temporarily responded to early season NO₃ peaks in the lakes with rocky watersheds, but chlorophyll means over the ice-free season were remarkably similar among lakes despite differences in both nutrient supply and zooplankton grazing. In most cases, phosphorus was limiting to phytoplankton growth, although the importance of N deficiencies was greater in lakes with forested watersheds and fringing wetlands.

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Document Type

Keywords

bioassay
mountain lakes
nitrogen deposition
nutrient
nutrient limitation
phytoplankton

Study Design

Field experiment

Peer review status

Regions

Colorado
Rocky Mountains

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Nitrogen regulation of algal biomass, productivity, and composition in shallow mountain lakes, Snowy Range, Wyoming, USA

Authors

Nydick, K.R.; Lafrancois, B.M.; Baron, J.S.; Johnson, B.M.

Year

2004

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

61 1256-1268

Annotation:

Enclosure experiment. Snowy Range lakes: Ctrl: NO₃ < 3ug/L, NH₄ 18-40 ug/L, TP 20-35 ug/L, Chl a 1.4-2.6 ug/L; Increasing N (NO₃ ~ 1000 ug/L in one single pulse)

increased Chl to 12-16 ug/L. Back to bgd in 2 weeks.

Abstract:

We investigated the effects of increased nitrate (NO₃), alone and in combination with phosphorus (P), on phytoplankton, epilithon, and epipelton in shallow lakes of the Snowy Range, Wyoming, using two enclosure experiments during early and late summer. Phytoplankton responded strongly to N and N + P, but not to P, with increased cell density, chlorophyll a, and photosynthesis and shifts in composition from chrysophytes to cyanophytes, chlorophytes, and diatoms. Zooplankton density and biomass were unaltered despite the additional phytoplankton stock, probably as the result of poor food quality. In the late summer, algae on tiles responded to N and N + P additions with greater chlorophyll a and increases in cyanophyte and chlorophyte density. Algae on sediment dominated whole-enclosure algal biomass but were spatially variable and responded insignificantly to nutrients. Consequently, N controlled productivity and community composition of phytoplankton and algae on hard substrates but had less impact on ecosystem algal biomass because of the large pool of nutrient-sufficient sediment algae. Phytoplankton were more photosynthetically efficient than the benthos, however, such that primary productivity did shift more toward the water column.

Reviewer Comments:

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Keywords

algae

algal biomass

chlorophyll

epilithon

epipelton

nitrate

phosphorus

phytoplankton

zooplankton

Regions

Snowy Range, WY

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Toxic cyanobacterial blooms in a shallow, artificially mixed urban lake in Colorado, USA

Authors

Oberholster, P.J.; Botha, A.-M.; Cloete, T.E.

Year

2006

Source

Lakes & Reservoirs: Research and Management

Volume Pages

11 111-123

Location

Annotation:

Toxic cyanos in Sheldon Lake, CO Summer means: SD < 0.25m, Chl a ~ 690 ug/L, TP = 2.2 mg/L, TN = 2.9 mg/L. Good overall review of toxic cyanos too.

Reviewer Comments:

Abstract:

One of the most severe problems associated with eutrophication of urban freshwater ecosystems is the occurrence of increasingly frequent blooms of toxic cyanobacteria. Cyanotoxins might accumulate in the trophic web, producing diverse intoxication symptoms and chronic effects that are difficult to diagnose and prevent. High mortality of domestic animals and fish has been reported previously under these prevailing conditions. This study investigates the taxonomic composition of phytoplankton assemblages in Sheldon Lake during the summer of 2004, a year after the completion of a restoration project on the lake. The study analysed the physical and chemical changes caused by urban run-off and artificial mixing, as well as the usefulness of microcystin molecular markers derived from the *mcy* gene cluster for the detection of toxic cyanobacterial strains in environmental samples from Sheldon Lake. This study clearly demonstrates that the artificial mixing rate alone was insufficient to cause a transition to a well-mixed aquatic system, and that cyanobacteria remained dominant throughout the summer months. The presence of toxic cyanobacterial strains was confirmed with the use of molecular markers that detected the presence of the *mcy* gene cluster responsible for the production of toxin by *Microcystis* spp. This approach might have a great potential use in the routine analyses of urban aquatic ecosystems. It also might make toxicity monitoring more feasible, allowing for the early application of corrective actions, especially for cases such as Sheldon Lake, which is a public recreational focal point.

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Keywords

artificial mixing

eutrophication

Microcystis spp.
molecular markers

urban run-off

Study Design

Survey

Regions

Colorado

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Eutrophication of Waters: Monitoring, Assessment and Control

Authors

Organization for Economic Cooperation and Development (OECD)

Year

1982

Source

Volume Pages Location

Annotation:

Foundation document, basis for most WQ modeling. Sets trophic classes for fixed boundary and range boundary for 5 classes. Well utilized document.

Reviewer Comments:

Abstract:

SUMMARY Program was designed to quantify the relationship between nutrient load in waters and their trophic reaction. The main control strategy is reduction of the external load...Although nitrogen or some other factor may in some particular instances outweigh the role of phosphorus as the limiting factor, most attention here is based on phosphorus control.

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Document Type

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Keywords

control

nitrogen

nutrient loading
phosphorus

trophic reaction

Regions

Alpine

Nordic

North America

Study Design

Uncertain

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Characterization of Water Quality in Government Highline Canal at Camp 7 Diversion and Highline Lake, Mesa County, Colorado, July 2000 through September 2003

Authors

Ortiz, R.F.

Year

2003

Source

USGS

Volume Pages Location

37 pp

Annotation:

Study of turbid, high nutrient reservoir in western CO. NH4 ~2-40 ug/L, NO3 ~ 10-250 ug/L, SRP ~ 3-17 ug/L; and TP ~ 20-300 ug/L. TSI low on chl, high on TP

(abiotic turbidity issue). Receives AG water from gov't canal.

Reviewer Comments:

Abstract:

The U.S. Geological Survey, in cooperation with the Colorado Division of Parks and Recreation, collected and analyzed water-quality data for the Government Highline Canal and Highline Lake from July 2000 through September 2003. Implementation of modernization strategies for the canal, which supplies most of the water to the lake, would decrease the amount of water spilled to Highline Lake from August through October. A reduction in spill water into Highline Lake could adversely affect the recreational uses of the lake. To address this concern and to characterize the water quality in the Government Highline Canal and Highline Lake, the U.S. Geological Survey conducted a study to evaluate limnological conditions prior to implementation of the modernization strategies. This report characterizes the water quality of inflow from the Government Canal and in Highline Lake prior to implementation of modernization strategies in the Government Canal. Flow entering the lake from the Government Canal was characterized using field properties and available chemical, sediment, and bacteria concentrations. Data collected at Highline Lake were used to characterize the seasonal stratification patterns, water-quality chemistry, bacteria populations, and phytoplankton community structure in the lake. Data used for this report were collected at one inflow site to the lake and four sites in Highline Lake. Highline Lake is a mesotrophic/eutrophic lake that has dimictic thermal stratification patterns. Samples collected in the photic zone indicated that there was little physical, chemical, or biological variability at this depth at any of the sampled sites in Highline Lake. Strong thermal and dissolved-oxygen stratification patterns were observed during summer. Dissolved-oxygen concentrations of less than 1 milligram per liter were observed during the summer. Ammonia likely was released from the bottom sediments of Highline Lake. The limiting nutrient in Highline Lake could be nitrogen or phosphorus. In general, the seasonal succession of phytoplankton was similar to that of other lakes in the temperate zone. Several types of algae associated with taste and odor issues were identified in samples, but critical concentrations were not exceeded for any listed algal group with the exception of the diatom genus *Cyclotella* in one sample. Bacteria concentrations were determined at the public swim beach at Highline Lake. *E. coli* samples were collected periodically by the USGS and weekly by the Colorado Division of Parks and Recreation. During the study period, no reported *E. coli* concentration exceeded the standard for natural swimming areas. Inflow water quality was characterized by samples collected at the Camp 7 check structure on the Government Canal. Inflow water temperatures reflected the seasonal patterns of the source water in the Colorado River. The water was well

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Keywords

algae
bacteria
dissolved oxygen
E. coli
eutrophic
fecal streptococcus
flow
mesotrophic
nitrogen
phosphorus
photic zone
phytoplankton

Regions

Colorado

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

oxygenated. Nitrogen and phosphorus concentrations were low, and concentrations did not differ substantially from year to year or seasonally within a year. All samples had reportable numbers of fecal streptococcus. The maximum reported concentration of *E. coli* was reported at 77 colonies per 100 milliliters of sample. Suspended-sediment

Stressor/Response/Threshold Info

Annotated Literature

concentrations were relatively low.

Citation Title:

[Protecting resources on federal lands: Implications of critical loads for atmospheric deposition of nitrogen and sulfur](#)

Authors

Porter, E.; Blett, T.; Potter, D.U.; Huber, C.

Year

2005

Source

Bioscience

Volume

55

Pages

603-612

Location

Annotation:

Review of critical loads to federal lands, reinforces N impacts on Western Montane lakes. Critical loads will be important to establish for N there.

Reviewer Comments:

Abstract:

Critical loads area potentially important tool for protecting ecosystems from atmospheric deposition and for promoting recovery. Exceeding critical loads for nitrogen and sulfur can cause ecosystem acidification, nitrogen saturation, and biotic community changes. Critical loads are widely used to set policy for resource protection in Europe and Canada, yet the United States has no similar national strategy. We believe that ecosystem science and resource protection policies are sufficiently advanced in the United States to establish critical loads for federal lands. Communication and interaction between federal area managers and scientists will ensure that critical loads are useful for assessing ecosystem conditions, influencing land management decisions, and informing the public about the status of natural resources. Critical loads may also be used to inform air pollution policy in the United States, regardless of whether critical loads are directly linked to air quality regulations and emissions reductions agreements, as they are in Europe.

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Document Type

Keywords

atmospheric deposition

critical loads

ecosystem threshold

land management

target load

Study Design

Review

Peer review status

Regions

Colorado Front Range

Mid-Atlantic region

Waterbody Types

unsure

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Unifying nutrient-chlorophyll relationships in lakes

Authors

Prairie, Y.T.; Duarte, C.M.; Kalff, J.

Year

1989

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

46 1176-1182

Annotation:

TN and TP vs Chlorophyll models change depending on N:P ratios. The slopes are steepest when N:P is between 23-28 (by weight). Both nutrients are important predictors, not one alone.

Reviewer Comments:

Abstract:

SUMMARY Nitrogen was not better correlated to chlorophyll in N limited lakes (as measured by the TN:TP ratio). Also examined whether the variability in published relationships between chl-a and nutrient levels in lakes can be explained by differences in the relative concentrations of N and P. Results showed that the coefficients and precision of the $Chl_a = f(TP)$ and $Chl_a = f(TN)$ regression equations vary systematically and concomitantly with TN:TP ratios, and are highest for lakes with TN:TP ratios of 23-28 (by weight). A model was proposed that predicts the coefficients of $Chl_a = f(TP)$ and $Chl_a = f(TN)$ equations for lakes with different TN:TP ratios. It proved useful in predicting the Chl trajectories of lakes over time.

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Document Type

Peer review status

Keywords

chlorophyll

Regions

N/A

model

nitrogen

phosphorus

Study Design

Modeling

Waterbody Types

lake

Review

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Nutrient Loading Estimates for Lakes

Authors

Rast, W.; Lee, G.F.

Source

Journal of Environmental Engineering

Annotation:

Calculating N and P loads from land cover.

Abstract:

The nitrogen and phosphorus loads to a waterbody may be reliably estimated on the basis of the waterbody's watershed land use pattern and the nitrogen and phosphorus export coefficients for each dominant type of land use. Good agreement was found in a comparison between the nitrogen and phosphorus export coefficients developed in this study and the measured amounts of nitrogen and phosphorus transported to 38 U.S. waterbodies. Good agreement was also found between the load estimated by the Vollenweider model relating the mean annual in-lake and inflow phosphorus concentrations of a waterbody, and the measured amounts of phosphorus that actually entered the 38 waterbodies.

Stressor/Response/Threshold Info

Year

1983

Volume

109

Pages

502-518

Location

Reviewer Comments:

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Document Type

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Keywords

nitrogen
phosphorus

Regions

Unsure

Vollenweider model

Study Design

Uncertain

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Fremont Lake, Wyoming: Preliminary Survey of a Large Mountain Lake

Authors

Rickert, D.A.; Leopold, L.B.

Source

Limnology

Annotation:

Very low nutrient concentrations. DO still 80% of saturation at 180m (clearly oligotrophic); Secchi depth of 9m; NO₃-N~20-50 ug/L; PO₄-P~3-33 ug/L; NH₄-N ~ 30-90 ug/L (seems high)

Abstract:

Fremont Lake, at an altitude of 2,261 m, has an area of 20.61 km² and a volume of 1.69 km³. The maximum depth is 185 m, which makes it the seventh deepest natural lake in the conterminous United States. Theoretical renewal time is 11.1 years. Temperature data for 1971 indicate that vernal circulation extended to a depth of less than 90 m. The summer heat income was 19,450 cal/cm². The dissolved-oxygen curve is orthograde, with a slight metalimnetic maximum, and a tendency toward decreasing concentrations at depth. At 180 m, oxygen was at 80 percent of saturation in late July 1970. The lake has a remarkably low dissolved-solids content of 12.8 mg/l, making it one of the most dilute medium-sized lakes in the world. Detailed chemical data are given for the water column at three sites in the lake and for the influent and effluent streams. Net plankton included representatives of seven genera of phytoplankters and three genera of zooplankters. A reconnaissance indicated substantially no bacteriological contamination in the lake, but there was an appreciable amount in two minor streams in the vicinity of a summer-home colony.

Stressor/Response/Threshold Info

Year

1972

Volume Pages Location

D173-D188

Reviewer Comments:

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Document Type

Peer review status

Keywords

dissolved oxygen

plankton

temperature

Regions

Wyoming

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Are the deep chlorophyll maxima in alpine lakes primarily induced by nutrient availability, not UV avoidance?

Authors

Saros, J.E.; Interlandi, S.J.; Doyle, S.; Michel, T.J.; Williamson, C.E.

Year

2005

Source

Arctic Antarctic and Alpine Research

Volume Pages Location

37 557-563

Annotation:

Beartooth lakes are oligotrophic Rocky mountain lakes. Ranges (not means) are TP ~ 0.6 - 20 ug/L; TN ~ 24 - 130 ug/L; NO3 ~ 0 - 98 ug/L

Reviewer Comments:

Abstract:

Alpine lakes are often highly transparent to ultraviolet (UV) wavelengths, which has led to the suggestion that it deep chlorophyll maximum (DCM) results in these systems from UV avoidance by phytoplankton. However, an alternative explanation is that the formation of the DCM is primarily driven by greater nutrient availability below the thermocline in these oligotrophic systems. We investigated the location of the chlorophyll maximum over spatial and temporal scales in it set of high-elevation lakes in the Beartooth Mountains (Montana/Wyoming). The position of the DCM was compared to a suite of physical and chemical variables across systems. Chlorophyll was strongly correlated to it suite of nitrogen variables, whereas correlations with UV parameters were not consistently observed. We also conducted an experiment with the natural phytoplankton assemblage from the DCM in Beartooth Lake; both UV exposure and nutrient additions were tested in it factorial design. The UV-exposed treatment and the control had the same final total phytoplankton biovolume, while the nutrient addition treatment had a final biovolume tell times as great. These results suggest that, its in other oligotrophic aquatic systems, greater nutrient availability in the hypolimnion leads to the development of the DCM in alpine lakes.

Stressor/Response/Threshold Info

Edited By: kristen

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On: 6/24/2009

Document Type

Peer review status

Keywords

deep chlorophyll maximum

Regions

Alpine

nitrogen

oligotrophic
phytoplankton

UV

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Recent changes in the diatom community structure of lakes in the Beartooth Mountain Range, USA

Authors

Saros, J.E.; Interlandi, S.J.; Wolfe, A.P.; Engstrom, D.R.

Year

2003

Source

Arctic Antarctic and Alpine Research

Volume Pages

35 18-23

Location

Annotation:

More data on same set of Beartooth lakes. Ranges: SRP < 1 ug/L, NO3 < 5 ug/L

Reviewer Comments:

Abstract:

In alpine lakes from several regions of the world, sedimentary diatom profiles indicate that rapid shifts in diatom community structure have occurred over the past century. A number of these recent shifts have been attributed to anthropogenic disturbances such as enhanced atmospheric nitrogen (N) deposition or climate change. When these disturbances are coupled, the response of alpine lakes becomes more complex and varies from region to region. The Beartooth Mountain Range, situated on the border between Montana and Wyoming, is part of the central Rocky Mountains; it is considered an area of relatively low N deposition but has experienced an increase in bulk precipitation rates, primarily in the form of snowfall, over the past century. We have examined a 400-yr sediment record from Beartooth Lake and have observed a rapid change in the diatom community structure over the past decade. A typical alpine lake diatom flora, consisting mainly of small *Fragilaria* sensu lato species, dominated this lake until approximately 1995, at which time *Fragilaria crotonensis* and *Cyclotella bodanica* var. *lemanica* rapidly increased to approximately 30% each of the total assemblage. The diatom assemblages from the tops and bottoms of short cores from three additional lakes in the area also reveal taxonomic shifts. These shifts appear indicative of both increased N loading to these systems as well as changes in thermal stratification patterns.

Stressor/Response/Threshold Info

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Document Type

Peer review status

Keywords

atmospheric deposition

atmospheric nitrogen

deposition

diatoms

loads

thermal stratification

Regions

Alpine

Study Design

Survey

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Resource requirements of *Asterionella formosa* and *Fragilaria crotonensis* in oligotrophic alpine lakes: implications for recent phytoplankton community reorganizations

Edited By: kristen

On: 6/26/2009

Entered By: kristen

On: 6/26/2009

Authors

Saros, J.E.; Michel, T.J.; Interlandi, S.J.; Wolfe, A.P.

Year

2005

Source

Canadian Journal of Fisheries and Aquatic Sciences

Volume Pages Location

62 1681-1689

Document Type

Peer review status

Annotation:

N enrichment appears to be driving the increase in this eutrophic algal species in western montane lakes. Beartooth lakes always below 6 ug/L TP, NO3 now about 81 ug/L (or 19 if NO3-N and not NO3)

Reviewer Comments:

Keywords

atmospheric nitrogen deposition

Regions

Alpine
Beartooth Mountains

diatoms

nitrogen
nutrient enrichment

oligotrophic
phosphorus

silica

Study Design

Field experiment

Waterbody Types

lake

Abstract:

A widespread increase in the relative abundances of *Asterionella formosa* and *Fragilaria crotonensis* has occurred in oligotrophic alpine lakes across the western United States. Previous investigations have suggested that enhanced atmospheric nitrogen (N) deposition is driving these shifts in diatom community structure; however, little information is available on N requirements of these taxa. We examined the distributions of these two taxa in relation to a variety of physicochemical parameters in a suite of lakes situated in the Beartooth Mountain Range (Montana-Wyoming, USA). We also conducted a series of nutrient enrichment experiments to assess the response of these taxa to changes in N, phosphorus (P), and silica (Si) supply. The distributions of both taxa were positively correlated with C:P, N:P, and Si:P seston ratios, revealing that these taxa are abundant when P availability is very low and the supply of N and Si are moderate to high. In the enrichment experiments, both taxa responded strongly to N additions, whereas P or Si enrichment alone had no effect. While these two taxa are indicative of P enrichment in temperate lakes, our results indicate that in these oligotrophic alpine lakes, N enrichment is driving their recent increase.

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Alteration of nutrient cycles and algal production resulting from fish introductions into mountain lakes

Authors

Schindler, D.E.; Knapp, R.A.; Leavitt, P.R.

Year

2001

Source

Ecosystems

Volume Pages Location

4 308-321

Annotation:

Fish alter P cycling by mobilizing P from benthos and terrestrial systems to water column in mountain lakes. Fish stocking should be halted to restore these systems due to increased nutrient loading. Associated with shifts in algae.

Reviewer Comments:

Abstract:

The introduction of salmonid fishes into naturally fishless lakes represents one of the most prevalent environmental modifications of aquatic ecosystems in western North America. Introduced fish may alter lake nutrient cycles and primary production, but the magnitude and variation of these effects have not been fully explored. We used bioenergetics modeling to estimate the contributions of stocked trout to phosphorus (P) cycles across a wide range of fish densities in lakes of the Sierra Nevada, California. We also assessed the larger effects of fish-induced changes in phosphorus cycling on primary production using paleolimnological analyses from lakes in the southern Canadian Rockies. Our analyses showed that total P recycling by fish was independent of fish density but positively related to fish biomass in the Sierra Nevada. In lakes with fish populations maintained by continued stocking, fish recycled P at over twice the rate of those in lakes where introduced fish populations are maintained by natural reproduction and stocking has been discontinued. We estimate that P regeneration by introduced fishes is approximately equivalent to atmospheric P deposition to these lakes. Paleolimnological analyses indicated that algal production increased substantially following trout introductions to Rocky Mountain lakes and was maintained for the duration of fish presence. The results of our modeling and paleolimnological analyses indicate that introduced trout fundamentally alter nutrient cycles and stimulate primary production by accessing benthic P sources that are not normally available to pelagic communities in oligotrophic mountain lakes. These effects pose a difficult challenge for managers charged with balancing the demand for recreational fisheries with the need to maintain natural ecosystem processes.

Stressor/Response/Threshold Info

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Keywords

algal production

exotic species

fish stocking

fishless lakes

introduced species

nutrient cycles

paleolimnology

phosphorus

Regions

Canadian Rockies

Sierra Nevada

Study Design

Modeling

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Factors regulating phytoplankton production and standing crop in the world's freshwaters

Authors

Schindler, D.W.

Year

1978

Source

Limnology and Oceanography

Volume Pages Location

23 478-486

Annotation:

General P vs Chl models. Support supposition that chl in lakes increases with TP, where P is limiting (>10:1 N:P), whereas N does below 5:1.

Reviewer Comments:

Abstract:

A regression analysis of global data for freshwater phytoplankton production, chlorophyll, and various nutrient parameters revealed the following: A high proportion of the variance in both annual phytoplankton production and mean annual chlorophyll could be explained by annual phosphorus input (loading), once a simple correction for water renewal time was applied. Good relationships were also found between phosphorus loading and mean total phosphorus concentration, and between total phosphorus concentration and chlorophyll. The slope of the regression of total phosphorus on phosphorus loading for stratified lakes was not significantly different from that for unstratified lakes, suggesting that the effect of stratification on phosphorus concentration is insignificant compared to external sources of the element. Nutrient input, which was unavailable in previous analyses, appears to be an important factor in controlling freshwater production. There is some evidence for a correlation between latitude and nutrient input, and it is possible that this may explain the good correlation between latitude and production observed by earlier investigators.

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Document Type

Peer review status

Keywords

chlorophyll

Regions

Various - Worldwide

loads

nutrient
phosphorus

phytoplankton
stratification

total phosphorus

Study Design

Review

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Nutrient Dependence of Primary Productivity in Lakes

Authors

Smith, V.H.

Year

1979

Source

Limnology and Oceanography

Volume Pages Location

24 1051-1064

Annotation:

Equations to predict primary production from chlorophyll and TP.

Reviewer Comments:

Abstract:

An analysis of growing season measurements of daily primary productivity, chlorophyll, water chemistry, and transparency from 58 north temperate lakes shows a strong correlation between volumetric rates of photosynthesis, chlorophyll, and nutrients. Mean daily rates of photosynthesis per unit volume euphotic zone, v , are correlated with mean chlorophyll concentration ($r^2=0.80$). The mean daily rate of photosynthesis at optimal depth, A_{opt} , is highly correlated with mean total P ($r^2=0.95$), and with mean total N ($r^2=0.91$). In contrast, integral rates of photosynthesis are linked less tightly to nutrient concentration because of their simultaneous dependence on transparency. The Dillon-Rigler phosphorus loading model is extended to predict volumetric rates of photosynthesis (v and A_{opt}) in lakes where the N:P balance indicates control by phosphorus ($N:P >= 13$).

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Document Type

Peer review status

Keywords

chlorophyll

nitrogen

nutrient

phosphorus

photosynthesis

primary productivity

water chemistry

Regions

North America

Study Design

Uncertain

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA

Authors

Spencer, C.N.; Gabel, K.O.; Hauer, F.R.

Year

2003

Source

Forest Ecology and Management

Volume Pages Location

178 141-153

Annotation:

Very low background stream SRP (~2 ug/L), NH4 (~5 ug/L) and NO3 (~20 ug/L) in streams draining Glacier.

Reviewer Comments:

Abstract:

We documented immediate and mid-term (5 years) impacts on streams from a large (15,500 ha) wildfire in northwestern Montana. Fire-related impacts were ecosystem-wide, extending from water chemistry to fish. During the initial firestorm, phosphorus and nitrogen levels increased 5- to 60-fold above background levels resulting from aerial deposition from smoke and ash. Nutrients returned to background concentrations within several weeks after the fire. During subsequent years, nutrient concentrations periodically increased in fire-impacted sites compared to reference sites, especially during spring run-off. Evidence of post-fire changes was also documented in the aquatic food web via stable isotope analyses. Macroinvertebrates and fish from fire-impacted sites were significantly more enriched in N-15 and depleted in C-13 than consumers from forested reference sites ($P < 0.001$). The post-fire isotopic shift in consumers was consistent with increased utilization of algae and/or other autochthonous food sources together with decreased reliance on terrestrial leaf litter and other allochthonous food sources. Such a post-fire shift from a detritus based on a periphyton-based food web fits predictions of the river continuum concept following canopy removal and nutrient enrichment. Following decades of active fire suppression, forest managers are now contemplating aggressive efforts to reduce the fuel build-up noted in forests throughout the western US. Such efforts could involve increased use of fire and mechanical thinning and harvest. Results from our work and others suggest that expanded fire activity could mobilize substantial quantities of highly available nutrients to lakes and streams. With significant nutrient delivery mechanisms involving water, as well as airborne transport via smoke and ash, the potential for increased nutrient loadings to surface waters could extend well beyond the catchment of any particular fire. As natural resource managers contemplate expanding the use of fire as a forest restoration tool, they face the dilemma that such efforts could run counter to a decades-long effort to reduce nutrient loadings to lakes and other surface waters threatened by eutrophication.

Stressor/Response/Threshold Info

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Document Type

Peer review status

Keywords

nutrient

Regions

Montana

stable isotopes

stream food webs

wildfire

Study Design

Survey

Waterbody Types

lake

stream

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Applicability of Trophic Status Indicators to Colorado Plains Reservoirs

Authors

Stednick, J.D.

Year

2002

Source

Colorado State University

Volume Pages Location

8 pp

Annotation:

All reservoirs sampled were eu/hypereutrophic based on 4 different trophic state indexes. Many appear to indicate N limitation as well.

Reviewer Comments:

Abstract:

Anecdotal evidence indicates that off-channel storage reservoirs on the eastern Colorado plains downstream of Denver, Colorado are experiencing symptoms of eutrophication. Measures of eutrophication include nutrient concentrations, chlorophyll-a measurements and water transparency. indices and models to Colorado reservoirs using existing and collected water quality data from several South Platte River reservoirs. Specific objectives of this research are to: 1. Compile existing nutrient, chlorophyll-a and secchi disk data for eastern Colorado reservoirs in the South Platte Basin. 2. Collect additional nutrient, chlorophyll-a and secchi disk data, where necessary. 3. Determine the applicability of various TSI (EPA 1974, Vollenweider 1976, Carlson 1977, OECD 1982) and linear phosphorous~chlorophyll-a models. 4. Evaluate TSI in relation to reservoir hydrology and management. This analysis will aid reservoir operators and water managers in Colorado, as well as explain the chemical and biological processes that control eutrophication in Colorado reservoirs.

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Document Type

Peer review status

Keywords

chlorophyll

Regions

Colorado

eutrophication

phosphorus
TSI

water transparency

Study Design

Survey

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

[Long-term limnological data from the larger lakes of Yellowstone National Park, Wyoming, USA](#)

Authors

Theriot, E.C.; Fritz, S.C.; Gresswell, R.E

Year

1997

Source

Arctic Antarctic and Alpine Research

Volume Pages Location

29 304-314

Annotation:

4 Lakes in yellowstone sampled. TP and TKN above d.l. Secchi indicate solid oligotrophic, chl a indicatye oligo to low meso (OECD 1982). Despite authors erroneous conclusions.

Reviewer Comments:

Abstract:

Long-term Limnological data from the four largest lakes in Yellowstone National Park (Yellowstone, Lewis, Shoshone, Heart) are used to characterize their limnology and patterns of temporal and spatial variability. Heart Lake has distinctively high concentrations of dissolved materials, apparently reflecting high thermal inputs. Shoshone and Lewis lakes have the highest total SiO₂ concentrations (averaging over 23.5 mg L⁻¹), apparently as a result of the rhyolitic drainage basins. Within Yellowstone Lake spatial variability is low and ephemeral for most measured variables, except that the Southeast Arm has lower average Na concentrations. Seasonal variation is evident for Secchi transparency, pH, and total-SiO₂ and probably reflects seasonal changes in phytoplankton biomass and productivity. Total dissolved solids (TDS) and total-SiO₂ generally show a gradual decline from the mid-1970s through mid-1980s, followed by a sharp increase. Ratios of Kjeldahl-N to total-PO₄ (KN:TP) suggest that the lakes, especially Shoshone, are often nitrogen limited. Kjeldahl-N is positively correlated with winter precipitation, but TP and total-SiO₂ are counterintuitively negatively correlated with precipitation. We speculate that increased winter precipitation, rather than watershed fires, increases N-loading which, in turn, leads to increased demand for TP and total SiO₂.

Stressor/Response/Threshold Info

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Document Type

Peer review status

Keywords

limnology

loads

pH

silica

Regions

Yellowstone National Park

Study Design

Survey

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Phytobenthos and phytoplankton as potential indicators of climate change in mountain lakes and ponds: a HPLC-based pigment approach

Authors

Vinebrooke, R.D.; Leavitt, P.R.

Year

1999

Source

Journal of the North American Benthological Society

Volume Pages

18 15-33

Location

Annotation:

General study for climate indicators. Limited utility here.

Reviewer Comments:

Abstract:

Shallow mountain lakes and ponds may function as reference systems for monitoring the effects of global climate change. A survey of phytobenthos and phytoplankton communities was conducted along an altitudinal gradient of Canadian Rocky Mountain lakes and ponds to relate patterns in algal abundance and community composition to catchment and climate-related variables. Algal abundance and community composition were quantified using pigments as analyzed by high performance liquid chromatography (HPLC). Regression analyses revealed that the abundance of rock-attached algae (epilithon) was negatively correlated ($r(2) = 0.54$, $p < 0.001$) to lake elevation and positively correlated to conductivity and dissolved organic carbon (DOC) content ($r(2) = 0.52$, $p(\text{cond.}) < 0.03$, $p(\text{DOC}) < 0.01$). Redundancy analysis (RDA) showed that elevation, conductivity, and DOC were also significant predictors of epilithon community composition. Epilithic diatoms (diatoxanthin diadinoxanthin, fucoxanthin) declined disproportionately with increasing water transparency and decreasing chemical concentrations. In contrast, patterns in sediment-dwelling algal (epipelon) abundance and community composition were not well-explained by the suite of measured environmental variables. Phytoplankton community composition, but not abundance, was best predicted by zooplankton biomass and elevation as cryptophytes (alloxanthin) were favored in low-elevation, montane lakes and ponds containing abundant zooplankton. Also, elevated conductivity and low DOC content were associated with a compositional shift away from planktonic cryptophytes and green algae (lutein violaxanthin) towards siliceous algae (fucoxanthin, chlorophyll c) and colonial cyanobacteria (mycoxanthophyll). These comparative results corroborate experimental findings that suggest epilithon is regulated by DOG, inorganic nutrients, and exposure to ultraviolet radiation (UV) in alpine littoral habitats. Thus, epilithon appears better suited than either phytoplankton or epipelon as a bioindicator of climatically induced variations in the abiotic environments of shallow mountain lakes and ponds.

Stressor/Response/Threshold Info

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Document Type

Peer review status

Keywords

bioindicator
climate change

Regions

Canadian Rockies

conductivity

dissolved organic carbon
high performance liquid
chromatograph

phytobenthos
phytoplankton

Study Design

Survey

Waterbody Types

lake
pond

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Use of hypolimnetic oxygen depletion rate as a trophic state index for lakes

Authors

Walker, W.W.

Year

1979

Source

Water Resources Research

Volume Pages Location

15 1463-1470

Annotation:

Simplified model of predicting anoxia risk in lakes using P concentration and mean depth. In lakes 5-10 m, mean TP > 10 ug/L have increased anoxic risk.

Reviewer Comments:

Abstract:

*SUMMARY - Water quality criteria (related to beneficial use) don't relate to subjective definitions of trophic state. This paper attempts to improve on existing methods by relating measures of P, Chl-a, and/or transparency to hypolimnetic dissolved oxygen. Modified version of Carlson's 1977 TSI is used. The methodology provides a link between P mass balance models and existing water quality criteria for DO.

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On: 6/26/2009

Document Type

Peer review status

Keywords

chlorophyll

Regions

Connecticut

dissolved oxygen

phosphorus

transparency

Study Design

Survey

Waterbody Types

lake

reservoir

Projects

Wyoming Nutrient Criteria Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Statistical bases for mean chlorophyll-a criteria

Authors

Walker, W.W., Jr.

Source

Lake and Reservoir Management

Annotation:

Bloom conditions (>20, 30 or 40 ug/L chl a) in lakes increases above mean arithmetic chl a concentrations of 10 ug/L (meso-eutrophic boundary).

Abstract:

*SUMMARY - Instead of just looking at mean chl-a concentrations, also look at maximum chl-a or nuisance bloom conditions for trophic state classifications. Frequency distribution models are calibrated to 3 independent data sets and used to predict certain relationships. The methodology established has potential applications in forming lake water quality objectives/criteria.

Stressor/Response/Threshold Info

Year

1985

Volume

Pages

57-62

Location

Reviewer Comments:

Edited By: kristen

On: 6/26/2009

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On: 6/26/2009

Document Type

Peer review status

Keywords

chlorophyll

criteria

northern lakes

water level

Regions

Unsure

Study Design

Modeling

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

[Simplified Procedures for Eutrophication Assessment and Prediction: User Manual](#)

Authors

Walker, W.W.

Year

1996

Source

US ACE

Volume Pages Location

239 pp

Annotation:

Describes simplified procedures for eutrophication assessment and prediction.

Reviewer Comments:

Abstract:

*PIECE OF INTRO - The basis of the modeling approach described below is to relate eutrophication symptoms to external nutrient loadings, hydrology, and reservoir morphometry using statistical models derived from a representative cross section of reservoirs. When applied to existing reservoirs, the models provide a framework for interpreting water quality monitoring data and predicting effects of future changes in external nutrient loadings. The models can also be used to predict water quality conditions in a proposed reservoir.

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On: 6/26/2009

Document Type

Peer review status

Keywords

loads

nutrient

water quality

Regions

eutrophication Unsure

Study Design

Modeling

Waterbody Types

reservoir

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

Distribution of phytoplankton in Wyoming lakes

Authors

Williams, L.R.; Hern, S.C.; Lambou, V.W.; Morris, F.A.;
Morris, M.K.; Taylor, W.D.

Year

1979

Source

US EPA

Volume Pages Location

50 pp

Annotation:

All 5 lakes and 9 reservoirs sampled for eutrophication risk. All indicated eutrophic status based on Nygaard index.

Reviewer Comments:

Abstract:

*SUMMARY - Collection & analysis of phytoplankton data were included in the National Eutrophication Survey in an effort to determine relationships between algal characteristics & trophic status of individual lakes. During spring, summer and fall of 1975, 156 lakes were sampled in 11 states; 450 algal samples IDed & counted, 430 water sampled examined. Report presents species abundance of phytoplankton in the 14 lakes sampled in WY.

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Document Type

Keywords

algal characteristics

phytoplankton

trophic status

Peer review status

Regions

US

Study Design

Field experiment

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Stressor/Response/Threshold Info

Annotated Literature

Citation Title:

[Nitrogen saturation in the Rocky Mountains](#)

Authors

Williams, M.W.; Baron, J.S.; Caine, N.; Sommerfeld, R.; Sanford, R.

Year

1996

Source

Environmental Science & Technology

Volume Pages

30 640-646

Location

Annotation:

Glacier Lakes, WY among highest N loading in NADP network - 9 kg/ha/yr. NH₄ ~ 126 ug/L; NO₃ ~ 744 ug/L at Glacier Lakes. 10X above historic.

Reviewer Comments:

Abstract:

Nitrogen saturation is occurring throughout high-elevation catchments of the Colorado Front Range. Annual inorganic N loading in wet deposition to the Front Range of similar to 4 kg ha⁻¹ yr⁻¹ is about twice that of the Pacific States and similar to many sites in the northeastern United States. In the last ten years at Niwot Ridge/Green Lakes Valley and Glacier Lakes, annual minimum concentrations of NO₃⁻ in surface waters during the growing season have increased from below detection limits to similar to 10 µm equiv L⁻¹, indicating that these two catchments are at the threshold of N saturation. The Loch Vale watershed is N saturated, with annual minimum concentrations of NO₃⁻ in surface waters generally above 10 µm equiv L⁻¹; annual volume-weighted mean (VWM) concentrations of 16 µm equiv L⁻¹ in surface waters are greater than that of similar to 11 µm equiv L⁻¹ NO₃⁻ in wet deposition. At these high-elevation catchments, there has been a shift in ecosystem dynamics from an N-limited system to an N-saturated system as a result of anthropogenically fixed N in wetfall and dryfall. Results from the Western Lakes Survey component of the National Surface Water Survey show that N saturation is a regional problem in the Colorado Front Range, with many lakes having (NO₃⁻) concentrations greater than 10 µm equiv L⁻¹. Foliar N:P ratios in bristlecone pine increase with elevation in the Colorado Front Range, indicating that at higher elevations P is translocated from foliar tissue more efficiently than N and that increasing atmospheric deposition of N with elevation is causing a change from N limitation to P limitation in the highest-elevation bristlecone pines. Current concepts of critical loads need to be reconsidered since only modest atmospheric loadings of N are sufficient to induce N leaching to surface waters in high-elevation catchments of the

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Document Type

Peer review status

Keywords

catchment

N saturation

Regions

Colorado Front Range

Study Design

Survey

Waterbody Types

Projects

Wyoming Nutrient Criteria Development

Annotated Literature

Citation Title:

Role of organic nitrogen in the nitrogen cycle of a high-elevation catchment, Colorado Front Range

Authors

Williams, M.W.; Hood, E.; Caine, N.

Year

2001

Source

Water Resources Research

Volume Pages Location

37 2569-2581

Annotation:

Results suggest that sources of organic N may change with time.

Reviewer Comments:

Abstract:

Here we report on 3 years (1996-1998) of measurements of organic and inorganic nitrogen (N) fluxes to and from Green Lakes Valley, a high-elevation ecosystem in the Colorado Front Range of the Rocky Mountains. Nitrate-N (NO₃-N) was the dominant form of N in both precipitation and stream water. Annual precipitation contained 52% NO₃-N, 32% ammonium-N (NH₄-N), 9% dissolved organic N (DON), and 7% particulate organic N (PON). Annual export of N in streamflow was composed of 70% NO₃-N, 4% NH₄-N, 14% DON, and 12% PON. Thus the percentage of organic N increased from 16% of total N in precipitation to 26% of total N in streamflow. Subtracting inputs from outputs, Green Lakes Valley always shows net retention of inorganic N. The only form of N that showed net export was DON. DON export was low (0.18 to -0.13 kg ha⁻¹ yr⁻¹), with net export recorded in 2 years and basin retention recorded in 1 year. There was a seasonal pattern in the concentrations of inorganic N (NO₃-N + NH₄-N) and organic N (DON + PON). Concentrations of inorganic N were similar to 15-25 μmol L⁻¹ during base flow, increased to similar to 30 μmol L⁻¹ on the rising limb of the hydrograph during snowmelt runoff, then decreased to -5 μmol L⁻¹ on the recession limb of late summer, with a return to base flow values in the autumn. In contrast, organic N was 7-15 μmol L⁻¹ during base flow and decreased to near or below detection limits on the rising limb of the hydrograph, with a gradual but consistent increase on the recession limb and on into the autumn. The amount of N in dissolved organic matter changed over time, with the dissolved organic carbon (DOC):DON ratio decreasing from similar to 45 on the rising limb of the hydrograph to < 20 in the autumn. Spatially, there was a striking difference in the ratios of NO₃-N and DON between talus and tundra areas. Nitrate concentrations in surface water draining talus areas were always greater than DON. In contrast, DON concentrations in surface water draining tundra areas were always greater than NO₃-N. Concentrations of DON were not significantly correlated with DOC (R² = 0.04, p > 0.05), indicating that controls on DON export may be different than controls on DOC export. Our results suggest that the ratio of the annual mass flux of inorganic N to organic N in stream waters may provide a novel index to evaluate the N status of terrestrial ecosystems from various biomes.

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Keywords

inorganic N
organic N

Regions

Colorado Front Range
Rocky Mountains

precipitation

Study Design

Survey

Waterbody Types

lake

Projects

Wyoming Nutrient Criteria
Development

Annotated Literature

Citation Title:

Critical loads for inorganic nitrogen deposition in the Colorado Front Range, USA

Authors

Williams, M.W.; Tonnessen, K.A.

Source

Ecological Applications

Annotation:

N generation and deposition from rural counties in WY comparable to Denver. Median NO₃ historically was ~ 1 umol/L (62 ug/L NO₃) in surface waters. WY clearly affected in ways similar to CO. See Figs 2 and 3.

Abstract:

We suggest an empirical approach for determining critical loads for inorganic nitrogen (N) deposition in wetfall to the central Rocky Mountains (USA). We define "critical loads" as a deposition amount above which natural resources can be negatively affected. The arithmetic average from 1992 to 1996 of annual inorganic N deposition in wetfall at the eight National Acid-Deposition Program (NADP) sites located at elevations >2500 m in the central Rocky Mountains ranged from 2.5 to 3.5 kg.ha⁽⁻¹⁾.yr⁽⁻¹⁾. In contrast, inorganic N deposition was <2.5 kg.ha⁽⁻¹⁾.yr⁽⁻¹⁾ at all 23 NADP sites below 2500 m in elevation. At the Niwot Ridge NADP site in the Colorado Front Range, a simple linear regression of inorganic N in wetfall with time shows a significant increase in deposition of inorganic N in wetfall at the rate of 0.32 kg.ha⁽⁻¹⁾.yr⁽⁻¹⁾ (r² = 0.62; P < 0.001, n = 13). In turn, the increasing amount of inorganic N in wetfall is causing episodic acidification in headwater catchments of the Green Lakes Valley in the Colorado Front Range, with acid-neutralizing capacity (ANC) values below 0 mu mol(c)/L in surface waters during snowmelt runoff at 9-ha and 42-ha sampling sites. At present rates of ANC decrease, we can expect the 9-ha and 42-ha sites to become chronically acidified within the next decade and the 220-ha basin of Green Lake 4 to become episodically acidified. A synoptic survey in 1995 of 91 high-elevation lakes in the central Rocky Mountains suggests that water quality is being affected by inorganic N in wetfall throughout the region. Federal land managers are required to "err on the side of protection" when assessing the amount of deposition that will alter ecosystem processes. However, given the political and economic ramifications of policy decisions, land managers are aware of the need to provide a scientific basis for these decisions and to balance conflicting needs. To achieve this balance and to allow for natural-resource protection, we make a conservative recommendation that critical loads of inorganic N in wetfall to Class 1 areas in the central Rocky Mountains be set at 4 kg.ha⁽⁻¹⁾.yr⁽⁻¹⁾. Target loads may be set at lower levels of inorganic N deposition in wetfall to allow a margin of safety to protect extremely sensitive natural

Stressor/Response/Threshold Info

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Rocky Mountains

Study Design

Uncertain

Waterbody Types

Projects

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Development

Annotated Literature

Citation Title:

Anthropogenic nitrogen deposition induces rapid ecological changes in alpine lakes of the Colorado Front Range (USA)

Authors

Wolfe, A.P.; Baron, J.S.; Cornett, R.J.

Source

Journal of Paleolimnology

Annotation:

Mesotrophic Asterionella and Fragilaria showing up in sediments since 1950s. No longer pristine, even though in protected lands.

Abstract:

Recent sediments from two alpine lakes (> 3300 m asl) in the Colorado Front Range (USA) register marked and near-synchronous changes that are believed to represent ecological responses to enhanced atmospheric deposition of fixed nitrogen from anthropogenic sources. Directional shifts in sediment proxies include greater representations of mesotrophic diatoms and increasingly depleted delta N-15 values. These trends are particularly pronounced since similar to 1950, and appear to chronicle lake responses to excess N derived from agricultural and industrial sources to the east. The rate and magnitude of recent ecological changes far exceed the context of natural variability, as inferred from comparative analyses of a long core capturing the entire 14,000-year postglacial history of one of the lakes. Nitrogen deposition to these seemingly pristine natural areas has resulted in subtle but detectable limnological changes that likely represent the beginning of a stronger response to nitrogen enrichment.

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Colorado Front Range

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lake

Projects

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Annotated Literature

Citation Title:

Annual wet and dry deposition of sulfur and nitrogen in the snowy range, Wyoming

Authors

Zeller, K.; Harrington, D.; Riebau, A.; Donev, E.

Year

2000

Source

Atmospheric Environment

Volume Pages Location

34 1703-1711

Annotation:

N and S deposition higher at high elevations in the Medicine Bow range. Lower than eastern US, but still significant. In the range observed in the CO Rockies impacted by Front Range. Within critical load range for ecosystem impacts.

Reviewer Comments:

Abstract:

The collocation of three national networked programs NADP, EPA's CASTNET, and the Forest Service's IMPROVE Module A, within a few hundred meters of each other in the pristine Medicine Bow forest of Wyoming has made it possible to assess the total amount of sulfur and nitrogen deposition, both wet and dry for this alpine/subalpine ecosystem. Additional sites within a few kilometers add spatial depth to this study. Wet deposition assessed using NADP data accounts for 1 to a little over 3 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ for both nitrogen and sulfur; however, annual trends for the two species differ. Dry deposition assessed using both CASTNET (a.k.a. NDDN) and IMPROVE (for sulfur) indicates 1-2 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ for nitrogen but less than 1 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ for sulfur. The overall trend of wet plus dry for nitrogen has been downward from 5 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ in 1989 to 3.6 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ in 1994, while varying between 2 and under 4 kg ha⁽⁻¹⁾ yr⁽⁻¹⁾ for sulfur. This paper introduces the sites and presents the three programs and the analysis approach. Spatial comparisons between sites are investigated. Weekly data are analyzed from three NADP sites, separated horizontally 6.8 and 2.4 km and vertically 430 and 98 m from the highest elevation site. The site comparisons demonstrate that winter season data requires careful analysis due to the Vagaries of inefficient precipitation collection during high

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