TETRA TECH

MEMO

To:	Utah Lake Science Panel; DWQ
Cc:	
From:	Kateri Salk and Michael Paul
Date:	2021-01-27
Subject:	Compilation of information from other studies to fill in the Utah Lake N and P conceptual models

1.0 GOALS AND APPROACH

Conceptual models for nitrogen (N) and phosphorus (P) cycles in Utah Lake were quantified, where possible, with data from Utah Lake studies (see “UtahCNP_LitReview_Memo_v2.1_20201119.docx” and “UtahLake_CNPDataCompilation.xlsx”). When data for a specific stock or process was not available for Utah Lake, we searched the literature for established values. As much as was possible, data were compiled from systems anticipated to act similarly to Utah Lake (e.g., eutrophic, shallow, and/or high alkalinity lakes) or from reviews that included data from multiple systems.

Literature was compiled from several sources:

- Textbooks (Wetzel 2001, Sterner and Elser 2002, Dodds and Whiles 2011)
- Google Scholar
- Web of Science

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2.0 ADDITIONAL LITERATURE TO FILL GAPS IN UTAH LAKE DATA

Stock or Process	Amount or Rate	Additional notes	Source
Phytoplankton N content	~5-9 % (IQR)	Biovolume and cell counts are available in the phytoplankton database, but a conversion to biomass is needed to calculate N standing stock	Sterner and Elser 2002
Phytoplankton P content	~0.7-2 % (IQR)	Biovolume and cell counts are available in the phytoplankton database, but a conversion to biomass is needed to calculate P standing stock	Sterner and Elser 2002
Phytoplankton N uptake	10-10,000 ng L^{-1} h^{-1}		Dodds and Whiles 2010
Phytoplankton P uptake	0.1-100 ng L^{-1} h^{-1}		Dodds and Whiles 2010
Phytoplankton N excretion	10-10,000 ng L^{-1} h^{-1}		Dodds and Whiles 2010
Phytoplankton P excretion	0.1-100 ng L^{-1} h^{-1}		Dodds and Whiles 2010
Zooplankton N content	5-14 % Small-bodied taxa: 0.5-1,400,000 µg L^{-1} Large-bodied taxa: 500-14,000 µg L^{-1}	Literature value for % N was multiplied by biomass mean in Utah Lake Zooplankton abundance (counts, relativized counts/length) reported in Richards reports, but conversions to biomass was not available	% N: Sterner and Elser 2002, Dodds and Whiles 2010 Utah Lake biomass: Landom and Walsworth 2020, Richards and Miller 2017, Richards 2018, Richards et al. 2019a, and Richards et al. 2019b
Zooplankton P content	0.5-1.6 % Small-bodied taxa: 0.05-160,000 µg L^{-1} Large-bodied taxa: 50-1,600 µg L^{-1}	Literature value for % P was multiplied by biomass mean in Utah Lake Zooplankton abundance (counts, relativized counts/length) reported in Richards reports, but conversions to biomass was not available	% P: Sterner and Elser 2002, Dodds and Whiles 2010 Utah Lake biomass: Landom and Walsworth 2020, Richards and Miller 2017, Richards 2018, Richards et al. 2019a, and Richards et al. 2019b

Stock or Process	**Amount or Rate**	**Additional notes**	**Source**
Zooplankton N uptake	1-1,000 µg phyto. ind^{-1} d^{-1} 1.2-2,160 µg N ind^{-1} h^{-1}	Literature value for feeding rate was multiplied by % N content above	Peters and Downing 1984
Zooplankton P uptake	1-1,000 µg phyto. ind^{-1} d^{-1} 0.17-480 µg P ind^{-1} h^{-1}	Literature value for feeding rate was multiplied by % N content above	Peters and Downing 1984
Zooplankton N excretion	0.01-10,000 µg ind^{-1} d^{-1}		Wen and Peters 1994
Zooplankton P excretion	0.01-0.13 µg L^{-1} d^{-1} 0.01-1,000 µg ind^{-1} d^{-1}		Vanni and Findlay 1990, Wen and Peters 1994
Fish N content	8-12 % 0.8-20 kg $acre^{-1}$	Literature value for % N was multiplied by sport fish biomass mean in Utah Lake	% N: Sterner and Elser 2002 Utah Lake biomass: Landom and Walsworth 2020
Fish P content	1-4.5 % 0.1-4.5 kg $acre^{-1}$	Literature value for % P was multiplied by sport fish biomass mean in Utah Lake	% P: Sterner and Elser 2002 Utah Lake biomass: Landom and Walsworth 2020
Fish N uptake	Not possible to calculate	Information needed: biomass of individual fish taxa, their food sources, and feeding rates	
Fish P uptake	Not possible to calculate	Information needed: biomass of individual fish taxa, their food sources, and feeding rates	
Fish N excretion	Carp: 496,000-1,140,000 kg y^{-1}	Information needed: biomass of individual fish taxa	Tetra Tech 2020
Fish P excretion	Carp: 51,100-117,000 kg y^{-1} Perch: 0.05-0.41 µg L^{-1} d^{-1} Gizzard shad: 0-300 µg µg wet $mass^{-1}$ d^{-1}	Information needed: biomass of individual fish taxa	Tetra Tech 2020, Vanni and Findlay 1990, Sterner and Elser 2002
Macrophyte N content	0.8-1.3 % of dry mass (Utah Lake data)	Information needed: total macrophyte biomass	Miller and Provenza 2007 (Utah Lake data)
Macrophyte P content	0.2-0.6 %	Information needed: total macrophyte biomass	Lytle and Smith 1995, Sterner and Elser 2002

Stock or Process	Amount or Rate	Additional notes	Source
Macrophyte N uptake and excretion	Not possible to calculate	Information needed: total macrophyte biomass	
Macrophyte P uptake and excretion	Not possible to calculate	Information needed: total macrophyte biomass	
Periphyton N content	Periphyton biomass assumed to be negligible		King et al. 2020
Periphyton P content	Periphyton biomass assumed to be negligible		King et al. 2020
Periphyton N uptake and excretion	Periphyton biomass assumed to be negligible		King et al. 2020
Periphyton P uptake and excretion	Periphyton biomass assumed to be negligible		King et al. 2020
Macroinvert. N content	42.7-141.2 mg N g dry weight^{-1} Total biomass: 719-2,912,284 kg wet weight (IQR) Chironomid biomass: ~2,000-8,000 mg wet weight m-2	Information needed: conversion from wet weight to dry weight	N content: Pennuto et al. 2014 Macroinvertebrate biomass: Richards and Miller 2017
Macroinvert. P content	5.3-17.0 mg N g dry weight^{-1} Total biomass: 719-2,912,284 kg wet weight (IQR) Chironomid biomass: ~2,000-8,000 mg wet weight m-2	Information needed: conversion from wet weight to dry weight	Pcontent: Pennuto et al. 2014 Macroinvertebrate biomass: Richards and Miller 2017
Macroinvert. N uptake	Not possible to calculate	Information needed: abundance of individual macrophyte taxa, their food sources, and feeding rates	
Macroinvert. P uptake	Not possible to calculate	Information needed: abundance of invidual macrophyte taxa, their food sources, and feeding rates	

Stock or Process	Amount or Rate	Additional notes	Source
Macroinvert. N excretion	0-168 μg N g dry weight^{-1} h^{-1}	Information needed: conversion from wet weight to dry weight	McManamay et al. 2011
Macroinvert. P excretion	0-496 μg P g dry weight^{-1} h^{-1}	Information needed: conversion from wet weight to dry weight	McManamay et al. 2011
DOP concentration	0-0.18 mg L^{-1}	Calculated from monitoring database as recommended in EFDC/WASP documentation: DOP = TP – PO_4^{3-} Note: concentrations are necessarily bounded by zero, but estimation by difference resulted in negative concentrations Designated as medium confidence due to high confidence in TP and PO_4^{3-} methodology but observations of negative values occurred when estimated by difference	Su and von Stackelberg 2020
PIP concentration	Not possible to calculate	Information needed: particulate organic phosphorus concentration (to estimate by difference: TP – POP) or direct measurement of particulate inorganic phosphorus	
PP settling rate	0.5-3.2 g m^{-2} y^{-1} 0-215 mg m^{-2} d^{-1} 192-1,230 tons y^{-1} 0-83 tons d^{-1}	Top: range of annual literature values Bottom: calculated from range of daily settling rates from the literature (0-113 g m^{-2} d^{-1}) and the range of measured sediment P content in Utah Lake (280-1900 mg P/kg) Rates multiplied by area of Utah Lake (95,000 ac)	Evans 1994, Wetzel 2001
PP resuspension rate	0.45-0.67 g m^{-2} y^{-1} 0-213 mg m^{-2} d^{-1} 173-257 tons y^{-1}	Top: range of annual literature values Bottom: calculated from range of daily resuspension rates from the literature (0-112 g m^{-2} d^{-1}) and the range of measured	Evans 1994, Wetzel 2001

Stock or Process	Amount or Rate	Additional notes	Source
	0-82 tons d^{-1}	sediment P content in Utah Lake (280-1900 mg P/kg) Rates multiplied by area of Utah Lake (95,000 ac)	
DON concentration	0-11.9 mg L^{-1} (calculated from TKN) 0-1.9 mg L^{-1} (calculated from TDN)	Calculated from monitoring database as recommended in EFDC/WASP documentation: DON = TKN – NH_3 DON = TDN – NH_3 – NO_3^- - NO_2^- Note: concentrations are necessarily bounded by zero, but estimation by difference resulted in negative concentrations Designated as medium confidence due to high confidence in TDN, TKN, NH_3, NO_3^-, and NO_2^- methodology, but observations of negative values occurred when estimated by difference	Su and von Stackelberg 2020
PN concentration	0-0.50 mg L^{-1}	Calculated from monitoring database as recommended in EFDC/WASP documentation: PN = TN - TDN Note: concentrations are necessarily bounded by zero, but estimation by difference resulted in negative concentrations Designated as medium confidence due to high confidence in TN and TDN methodology, but observations of negative values occurred when estimated by difference	Su and von Stackelberg 2020
PN settling rate	0-339 mg m^{-2} d^{-1} 0-130 tons d^{-1}	Calculated from range of daily settling rates from the literature (0-113 g m^{-2} d^{-1}) and the range of measured sediment P content in Utah Lake (280-1900 mg P/kg)	Evans 1994, Wetzel 2001

Stock or Process	Amount or Rate	Additional notes	Source
		Rates multiplied by area of Utah Lake (95,000 ac)	
PN resuspension rate	0-336 mg m^{-2} d^{-1} 0-129 tons d^{-1}	Calculated from range of daily settling rates from the literature (0-112 g m^{-2} d^{-1}) and the range of measured sediment P content in Utah Lake (280-1900 mg P/kg) Rates multiplied by area of Utah Lake (95,000 ac)	Evans 1994, Wetzel 2001
Porewater TDN concentration	0-16 mg L^{-1}		Urban et al. 1997, Qin et al. 2006
Denitrification rate	70.5 % of N inputs 1,372,000 kg y^{-1}	Using equation from Figure 5: % N removed = 88 * (depth(m)/water residence time(y))$^{-0.368}$ Average depth 2.74 m Average water residence time: 1.5 y N load: 1,946,000 kg y^{-1}	Seitzinger et al. 2006 N load: Merritt and Miller 2016
N fixation rate	Water column: mean 0.6-0.9 (range 0-4.65) µg L^{-1} h^{-1} Benthic: mean 0.83-0.93 ± 0.20-0.22 (range 0.25-2.63) mg m^{-2} h^{-1}	Benthic rates multiplied by area of Utah Lake (95,000 ac)	Beversdorf et al. 2013 McCarthy et al. 2016

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