Bacterial biomass
Lake Constance data documentation

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Lake name: Lake Constance

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Sampling site

Lake Constance (LC) is a temperate, large (476 km^2), deep (mean depth = 101 m, max. depth 252 m), and warm-monomictic lake north of the European Alps of glacial origin with weak pelagic-benthic coupling, and little allochthonous input into the pelagic zone (Bäuerle & Gaedke 1998). Plankton biomass and the factors regulating growth exhibit strong seasonality (Sommer *et al*. 1986, Boit & Gaedke 2014 and literature therein). The annually repeated, successional cycle in LC is largely driven by autogenic processes during the growing season from March until October/November (Sommer *et al.* 1986, Sommer 1986, Peeters *et al.* 2007, Tirok & Gaedke 2007) and by abiotic forcing during winter.

Sampling methods

Bacterioplankton biomass (BB) was measured *in situ* as described by Weisse (1991). Samples were taken at the deepest site (147 m) of the north-western part of Lake Constance ("Überlinger See"). During the growing season when the lake is more or less stratified, the routine sampling interval was once per week. In winter time, one sample was taken every 2-3 weeks. Samples were taken in 10 subsequent hauls using a 2 m long (4l volume) water sampler covering the entire water column from surface to 20 m depth. Samples were fixed immediately with formalin (final concentration 1.5% by volume) and later concentrated onto 0.2 µm Nuclepore filters under gentle vacuum. The filters were analysed for bacteria, autotrophic picoplankton (APP) and HNF using epifluorescence microscopy and DAPI staining (Porter & Feig 1980) as described in Weisse (1989, 1990, 1991). Bacterial cell counts were converted to bio volume either using a constant fixed mean cell volume of free-living bacteria measured in Lake Constance of 0.054 μm^3 (Simon 1987) resulting in a carbon content of 16 fg C/cell (Simon & Azam 1989) (cf. values published in Weisse (1991) and Simon *et al.* (1998)) or using seasonally resolved size distributions measured in Lake Constance. The measurements were performed by scanning electron microscopy (SEM) for bacteria throughout the season in 1982 (Simon 1985, 1987) for six depth intervals. Rods and coccoid cells were treated separately. In both cases the conversion from cell volume to carbon content was done using a non-linear relationship of 0.09 * (cell volume in $\mu m3)^{0.59}$ based on measurements by Simon and Azam

(1989). The nonlinearity of this relationship implies that differences in the total carbon biomass arise between calculations based on a constant mean cell volume or a seasonally changing cell size distribution (see below for details).

Bacterial biomass datasets

We provide four datasets 1-4 with approximately (bi-) weekly measurements comprising the long-term bacterial biomass data for each sampling date (1987-1996 or 1997).

Dataset 1 and Dataset 2 represent one set of biomass data (depth-resolved over 0-8m and 8-20m, and depth-integrated over 0-20m) based on bacterial cell counts (Weisse 1991). Dataset 1 maps onto Dataset 2 by depth integration.

Dataset 3 and Dataset 4 represent an alternative depth-averaged biomass dataset (0-20m) based on a categorization of the bacterial cells into different size classes (Gaedke 1992). Dataset 3 maps exactly onto Dataset 4 by summation of the biomass over all size classes. Fig. 1 shows the time series of the total bacterial biomass (Dataset 4) as a reference plot for database users.

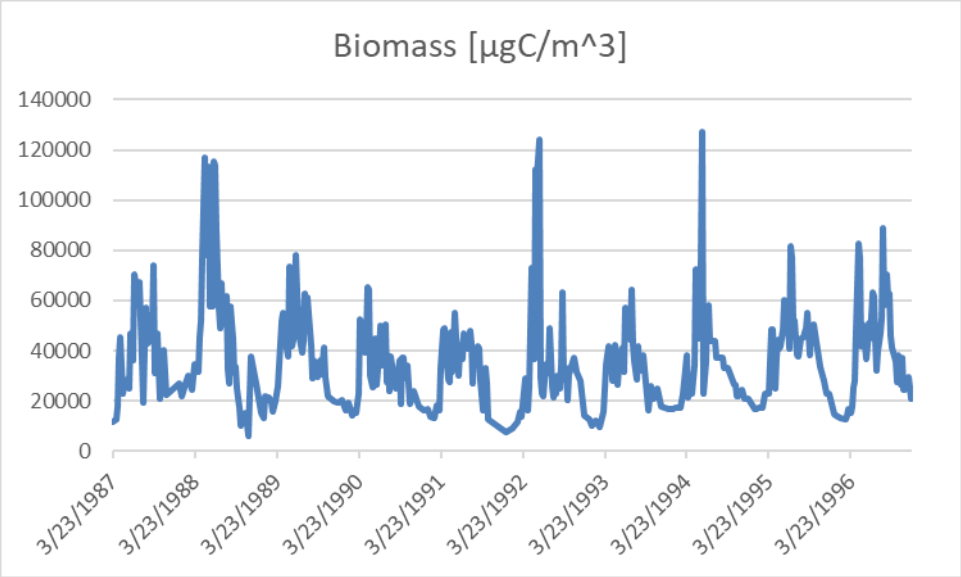

Fig. 1. Time series of total bacterial biomass as provided by Dataset 4.

Comparison between datasets

The seasonal course of the bacterial biomass in all datasets 1-4 is qualitatively very similar. Datasets 1 and 2 report generally higher biomass values than Datasets 3 and 4 which are up to factor 1.5-2.0 higher for specific days due to different conversion factors from cell numbers to biomass in units of carbon (see above). The cell volume of bacteria in Lake Constance is 0.054 μm^3 on average (Simon 1987).

Data gaps

Dataset 1 and 2 contain some gaps in sampling dates, especially in winter (e.g. 1994-1995). The missing data periods amount to less than 10% of the entire time covered by the dataset. Datasets 3 and 4 linearly interpolate some of the data gaps in Dataset 1-2, e.g. during winter 1994/95.

Dataset 1: Depth-resolved bacterial biomass

Filename: "Dataset_1_Lake_Constance_Bacterial_Biomass_Depth_Resolved"
This dataset contains the bacterial biomass from 1987-1997 in µg C/m^3 resolved by two depth layers (0-8m and 8-20m, n = 782). No data are available at individual dates and there is a larger data gap in winter 1994/95. In addition to biomass, we also report the bacterial abundances in cells/ml for comprehensiveness so that alternative conversion factors from cell volume to biomass can be applied. The seasonal development of the bacterial biomass in this dataset is very similar to the Fig. 6 in the original publication by Weisse (1991). Differences are due to different conversion factors from cell volume to biomass.

Column headers

A. Date
B. Depth [m]
C. Abundance [cells/ml]
D. Biomass [µg C/m^3]

Dataset 2: Depth-averaged bacterial biomass

Filename: "Dataset_2_Lake_Constance_Bacterial_Biomass_Depth_Averaged_a"
This dataset is based on Dataset 1 and contains the bacterial biomass in µg C/m^3 from 1987-1997 averaged over 0-20m depth. (n = 391). Some dates are not available anymore. There is a larger data gap in winter 1994/95.

Column headers

A. Date
B. Abundance [cells/ml]
C. Biomass [µg C/m^3]

Dataset 3: Depth-averaged bacterial biomass in size classes

Filename: "Dataset_3_Lake_Constance_Bacterial_Biomass_Size_Classes_Depth_Averaged"
This dataset is contains the bacterial biomass in µg C/m^3 from 1987-1996 averaged over 0-20m depth and resolved into 8 different size classes (n = 2237). Size classes of bacterial cells range between -10 and -3 and represent the logarithm of the cell's weight in units of carbon: size class = $\log_2$ [pg C] (as mean weights, i.e. size class -10 comprises cells with $2^{-10.5}$ to $2^{-9.5}$ pg C).

Column headers

A. Date
B. Size class (GK = $\log_2$ [pg C])
C. Biomass [µg C/m^3]

Dataset 4: Depth-averaged bacterial biomass summed up over size classes

Filename: "Dataset_4_Lake_Constance_Bacterial_Biomass_Depth_Averaged_b"

This dataset is directly derived from Dataset 3 by summing up the bacterial biomass over all size classes. This file contains the bacterial biomass in µg C/m^3 from 1987-1996 averaged over 0-20m depth (n = 378). Size classes of bacterial cells range between -10 and -3 and represent the logarithm of the cell's weight in units of carbon: size class = $\log_2$ [pg C].

Column headers

A. Date

B. Size class (GK = $\log_2$ [pg C])

C. Biomass [µg C/m^3]

References

General references on Lake Constance

Bäuerle E, Gaedke U (1998) Lake Constance: characterization of an ecosystem in transition. Stuttgart, Germany: Schweizerbartsche Verlagsbuchhandlung.

Boit A, Gaedke U (2014) Benchmarking Successional Progress in a Quantitative Food Web. *PLoS One,* 9(2): e90404

Peeters F, Straile D, Lorke A, Ollinger D (2007) Turbulent mixing and phytoplankton spring bloom development in a deep lake. *Limnology and Oceanography,* 52: 286–298.

Sommer U (1986) The periodicity of phytoplankton in Lake Constance (Bodensee) in comparison to other deep lakes of central Europe. *Hydrobiologia,* 138: 1–7.

Sommer U, Gliwicz ZM, Lampert W, Duncan A (1986) The PEG-Model of Seasonal Succession of Planktonic Events in Fresh Waters. *Archiv für Hydrobiologie,* 106: 433–471.

Tirok K, Gaedke U (2007) The effect of irradiance, vertical mixing and temperature on spring phytoplankton dynamics under climate change – long-term observations and models. *Oecologia,* 150: 625-642.

Specific references for this data package

Gaedke U (1992) The Size Distribution of Plankton Biomass in A Large Lake and Its Seasonal Variability. *Limnology and Oceanography,* 37: 1202–1220.

Porter KG and Feig YS (1980) The use of DAPI for identifying and counting aquatic microflora. *Limnology and Oceanography*, 25, 943-948.

Simon M (1984) Bacterial production and its relation to heterotrophic activity parameters in Lake Constance. *Ergeb. Limnol.,* 19:131–139

Simon M (1985) Specific uptake rates of amino acids by attached and free-living bacteria in a mesotrophic lake. *Appl. Environ. Microbiol.,* 49:1254–1359

Simon M (1987) Biomass and production of small and large free-living and attached bacteria in Lake Constance. *Limnol. Oceanogr*., 32, 591-607.

Simon M, Bunte C, Schulz M, Weiss M, Wünsch C (1998) Bacterioplankton dynamics in lake Constance (Bodensee): Substrate utilization, growth control, and long-term trends. *Arch. Hydrobiol. Spec. Issues Advanc. Limnol.,* 53:195-221.

Simon M and Azam F (1989) Protein content and protein synthesis rates of planktonic marine bacteria. *Mar. Ecol Prog. Ser.*, 51, 201-213.

Weisse T (1989) The microbial loop in the Red Sea: dynamics of pelagic bacteria and heterotrophic nanoflagellates. *Mar. Ecol. Prog. Ser.*, 55, 241-250.

Weisse T (1990) Trophic interactions among heterotrophic microplankton, nanoplankton, and bacteria in Lake Constance (FRG). *Hydrobiologia*, 191, 111-122.

Weisse T (1991) The annual cycle of heterotrophic freshwater nanoflagellates: role of bottom-up versus top-down control. *Journal of Plankton Research*, 13(1): 167-185