ReadMe File for Mean Exit Times & Bootstrap 2019-2020-2021
"Extremes of Physical-Chemical Drivers and Cyanobacteria Concentrations . . . ."

The file presents the data files and R scripts for mean exit time and median survival time of alternate states in 2021, and their bootstrapped uncertainties. As an example that is fast to compute, we use only 100 bootstrap cycles for only one year, 2021. The paper presents 1000 bootstrap cycles for all years. The R scripts are the same, except the parameter 'nboot' is changed to 1000.

Datasets input to the analysis are **Me_BGA+cov_1min_YYYY.Rdata** where YYYY is four-digit year. Each file is the observations of meteorology and lake surface variates made each minute at a centrally-located buoy (Magnuson, Carpenter, & Stanley, 2022). Data were downloaded as .csv files and converted to .Rdata files for analysis.

All worked examples used **Me_BGA+cov_1min_2021.Rdata** as input data. The R scripts are easily modified for later years by changing input and output file names to the appropriate year.

All other .Rdata files in this archive are intermediate files generated by the R scripts and will not be described further.

The calculation of nominal mean exit time is accomplished by running

Step1_DLM_Mendota_2022-01-17.R
Step3_DDbintau+D4_Mendota_2022-01-22.R
Step4_ET_effpot_DD+bintau_MendotaYYYY_2022-01-18.R

in sequence. YYYY is 4-digit year. There is no Step2; Step2 was a back-transformation abandoned earlier in the research project. These scripts call functions in **ODLMAR_NoBoot_2018-10-20.R** and **DDbintau+D4.R**.

A more detailed explanation of the background and R scripts for nominal exit time is presented in (Carpenter, Arani, Van Nes, Scheffer, & Pace, 2022) and the GitHub library https://github.com/SRCarpen/Exit-SurvivalTime_Aug2021.git

After nominal mean exit time is computed, nominal median survival times for each attractor are computed by **Survival_Left_DDbin_tauwts_FromStep4_2021-06-03.R** and **Survival_Right_DDbin_tauwts_FromStep4_2021-06-03.R**

After the nominal calculations are complete, uncertainties can be computed by bootstrap from residuals following (Carpenter et al., 2022). The sequence of R scripts for 2021 is:

1) **Bootstrap_DLM_Mendota2021_2022-02-13.R** Here user must specify the number of bootstrap iterations by defining nboot in line 48. Start with a small number, such as

nboot = 10, and if the sequence of programs is working then select the desired number of bootstrap cycles.

2) **Bootstrap_DDbintau+xeq_2021-08-03.R**

3) **BootALL_Step4_ET+survival_2022-02-13.R**

4) **Analyze_Bootstrap_ET+HalfLife_2021.R**

The last step, **Analyze_Bootstrap_ET+HalfLife_2021.R**, requires the user to enter the nominal exit times on lines 13 and 14 and the nominal half-lives on lines 49 and 50. Further analyses, such as density plots for larger bootstrap

These R scripts call functions in the files **ODLMAR_for_Bootstrap_2020-11-23.R** and **DDbintau+D4.R.**

References

Carpenter, S. R., Arani, B. M. S., Van Nes, E. H., Scheffer, M., & Pace, M. L. (2022). Resilience of phytoplankton dynamics to trophic cascades and nutrient enrichment. *Limnology and Oceanography, 67*(S1), S258-S265. doi:https://doi.org/10.1002/lno.11913

Magnuson, J. J., Carpenter, S. R., & Stanley, E. H. (2022). *North Temperate Lakes LTER: High Frequency Data: Meteorological, Dissolved Oxygen, Chlorophyll, Phycocyanin - Lake Mendota Buoy 2006 - current*. Retrieved from: https://doi.org/10.6073/pasta/fc8bd96677405945024ad708003be1fc