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BORIS-2 – a benthic ecosystem model based on allometry

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Supplement

User Manual for BORIS-2 benthic ecosystem model

Overview:

BORIS-2 is a model describing the population dynamics of benthic biota, feeding from a common resource that is supplied by a flux of sinking organic carbon arriving on the seafloor. By using allometric relationships for the physiological processes of growth, mortality and respiration, and for food limitation, the model represents the population dynamics of organisms ranging in size from bacteria (10^{-14} g wet weight C) to large metazoans (10^{3} gwwt C). The effect of temperature on physiological rates is also included. The only forcing information required is the ambient temperature and the rate of supply of sinking organic carbon. The model can be used for, and tuned to, specific locations. However, a parameter set has been provided that is generally applicable. The model can simultaneously reproduce biomass size distributions at five contrasting sites using this parameter set. This model has an analytic steady state solution and can also be run dynamically.

All code and data for generating the figures in this paper and for using BORIS-2 either at steady state or dynamically are available on Zenodo at https://doi.org/10.5281/zenodo.19235638 (Martin et al., 2026).

The model has been configured using data from 5 contrasting sites. Details can be found in the manuscript and locations are shown in Figure 2 of the manuscript. In the order in which they are used/referred to in the code and manuscript, these sites are:

1. Clarion Clipperton Zone (CCZ)
2. Fladden Ground (FG)
3. Faroe Shetland Channel (FSC)
4. Oman Margin (OM)
5. Porcupine Abyssal Plain (PAP)

Platform:

All code is in Matlab. It was developed, tested and run in version 25.1.0.2973910 (R2025a) Update 1.

Running the model:

1. Code should be downloaded from Zenodo (https://doi.org/10.5281/zenodo.19235638 (Martin et al., 2025)) and saved to a single folder
2. Matlab should be started either in the BORIS-2 folder or else have that folder added to the path
3. Typing

```
params
```

sets up basic parameters used by all the example code, including the representative mass of each size class (`M`) and the parameters for the model.

The model is available in two forms: to provide both a dynamic and a steady state solution.

4. To see how to use the model in a dynamic manner,

   Type

   `Fig7`

   This will run an example showing the response of the ecosystem to a doubling of POC flux. This code is easily modified to explore other situations:

   - To change the time-varying POC flux:
     - search in `Fig7.m` for "% create time series for POC flux".
     - `POCFmod` should be given the required values for POC flux (units: gwwt/m^2/d)
     - `POCFtmod` should carry the associated timestamps (units: d).
   - To change the ambient temperature:
     - Search in Fig7.m for "% set temperature"
     - Set `TC` to the required temperature (units: ^oC)

       Fig7.m does not currently have time-varying temperature
   - To change initial conditions:

     Fig7.m sets the initial conditions by calculating the steady state solution corresponding to the initial POC flux and ambient temperature.

     If it is required to set the initial conditions manually then:
     - Search in `Fig7.m` for "% calculate steady state solution"
     - Either set or read in values for `B` (biomass for each size class of organism, 59 size classes, 1=smallest, 59=largest, units: gwwt/m^2) and `R` (biomass of detritus, units: gwwt/m^2)

5. To calculate the steady state solution for the model

   Type

   `[B,R]=steady_state(POCF,TC);`

   where `POCF` is your required POC flux (units: gwwt/m^2/d) and `TC` (units: ^oC) is your required ambient temperature.

   On completion, `B` will contain the biomass of all 59 size classes (class 1 being smallest and class 59 the largest, units: gwwt/m^2) and `R` will contain the biomass of detritus (units: gwwt/m^2).

   You can also find examples of using `steady_state.m` in `Fig6.m` and `Fig7.m`

Reproducing figures from the manuscript:

- Each figure using model output in the manuscript (figures 2 to 7) has a separate Matlab routine (`Fig2, Fig3, Fig4, Fig5, Fig6, Fig7`)
- Just type the routine name to run it and generate the figure.

Code description:

`params.m`

- Sets parameters used in the BORIS-2 model - called by both dynamic and steady state versions

`rates.m`

- Uses information from `param.s` and location temperature to set physiological rates (maximum growth, respiration and mortality) and interference
- Other routines called:
    `params.m`

`siteinfo.m`
- Sets up information on the 5 sites used in the manuscript
- Information is:
    site location (latitude and longitude)
    seafloor temperature
    temperature effect on rates

`steady_state.m`
- Function to calculate steady state solution given input of temperature and POC flux
- Equations for steady state are given in manuscript
- Other routines called:
    `param.s`
    `rates.m`

`benthic_dydt.m`
- Function to calculate rate of change of biomass and detritus with time for use in dynamic version of model
- Equations are given in manuscript
- Other routines called:
    None directly but requires global variables for fluxes, time and rates to have been set up - see `Fig5.m`

`Fig2.m`
- Creates Figure 2 for the manuscript: plots showing how the interference function f(R,B) varies with both R and B

`Fig3.m`
- Creates Figure 3 for the manuscript: a fit of a power law relation to observations of biomass from 5 contrasting sites
- Other routines called:
    `param.s`
- Data used:
    BiomassData.zip

`Fig4.m`
- Creates Figure 4 for the manuscript: a set of diagnostics for assessing the performance of the model
- Other routines called:
    `param.s` (by calling `Fig3.m`)
    `rates.m`
    `Fig3.m`

Data used:
    BiomassData.zip (by calling `Fig3.m`)

`Fig5.m`

- Creates Figure 5 for the manuscript: a set of sensitivity analyses for metrics shown in Figure 4
- Other routines called:
  - `param.s`
  - `rates.m`
  - `siteinfo.m`

`Fig6.m`

- creates Figure 6 for the manuscript: showing global distribution of benthic biomass based on temperature and POC flux data
- Other routines called:
  - `param.s`
  - `rates.m` (by calling `steady_state.m`)
  - `steady_state.m`
- Data used:
  - WOAbott,mat
  - fluxglobdat,mat
- Also uses:
  - Scientific Color Maps

`Fig7.m`

- creates Figure 7 for the manuscript: showing response of ecosystem to a doubling of POC flux
- This code is easily modified to explore other situations with time-varying POC flux and temperature
- Other routines called:
  - `param.s`
  - `rates.m`
  - `steady_state.m`
  - `benthic_dydt.m`

Data:

WOAbott.mat

- Seafloor latitude, longitude, depth and temperature data extracted from the World Ocean Atlas - Reagan et al. (2024)
- Used by `Fig6.m`

fluxglobdat.mat

- POC fluxes calculated using Lutz. et al. (2007) algorithm for same latitude, longitude grid and depths as WOAbott.mat
- Used by `Fig6.m`

BiomassData.zip

- Compressed folder with biomass observations from the 5 sites used in the manuscript
  - CCZ_biomass
  - FG_biomass

FSC_biomass

OM_biomass

PAP_biomass

- Information on sites and how data were generated can be found in the manuscript
- Used by `Fig3.m` (and indirectly by `Fig4.m` by running `Fig3.m`)

Scientific Color Maps (c) 2023, Fabio Crameri

Fig6.m makes use of the batlow color map which is part of this suite of color maps created by Fabio Crameri.
They are designed to optimise viewing for as wide a range of people as possible.
The Scientific colour maps are licensed under a MIT License.
More information can be found here: https://www.fabiocrameri.ch/colourmaps/