INSA 5BIM 2022-2023

Modelling biological systems: from individuals to ecosystems

December, the 13th of 2022

Duration: 1h

Effects of different temperatures in mercury toxicity to the terrestrial isopod *Porcellionides pruinosus*.

Figure 1: The terrestrial isopod *Porcellionides pruinosus*

Morgado and colleagues[1] recently studied the effects of different temperatures in mercury (Hg) toxicity to the terrestrial isopod *Porcellionides pruinosus*[2] (Figure 1). In this perspective, they collected experimental data under controlled lab conditions, performing survival and bioaccumulation experiments with isopods collected in a horse manure heap. TK and TKTD modelling was used to understand the biological mechanisms leading to temperature-related differences in Hg toxicity.

It is expected that you fully justify all your answers to the questions hereafter.

Survival

The same experimental design was run at 15, 20 and 25°C. For each survival experiment, this design consisted of six Hg concentrations (3, 6, 12, 24, 42 and 84 mg Hg/kg soil) plus a non-treated control, each with 20 replicates for which mortality was checked daily. Data were analysed using the `morse` R-package.

[1]Morgado, Rui G., Andreia Pereira, Diogo N. Cardoso, Marija Prodana, Catarina Malheiro, Ana Rita R. Silva, André Vinhas, Amadeu M.V.M. V M Soares, and Susana Loureiro. 2022. "The Effects of Different Temperatures in Mercury Toxicity to the Terrestrial Isopod *Porcellionides Pruinosus*." Environmental Pollution 314 (June): 120209. https://doi.org/10.1016/j.envpol.2022.120209.

[2]The isopod *Porcellionides pruinosus* is a sow bug (**cloporte** in French). Sow bugs are the only terrestrial crustaceans, although some species are amphibious. They have an external skeleton made of chitin encrusted with calcium carbonate and calcium phosphate which serves to protect the body. They are small arthropods ranging in size from a few millimetres to just over a centimetre. The body is flattened and ovoid in shape. It consists of a head with a pair of usually well developed antennae, seven thoracic segments, six abdominal segments and a terminal telson. Sow bugs have 7 pairs of legs, all similar and inserted on the thorax segments. Worldwide, this group comprises about 4,000 species

Figure 2 is showing the fitting results.

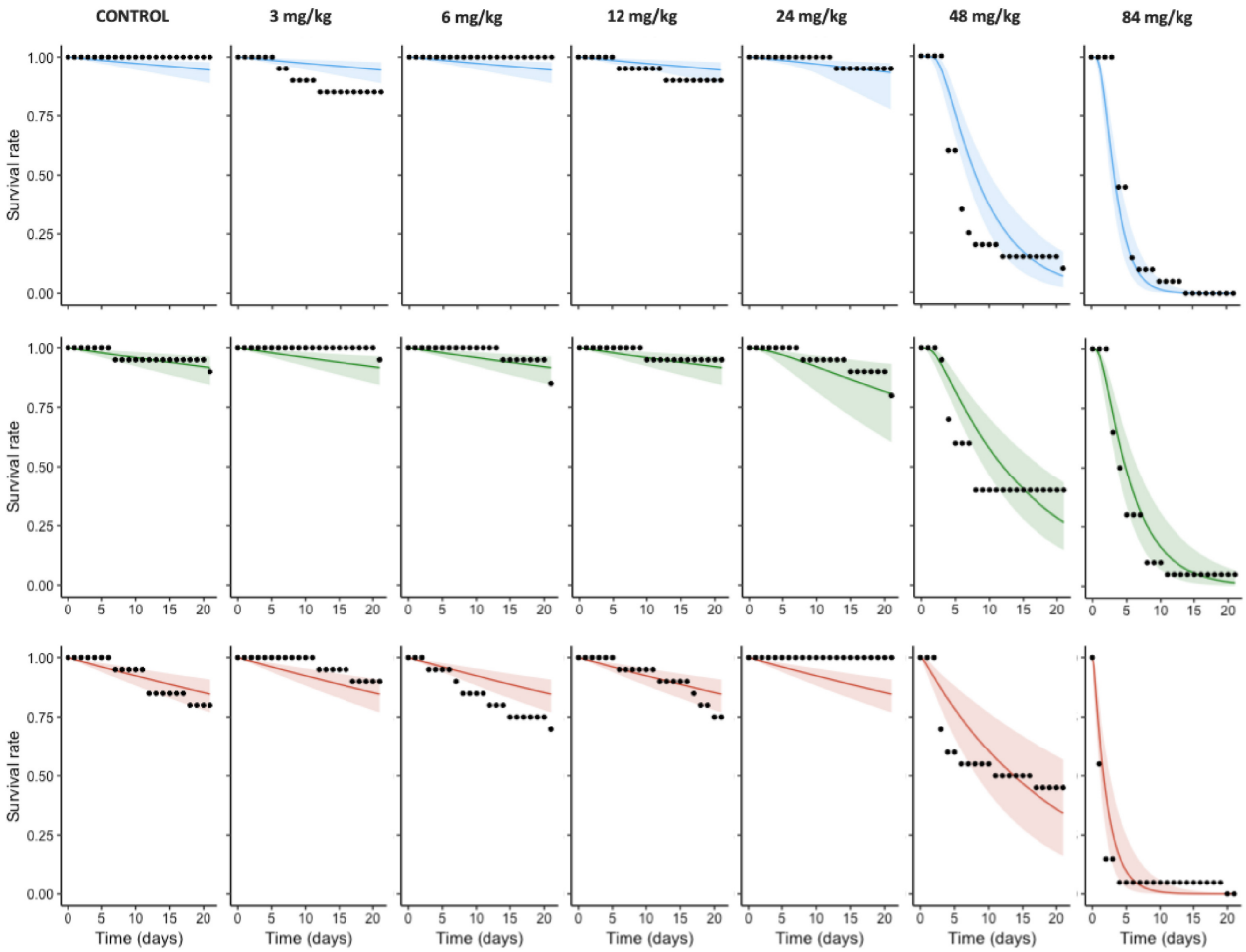

Figure 2: Observed (circles) and predicted survival rates (GUTS-RED-SD model) with 95% credible bands of *Porcellionides pruinosus* throughout the experiment upon exposure to different Hg treatments under three temperature conditions, 15°C (blue), 20°C(green) and 25°C (red).

1. How long is the duration of the survival experiments?
2. Would it be reasonable to fit a dose-response model?
3. If yes, which model would you propose? Which of the parameters in this model is of particular interest?
4. Which TKTD model was used?
5. Mathematically speaking, what does "RED" mean?
6. Biologically speaking, what does "SD" mean?
7. Is there a temperature dependency of the toxicity threshold?
8. Which function of the `morse` R-package allows producing Figure 3?
9. What do black dots represent? What are their x and y coordinates? How many are they at each temperature?
10. What do vertical segments represent?
11. Why are some vertical segments highlighted in green?

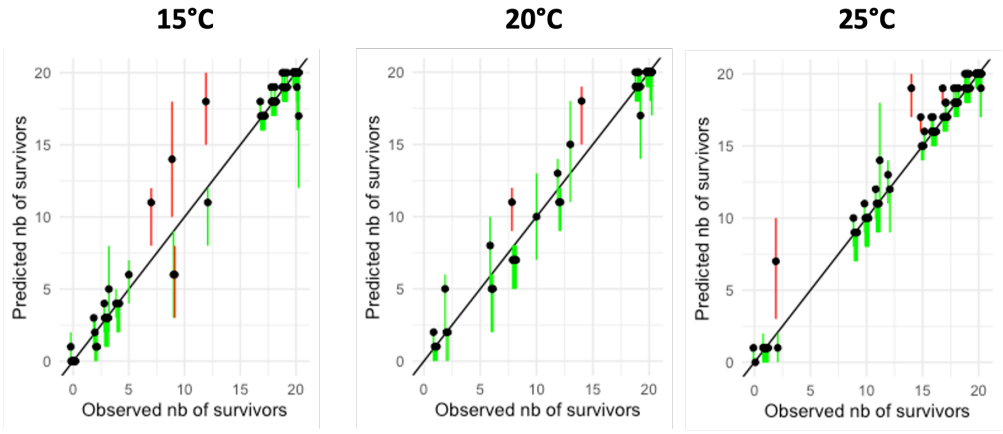

Figure 3: Posterior Predictive Check for the GUTS-RED-SD models for Hg at different temperatures.

12. Given Figure 3, would you say that the TKTD fitting results are good?

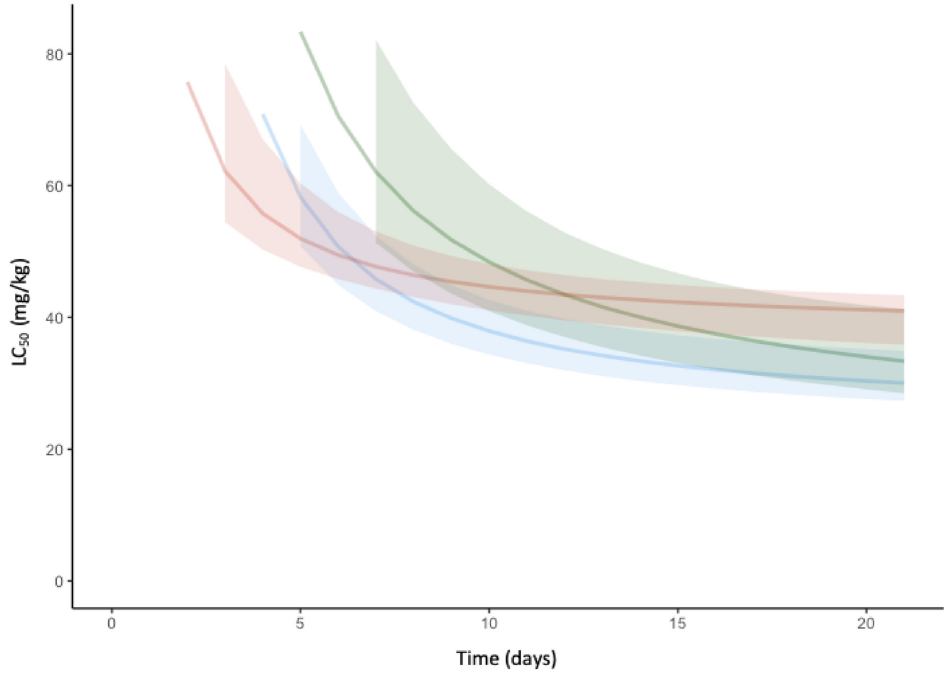

Figure 4: Time-course of the *Porcellionides pruinosus* LC50 (solid lines) and their 95% credible intervals estimated with GUTS-RED-SD models for Hg exposure via soil, at 15°C (blue), 20°C (green), and 25°C (red).

13. Based on Figure 4, what do you think about the effect of temperature on the mercury toxicity of the terrestrial isopod *Porcellionides pruinosus*?

14. Fill in the dotted lines in the legend of Figure 5, namely: what is h_b? what is the unit of z? what is b_s?

	15 °C	20 °C	25 °C
k_d	5.49×10^{-1} (3.67×10^{-1} -9.37×10^{-1})	7.64×10^{-1} (4.12×10^{-1}-$2.02 \times 10^{\circ}$)	$9.84 \times 10^{\circ}$ (7.96×10^{-1}-2.14×10^{2})
h_b	2.75×10^{-3} (1.08×10^{-3}-5.68×10^{-3})	4.17×10^{-3} (1.76×10^{-3}-7.99×10^{-3})	7.96×10^{-3} 4.62×10^{-3}-1.25×10^{-2})
Z	2.5×10^{1} (2.22×10^{1}-3.05×10^{1})	2.17×10^{1} (1.51×10^{1}-3.3×10^{1})	3.77×10^{1} (3.06×10^{1}-4.05×10^{1})
b_s	9.12×10^{-3} (5.8×10^{-3}-1.37×10^{-2})	3.48×10^{-3} (2.03×10^{-3}-5.82×10^{-3})	1.11×10^{-2} (5.32×10^{-3}-1.72×10^{-2})

Figure 5: Parameters estimated by GUTS-RED-SD models (and credible intervals) fitted to isopods' survival experiments with Hg under the three different temperature conditions. Parameter k_d is the dominant rate constant (d^{-1}); parameter h_b is the ..... (d^{-1}); parameter z is the threshold for effects (.....); parameter b_s is the ..... (kg_{soil} mg^{-1} d^{-1}).

Bioaccumulation

The bioaccumulation experiments were conducted with two Hg concentrations (6 and 24 mg/kg) plus a non-treated control, each repeated for 15, 20 and 25°C. These bioaccumulation experiments consisted of two-phase experiments, starting with an uptake phase and then an elimination phase. During the uptake phase, organisms were exposed to treated soil, being afterwards transferred to clean soil for the elimination phase. At predefined sampling times, selected at 0 (i.e., before exposure takes place), 1, 3, 6, 12, 21 days in the uptake phase and 1, 3, 6, 12, 21 days in the elimination phase, three replicates with one organism per each concentration were sampled. According to the same sampling protocol, control organisms were sampled on days 1, 21, and 42. Data are showed on Figure 6 below.

15. What are the durations of both phases in bioaccumulation experiments?
16. Why these two exposure concentrations have been chosen?
17. Given that *Porcellionides pruinosus* is a terrestrial isopod, which bioaccumulation metrics should we calculate (BCF, BSAF, BMF)?
18. Which type of bioaccumulation metrics should we calculate: kinetic or steady-state?
19. Calculate the numerical values of the kinetic bioaccumulation metrics for *Porcellionides pruinosus* exposed to 6 mg/kg Hg and 24 mg/kg Hg at 15°C, 20°C, and 25°C.
20. What can you conclude about the bioaccumulation capacity of Hg within the isopod *Porcellionides pruinosus*?

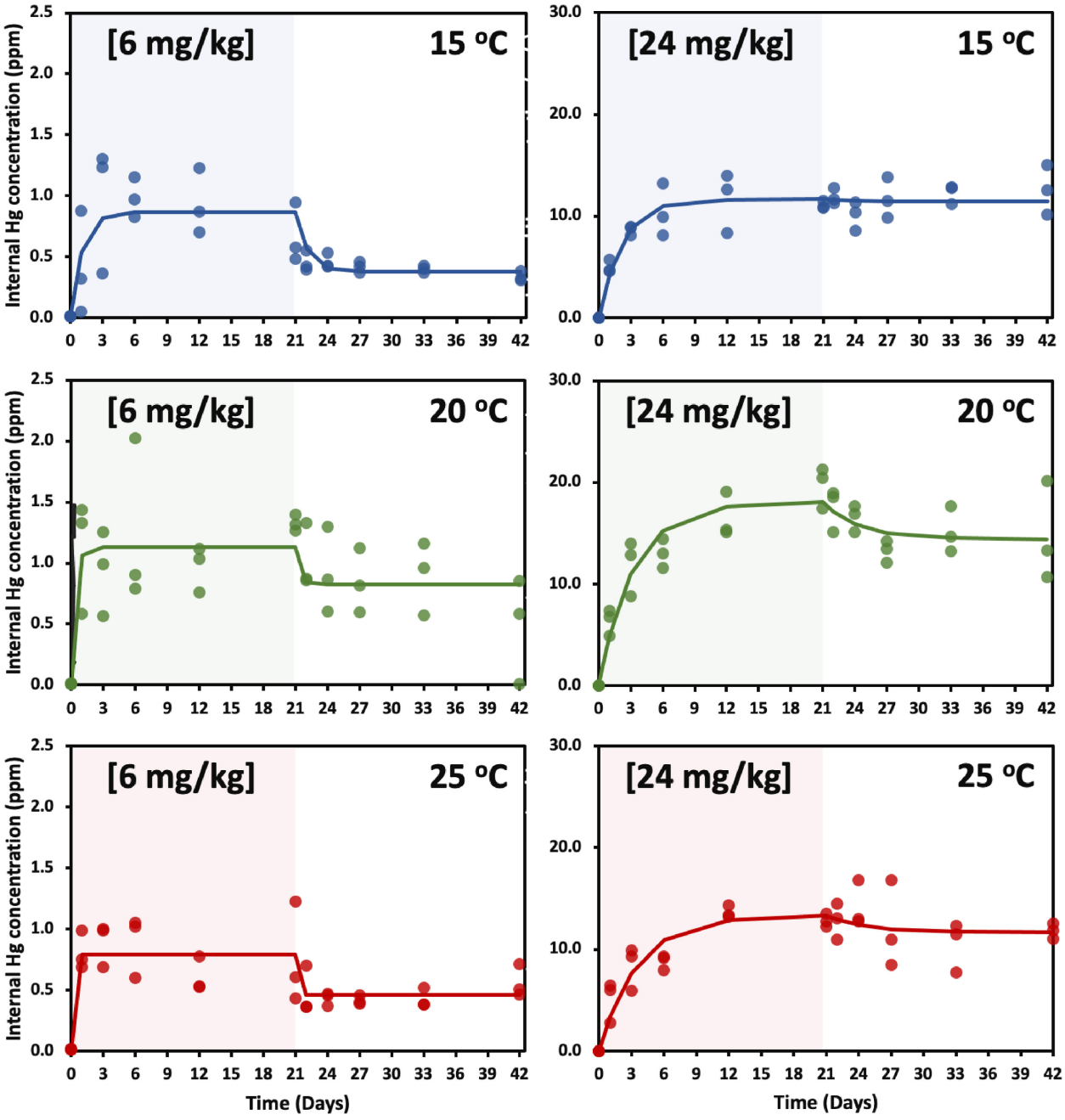

Figure 6: Uptake and elimination kinetics of mercury (Hg) in the terrestrial isopod *Porcellionides pruinosus* exposed to 6 mg Hg/kg soil (left column) and 24 mg Hg/kg soil (right column), at 15°C (blue; upper row), 20°C (green; middle row), and 25°C (red; lower row). Circles represent measured data in isopods.

	15 °C	20 °C	25 °C
6 mg/kg			
k1	0.14 (0.04–0.23)	0.53 (−0.65-1.7)	1.39 (−)
k2	0.95 (0.24–1.66)	2.81 (−3.66-9.29)	10.75 (−)
Fi	0.42	0.73	0.6
24 mg/kg			
k1	0.23 (0.15–0.31)	0.23 (0.16–0.3)	0.16 (0.1–0.21)
k2	0.47 (0.28–0.66)	0.31 (0.2–0.41)	0.28 (0.16–0.4)
Fi	0.98	0.8	0.87

(−) It was not possible to calculate the 95% confidence intervals.

Figure 7: Toxicokinetic parameters estimated for *Porcellionides pruinosus* exposed to 6 mg/kg Hg and 24 mg/kg Hg at 15°C, 20°C, and 25°C. Parameter k_1 is the uptake rate constant (mg kg_{soil} d^{-1}); k_2 is the elimination rate constant (d^{-1}).