EARTH & LIFE INSTITUTE

Modelling the mortality of *Hylotrupes bajulus* (L.) larvae exposed to anoxic treatment for disinfestation of wooden art objects

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Motivation

Efficient use of anoxic treatment requires a protocol that:

- Indicates the treatment duration for insect eradication
- Takes into account all the variables influencing mortality

State of the art

Large number of studies on the topic

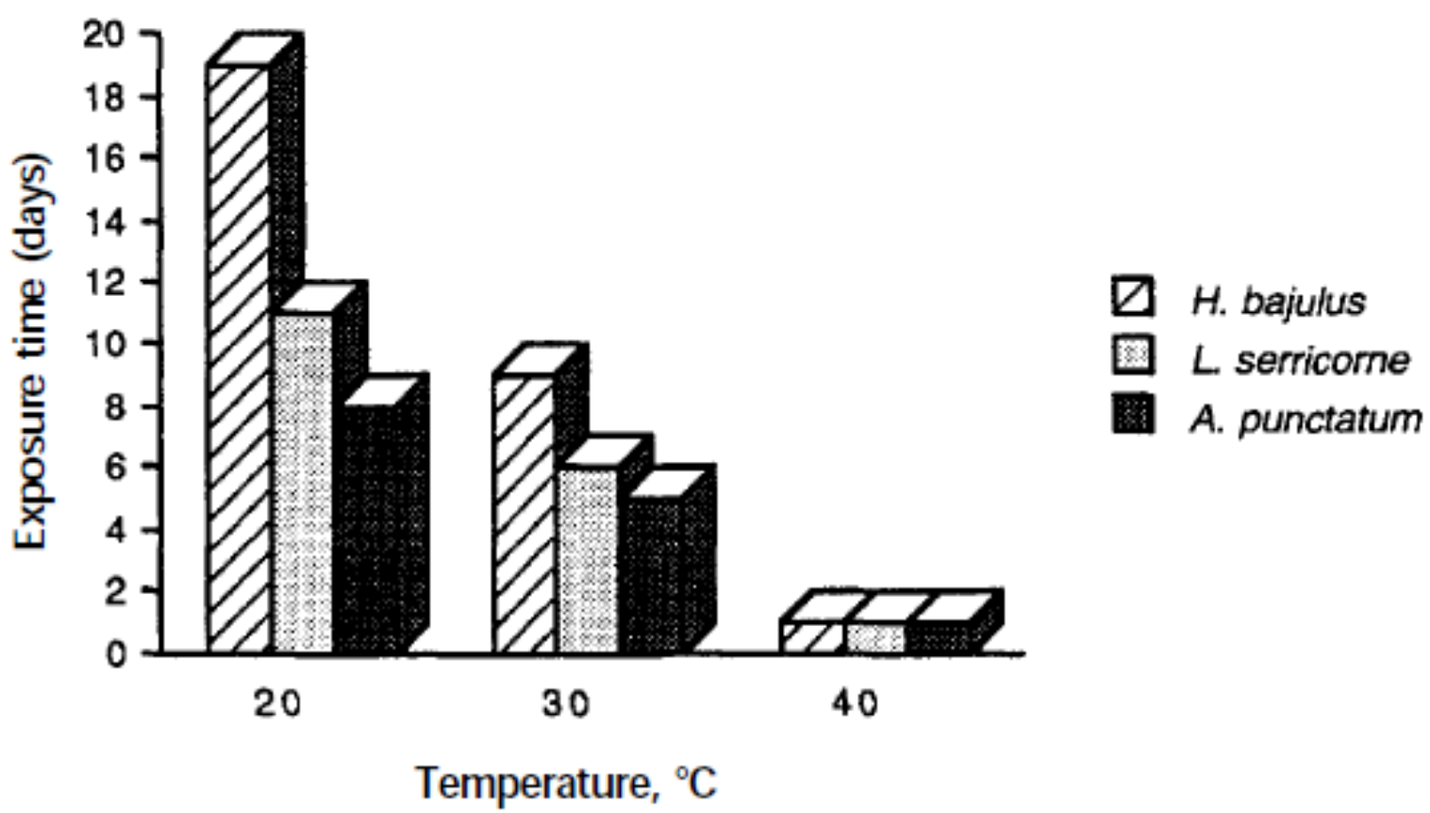
State of the art

Large number of studies on the topic

Observation N°1: Large number of treatment conditions involved

- Treatment efficiency dependent on :

  - Temperature[1]



[1] Valentin N (1998) Preservation of historic materials by using inert gases for biodeterioration control. In Maekawa S (ed) Oxygen-free museum cases. The Getty Conservation Institute, Los Angeles

State of the art

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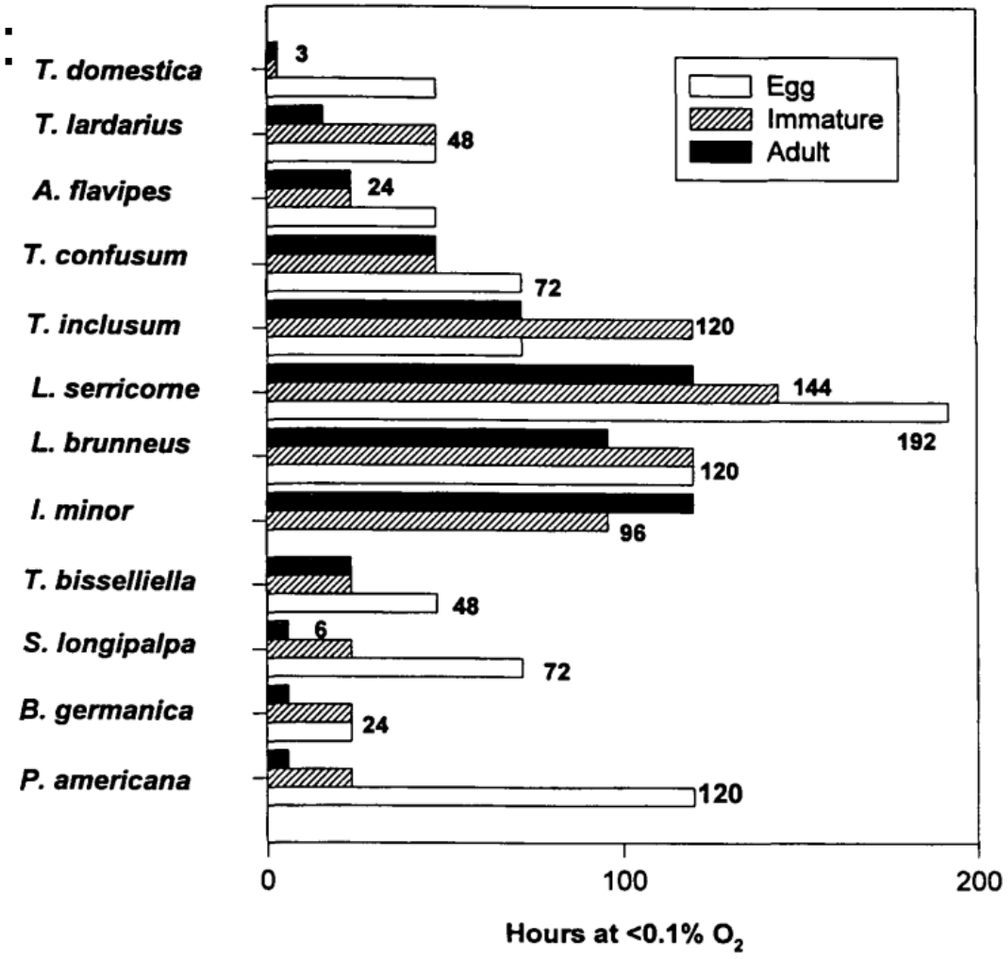
Observation N°1: Large number of treatment conditions involved

- Treatment efficiency dependent on :
  - Temperature
  - Insect[2] : species;
    development stage;
    body mass;
    etc.



[2] Reierson DA, Rust MK, Kennedy JM, Daniel V, Maekawa S (1996) Enhancing the effectiveness of modified atmospheres to control insect pests in museums and similar sensitive areas. In: Proceedings of the 2nd international conference on urban pests, pp 319-327

State of the art

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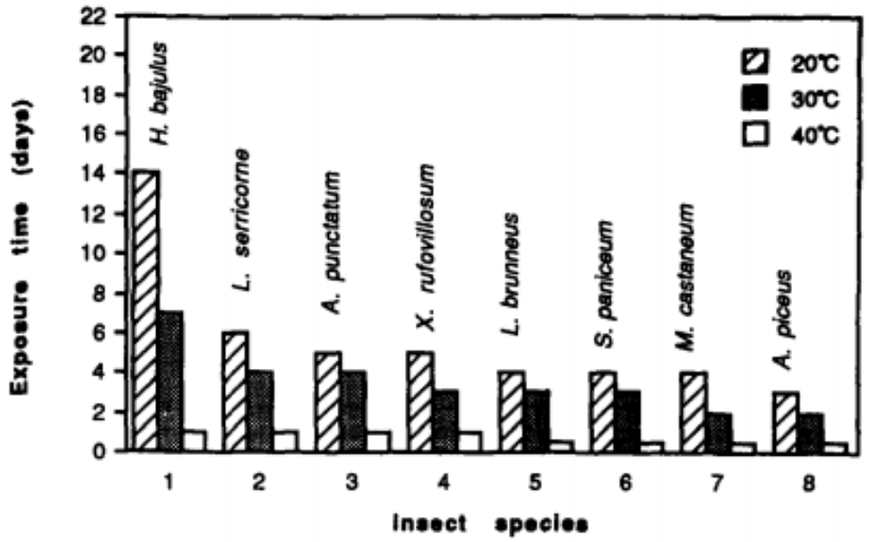
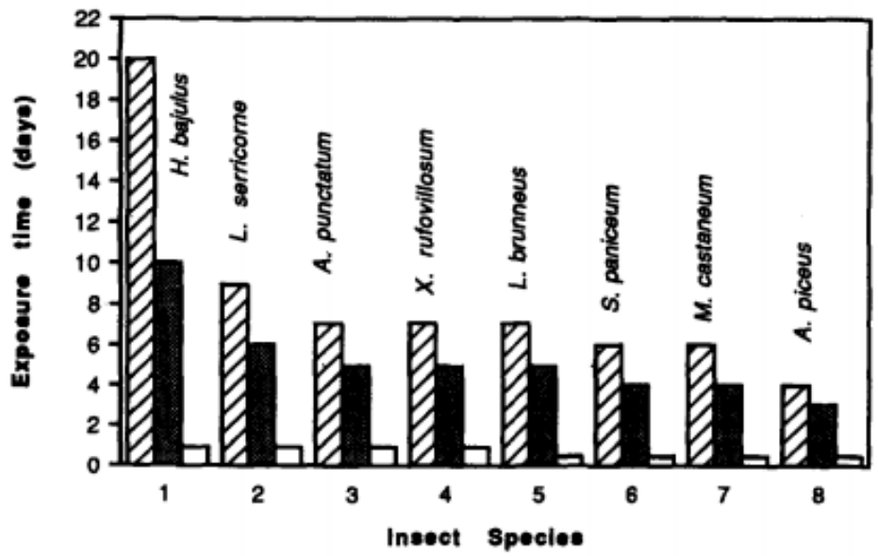
Observation N°1: Large number of treatment conditions involved

- Treatment efficiency dependent on :
  - Temperature
  - Insect
  - Nature of the Gas[3]



(a) **Argon**



(b) **Nitrogen**

[3] Valentin N (1993) Comparative analysis of insect control by nitrogen, argon and carbon dioxide in museum, archive and herbarium collections. Int Biodeterior Biodegradation 32:263-278

State of the art

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Observation N°1: Large number of treatment conditions involved

- Treatment efficiency dependent on :

- Temperature
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- Nature of the Gas

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State of the art

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Observation N°1:

- Large number of treatment conditions involved

Observation N°2:

- Studies using one specific insect population

State of the art

Large number of studies on the topic

Observation N°1:

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Observation N°2:

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Physical and statistical difficulties to treatment applicability

Objective

Building a model

Objective

Building a model

- Taking into account:

Objective

Building a model

- Taking into account:
    - Variables with high influence on mortality

Objective

Building a model

- Taking into account:
    - Variables with high influence on mortality
    - Biological heterogeneity

Objective

Building a model

- Taking into account:
    - Variables with high influence on mortality
    - Biological heterogeneity
- Allowing to determine treatment duration required to achieve insect eradication

Outline

- Motivation
- State of the art
- Objectives
- Model design

  - Variables
  - Output
  - Construction

- Results

- Conclusion

Model design - Variables

- Temperature:

  20°C, 30°C and 40°C

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  0.5 to 25 days

Model design - Variables

- Temperature:

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- Treatment duration:

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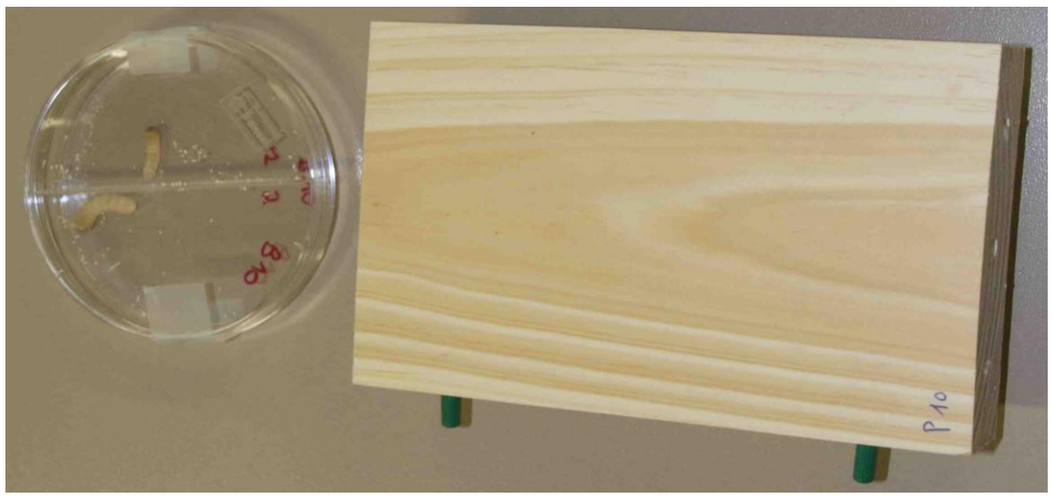
- Environment:

  Petri dish or wood board



Model design - Variables

- Temperature:

  20°C, 30°C and 40°C

- Treatment duration:

  0.5 to 25 days

- Environment:

  Petri dish or wood board

- Insect:

  Larvae of *Hylotrupes bajulus* (L.)
  (old house borer)

Model design - Variables

- Temperature:
  20°C, 30°C and 40°C
- Treatment duration:
  0.5 to 25 days
- Environment:
  Petri dish or wood board
- Insect:
  Larvae of *Hylotrupes bajulus* (L.)
- Initial mass of the insect: 32 to 638 mg
  (μ= 176.14 ± 116.73)

Model design – Output/model

- Model:

$$\ln \frac{p(1|X)}{1-p(1|X)} = a_0 + a_1 D + a_2 x_1 + \ldots + a_j x_j$$

$p(1|X)$: mortality probability
D: treatment duration

[4] FAO (2011) ISPM 15:2009 draft revision of annex 1: approved treatments associated with wood packaging material. Food and Agriculture organization of the United Nations, Secretariat of the International Plant Protection Convention, Rome

Model design – Output/model

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- Mortlity probability target: 99.9968% ⇒ Probit 9 level = International Standard for Phytosanitary Measures[4]

[4] FAO (2011) ISPM 15:2009 draft revision of annex 1: approved treatments associated with wood packaging material. Food and Agriculture organization of the United Nations, Secretariat of the International Plant Protection Convention, Rome

Model design – Construction

- Independant analysis of each variable

Significant effect	Non-significant effect
Temperature **(T)**	Environment **(E)**
Treatment duration **(D)**	
Insect inital mass **(M)**	

Model design – Construction

- Independant analysis of each variable

Significant effect	Non-significant effect
Temperature **(T)**	Environment **(E)**
Treatment duration **(D)**	
Insect inital mass **(M)**	

- Models comparison

	Full model	Simplified model 1	Simplified model 2
M	x	x	x
D	x	x	x
T	x	x	x
E	x	x	
M*D	x		
M*T	x		
D*T	x	x	x
M*E	x		
D*E	x	x	
T*E	x	x	
M*D*T	x		
M*D*E	x		
M*T*E	x		
D*T*E	x	x	
M*D*T*E	x		

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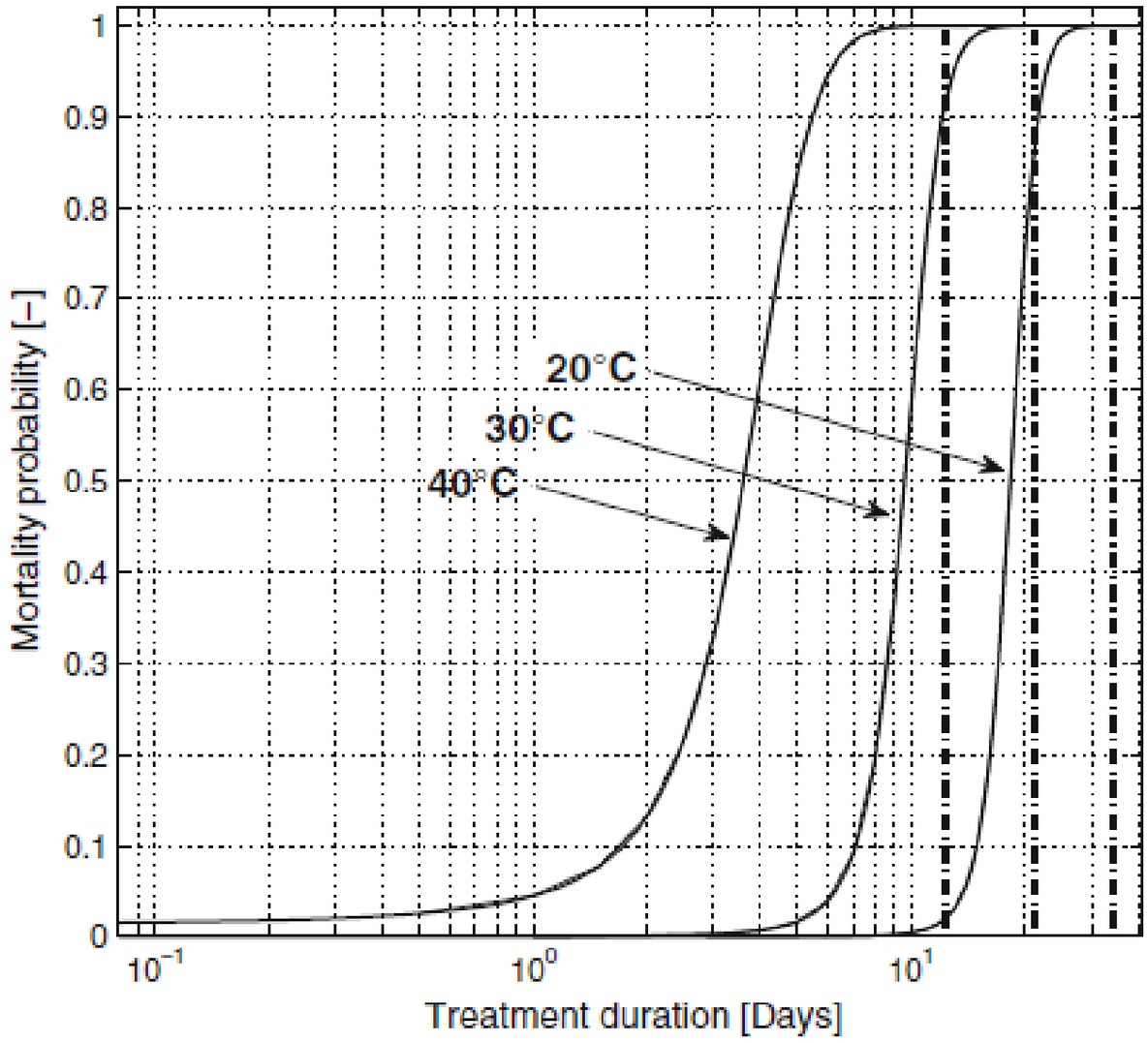
Results

Selected model (simplified model 2):



Initial mass — Treatment duration — Temperature

$$\ln\left(\frac{\pi}{1-\pi}\right) = \exp(-24.703 - 0.005 \times M + 0.935 \times D + 0.676 \times T + 0.029 \times (D - 8.553) \times (T - 31.722))$$

Results

Comparison with other studies:

Studies	Temperature [°C]	Treatment duration [days]
Valentin, 1998[5]	20 30 40	19 9 1
Gunn, 2008[6]	25	14
Gialdi & Ratto, 2002[7]	25 20	21 28/35
de Streel et al., 2016[8]	21 30 40	36 21 12

[5] Valentin N (1998) Preservation of historic materials by using inert gases for biodeterioration control. In: Maekawa s (ed) Oxygen-free Museum cases. The Getty Conservation Institute, Los Angeles

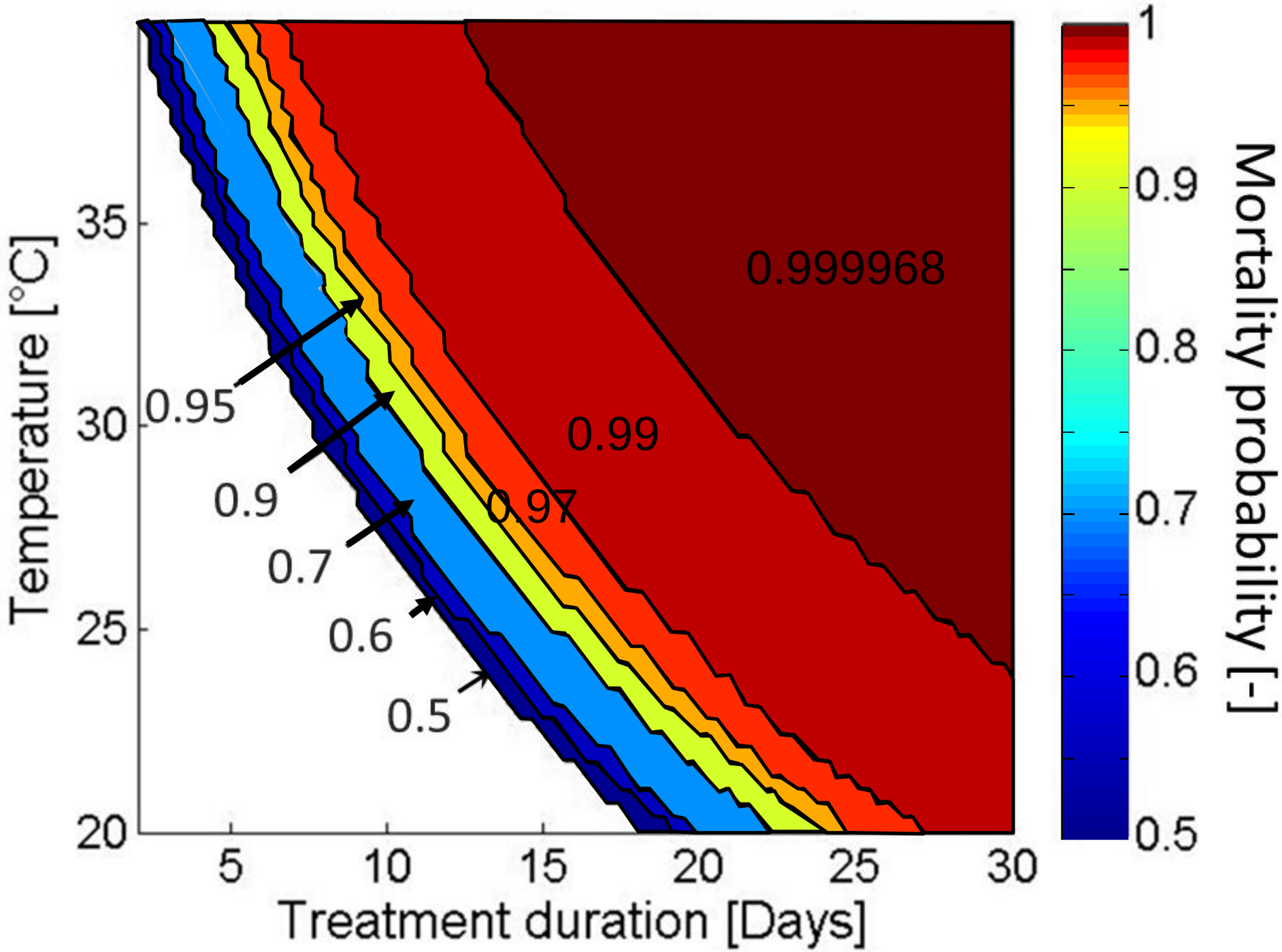
[6] Gunn M (1989) Inert atmosphere fumigation of museum objects. Stud Conserv 32(2):80-84

[7] Gialdi E, Ratto L (2002) The SAVE ART project and its outcome: VELOXY. Cultural Heritage Research: a pan-European Challenge, 207-209

[8] De Streel, G., Henin, J.-M., Bogaert, P., Mercier, E., Rabelo, E., Vincke, C., Jourez, B. Modelling the mortality of *Hylotrupes bajulus* (L.) larvae exposed to anoxic treatment for disinfestation of wooden art objects, *Wood Science and Technology,* 2016, 50(5), 1015-1035

Results

Mortality map



Results

- Mortality assessment after treatment:

	Alive	**Dead**
Mandibles activity	++	-
Body color	White	Brown
« Turgescence »	Turgid	Withered
Movements when stimulated	++	-

Results

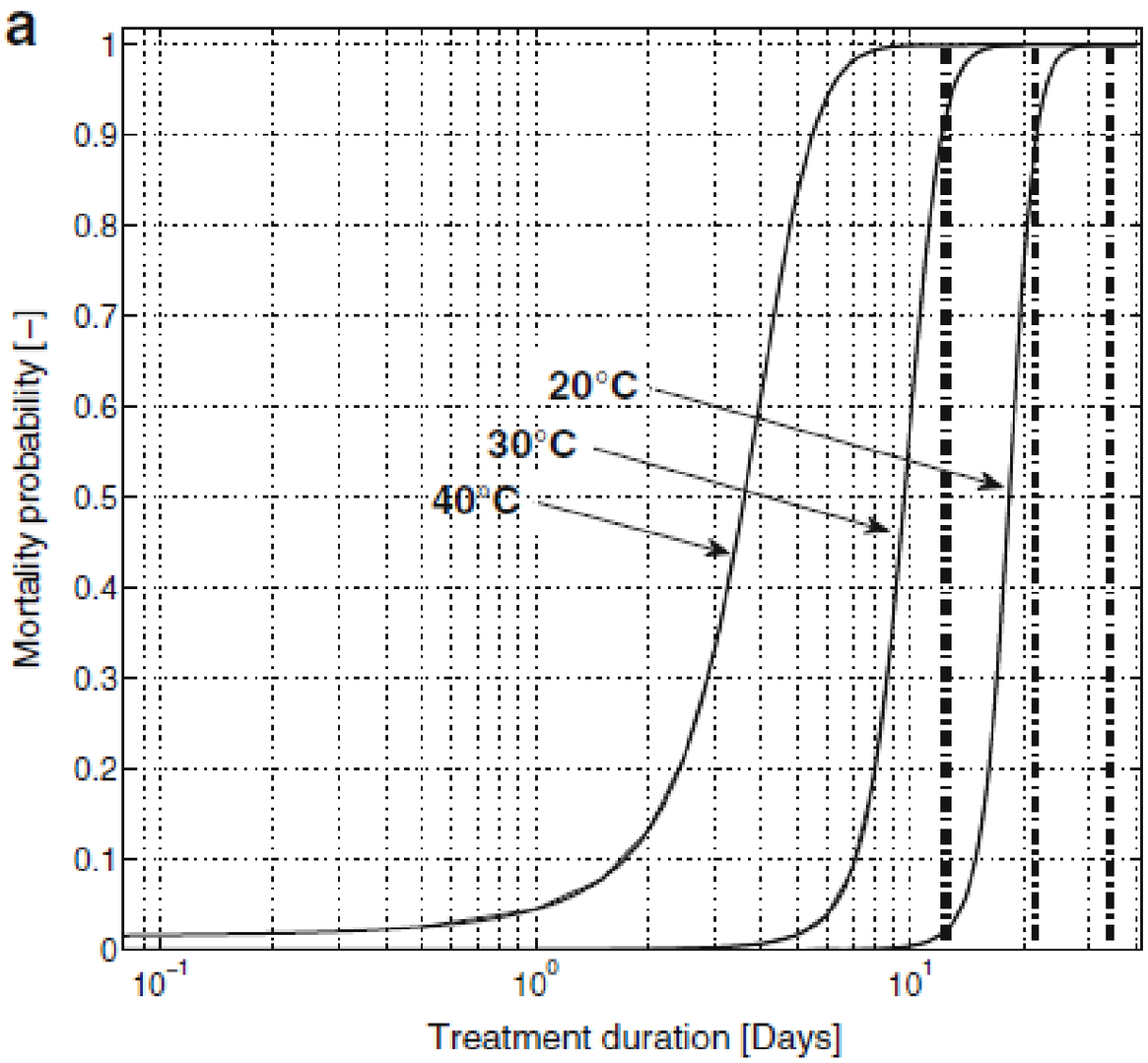
Clear-cut cases

Intermediate situation

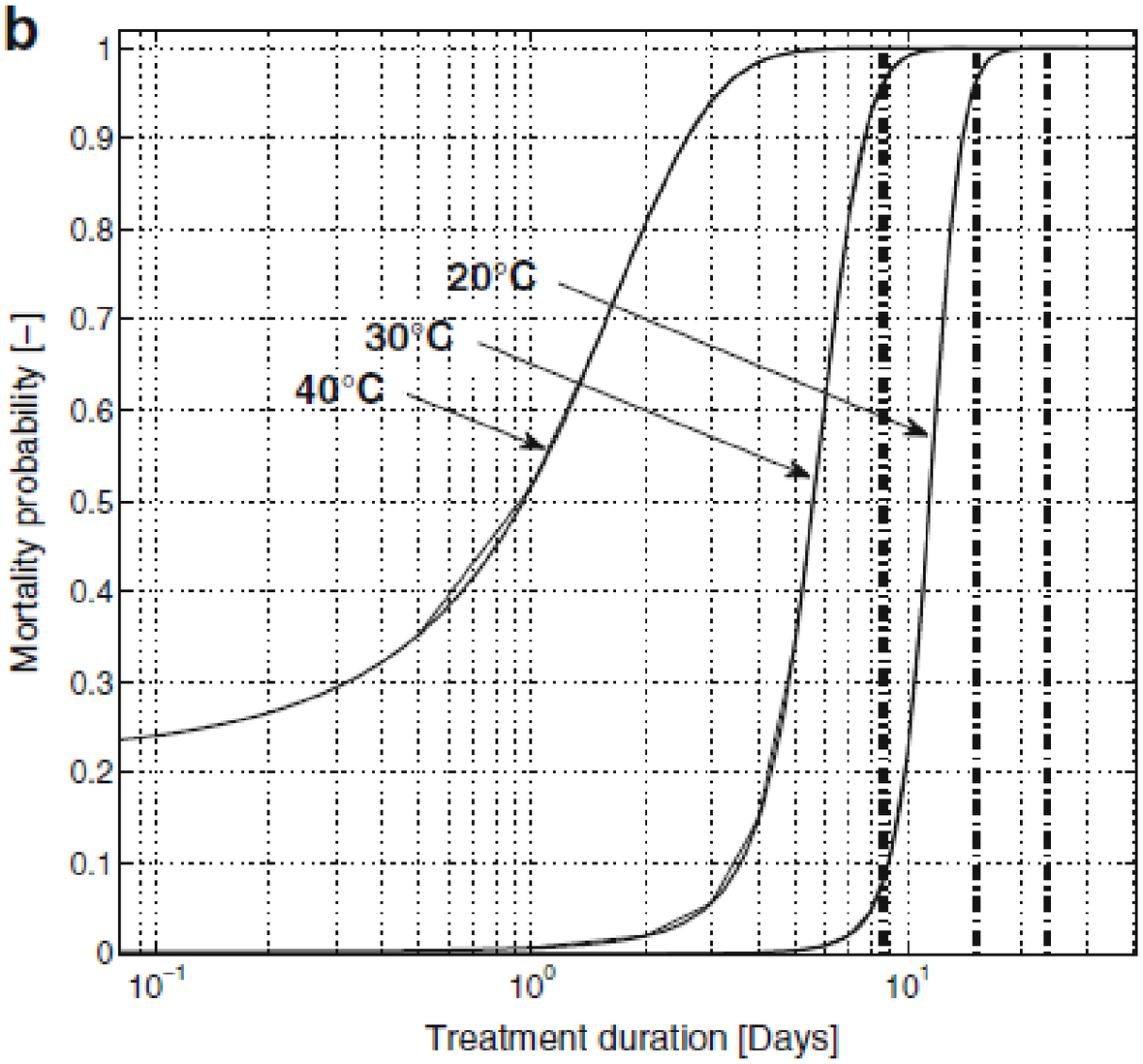
?

back into wood boards

Results



Before transplanting



After transplanting

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Conclusion

- Effect of initial body mass on mortality
- No visible effect of environment on sensitivity to treatment
- Interest of modelling to define the modalities for anoxic treatment
- Existence of a « mortally affected » state
- Perspectives

  - Specific analysis of the « mortally affected » state
  - Check of the predictive power of the model
  - Testing the relevance of other variables

Thank you!

Any questions?