

Complexity reduces the feeding strength of freshwater predators (CRITTER)

Supplemental Statistics Report

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Contents

Overview	3
Summary	3
License	3
How to cite this report	3
Related Works	3
Methods	3
Required Packages	3
Theoretical Background	4
Functional response statistics	5
Independence of variables	5
Data distribution	6
Functional response type selection	6
Habitat complexity as an independent variable	6
Data Availability	7
Code availability	7
Results	7
The functional response type	7
Using the phenomenological test	7
Direct shape estimation using the generalized functional response model	8
Habitat presence, amount, and complexity results	8
<i>Ischnura elegans</i> results	9
<i>Notonecta glauca</i> results	12
Funding Information	16
References	17
Appendix	19
Phenomenological Test Rationale	19
Full AIC / BIC tables	20
<i>Ischnura elegans</i>	20
<i>Notonecta glauca</i>	21
All summary including original <code>bbmle::summary</code> outputs	22
<i>Ischnura elegans</i>	22
<i>Notonecta glauca</i>	26
Project Settings	30

Overview

Summary

This repository hosts the statistics report that is supplementing our [scientific preprint article](#) by Aranbarri et al. (2025) investigating the effect of habitat complexity on the feeding functional response of two freshwater invertebrate predators. Find below information on related works and the location of the data and code.

License

This report is published under the [Creative Commons BY 4.0](#) license. The underlying code is licensed under the [GNU General Public License 3](#).

How to cite this report

If you want to refer to our report, please cite:

Rall, B.C., Aranbarri, M., Flores, L., Guzmán, I. de, Larrañaga, A., & Reiss, J.(2025): Habitat complexity reduces the feeding strength of freshwater predators (CRITTER) - Supplemental Statistics Report. Zenodo. <https://doi.org/10.5281/zenodo.1489459>.

Related Works

- [Data on Zenodo](#) (Flores et al., 2025)
- [Data on GitHub](#)
- [R-Code on Zenodo](#) (Rall et al., 2025b)
- [R-Code on GitHub](#)
- [Statistical Report on Zenodo](#) (Rall et al., 2025a)
- [Statistical Report on GitHub](#)
- [Scientific Preprint Article](#) (Aranbarri et al., 2025)

Methods

Required Packages

If you want to knit this report for yourself, you need to install:

- `bbmle` (Bolker et al., 2023)
- `bookdown` (Xie, 2025)
- `doParallel` (Microsoft & Weston, 2022a)
- `dplyr` (Wickham et al., 2023)
- `emdbook` (Bolker, 2023)
- `foreach` (Microsoft & Weston, 2022b)
- `frair` (Pritchard, Barrios-O'Neill, et al., 2017)
- `here` (Müller & Bryan, 2020)
- `kableExtra` (Zhu, 2024)
- `knitr` (Xie, 2024)
- `lhs` (Carnell, 2024)
- `MASS` (Ripley et al., 2025)

- `odin` (FitzJohn, 2024)
- `png` (Urbanek, 2022)
- `purrr` (Wickham & Henry, 2025)
- `RCurl` (CRAN Team & Temple Lang, 2024)
- `sessioninfo` (Csárdi et al., 2025)
- `supportR` (Lyon, 2024)
- `tinytex` (Xie & Posit Software, PBC, 2025)

We used TinyTex (Xie & Posit Software, PBC, 2025) to create the pdf report. Please follow their installation guidelines using on [their homepage](#). You can, of course, use another LaTeX distribution, but we only tested if the RMarkdown script works using TinyTex.

Please let us know if we forgot required packages.

Theoretical Background

The feeding functional response describes how a consumer's feeding rate reacts to its resource density (Holling, 1959a). The most basic shape of the feeding functional response is a hyperbolic curve, also called the type II functional response (Jeschke et al., 2002). The attack rate, a , controls the initial increase in the feeding rate, F , with increasing resource density, N (Holling, 1959a), and the handling time, T_h controls the satiation of the curve:

$$F = \frac{aN}{(1 + aT_h N)}. \quad (1)$$

If the attack rate is a function of resource density, the functional response becomes s-shaped (Holling, 1959b; Kalinkat et al., 2023). In the simplest form of this **type III functional response**, the attack rate is a linear function of resource density (Juliano, 2001):

$$a = bN, \quad (2)$$

in which b is the attack coefficient. The functional response becomes

$$F = \frac{bN^2}{(1 + bT_h N^2)}. \quad (3)$$

(Real, 1977, 1979) presented an alternative formulation of the functional response inspired by chemical reactions and the Michaelis-Menten kinetics (Barcroft & Hill, 1910). By substituting

$$T_h = \frac{1}{F_{max}} \quad (4)$$

and

$$a = \frac{F_{max}}{N_{half}}, \quad (5)$$

the **type II functional response** becomes

$$F = \frac{F_{max}N}{N_{half} + N}. \quad (6)$$

Here, the curve's satiation is controlled by the maximum feeding rate, F_{max} , and the half saturation density, N_{half} controls the steepness of the functional response curve. The **type III functional response** written in this style is as follows:

$$F = \frac{F_{max}^2 N}{N_{half}^2 + N^2}. \quad (7)$$

The above-described **type III functional response** model has a linearly increasing attack rate, but the attack rate can also be a more complex function of resource density (Juliano, 2001; Kalinkat et al., 2023). A commonly used version is a power law function of the resource density (Kalinkat et al., 2023; Rall et al., 2008; Williams & Martinez, 2004):

$$a = b^q. \quad (8)$$

The Holling-style functional response becomes (Vucic-Pestic et al., 2010):

$$F = \frac{bN^{1+q}}{(1 + bT_h N^{1+q})}, \quad (9)$$

and the Real-style functional response becomes (Rall et al., 2008; Williams & Martinez, 2004):

$$F = \frac{F_{max}^{1+q} N}{N_{half}^{1+q} + N^{1+q}}. \quad (10)$$

We will refer to the above-mentioned functional response models as either the Holling-style or the Real-style **generalized functional response** model. Note that many other functional response models exist, but the ones presented above are most practical and most often used to analyze laboratory functional response experiments (Jeschke et al., 2002; Juliano, 2001; Kalinkat et al., 2023). In our analyses, we will focus on the **generalized functional response** models and, if statistically appropriate, on the **type II or type III functional response** models.

Functional response statistics

Independence of variables

Scientific laboratory experiments are designed to manipulate one or more external variables that are typically called the **independent** or **explanatory variables**. We measure a response of our experimental system, and this measure is normally called the **dependent**, or **response variable**. See, e.g., Zar (2010), chapter 17, or Crawley (2012) chapter 10, for details. In functional response experiments, we manipulate the resource density, N , and measure the number of prey eaten, N_{eaten} , at the end of the experiment. This means that during the experiment, the prey density decreases over time. In contrast, in all the above-mentioned functional response models, the feeding rate, F , depends on a constant prey density, N . To account for the decay of resource density over time, we set up a differential equation, describing the temporal process:

$$\frac{dN}{dt} = -F. \quad (11)$$

The **change of resource density**, dN , over a given **time span**, dt , is described by the negative of the feeding rate F . F can be any of the functional response models introduced above (or described elsewhere). This differential equation model can not be fitted directly to data, but it needs to be solved beforehand. The solution depends on the type of functional response. For a **type II functional response**, the solution is (Rogers, 1972; Rosenbaum & Rall, 2018; Royama, 1971):

$$N_{eaten} = N_{initial}(1 - e^{a(N_{initial}T_h - Pt)}). \quad (12)$$

The number of resources eaten, N_{eaten} at the time t (e.g., the end of the experiment) depends on the initial number of resources, $N_{initial}$. All other parameters are as described above. This equation is commonly known as **Roger's Random Predator Equation** (RRPE). By substituting $T_h = \frac{1}{F_{max}}$ and $a = \frac{F_{max}}{N_{half}}$ into Roger's Random Predator Equation, we get the version for the Real-style functional response model:

$$N_{eaten} = N_{initial}(1 - e^{\frac{N_{initial}}{N_{half}} - \frac{Pt}{F_{max}}}). \quad (13)$$

Model parameters are as described above.

These equations share the issue that N_{eaten} appears on both sides of the equation. Traditionally, this problem is solved using Newton's method, an iterative numerical procedure (Juliano, 2001; Vonesh & Bolker, 2005), but Bolker (2008) found that the Lambert **W** function (Corless et al., 1996) allows for an analytical solution:

$$N_{eaten} = N_{initial} - \frac{W(aT_h N_{initial} e^{-a(Pt - T_h N_{initial})})}{aT_h}. \quad (14)$$

The Real-style version is:

$$N_{eaten} = N_{initial} - \frac{W\left(\frac{1}{N_{half}} N_{initial} e^{-\frac{F_{max}}{N_{half}}(Pt - \frac{N_{initial}}{F_{max}})}\right)}{\frac{1}{N_{half}}}. \quad (15)$$

All parameters are as described above.

Neither the type III nor the generalized functional response can be solved analytically and must be solved using numerical simulations (Rosenbaum & Rall, 2018). We follow the methods published by Rosenbaum & Rall (2018), but find more details in the section “Brief Code Description” below.

Data distribution

So far, we described the mathematical model describing the average number of resources eaten throughout the experimental trials. Each experimentally derived replicate, however, must deviate from this overall model mean (see, e.g., Zar (2010), chapter 17, or Crawley (2012) chapter 10, for assumptions of regression statistics). Our dependent data, N_{eaten} , has the following characteristics: integer numbers (0, 1, 2, ..., n), and the number of prey eaten cannot exceed the number of initially available resource items ($N_{initial}$). Data following these characteristics are known as proportion data and well described by a binomial probability distribution; see Crawley (2012) chapter 16 for further explanations. We also apply this distribution to our data, as it is commonly used for functional response fitting (Bolker, 2008; Rosenbaum & Rall, 2018). Please also read the description of our code in the corresponding README file, either directly in our [repository](#) or download it from Zenodo (Rall et al., 2025b).

Functional response type selection

As the initial step, we analyzed which functional response type describes our data best (Juliano, 2001). We used two methods: (1) the phenomenological test after Juliano, implemented in the **frair** package (Juliano, 2001; Pritchard, Paterson, et al., 2017)[^1]; and (2) by fitting the Real-style **generalized functional response model** and test if q is significantly different from zero (Rall et al., 2008; Rosenbaum & Rall, 2018; Vucic-Pestic et al., 2010; Williams & Martinez, 2004). If the tests suggest, that at least one functional response treatment is not of type II, we will analyze our data further using the **generalized functional response** model. If the tests suggest that **all** treatments are type II, we will analyze our data further using the **Roger's Random Predator Equation** models.

Habitat complexity as an independent variable

The main scientific question of this project is to figure out how habitat complexity affects the interaction strength of two freshwater invertebrate predators (the consumers) on their prey (the resources). We have three different ways to address this question given the data: (1) the absence and presence of habitat; (2) the amount of habitat (either 0, 2, or 3 plastic ring structures); (3) five levels of complexity (0 to 5). The complexity levels originate from different spatial arrangements of the artificial ring structures, where 0 rings are complexity level 0, 2 rings comprise complexity levels 2 and 3, and 3 rings comprise complexity levels 4 and 5. See Flores et al. (2016) and Aranbarri et al. (2025) for further details. Contrasting the above-described analysis of the functional response type, we use here all data at once, separated by predator species. Each functional response parameter can react to habitat independently of the other parameters. For example, the attack rate can be different for all five complexity levels, whereas the handling time is a function of ring number. For each parameter, we can formulate the following hypotheses:

- H_0 : Habitat has no effect on the functional response parameters.

- H₁: The sheer presence of habitat changes the functional response parameters.
- H₂: The amount of habitat structure (number of rings, continuous) alters the functional response parameters.
- H₃: The spatial arrangements modify the functional response parameters in addition to the amount of habitat structure.

Any functional response parameter independently can fulfill one of the above-stated hypotheses. If we want to test all possible combinations, we need 4×4 models (4 hypotheses per parameter) for each functional response style (Real-style and Holling style), in the case of a **type II functional response**, resulting in 32 statistical models per predator species. In the case of **generalized functional response**, we would have to test 64 statistical models for each functional response style, resulting in 128 models per species. Note that some of these models of how habitat affects the functional response are interchangeable, but not all. We will show for which models this is true in the results part below ([Habitat presence, amount, and complexity statistics]).

Data Availability

You can either download the data from our data publication on [Zenodo](#) (Flores et al., 2025), or from our [GitHub repository](#).

Code availability

You can either download the code from our code publication on [Zenodo](#) (Rall et al., 2025b), or from our [GitHub repository](#).

Results

The functional response type

Using the phenomenological test

Table 1: The results of testing for the functional response type by using the phenomenological test (Juliano 2001, Pritchard et al. 2017). We found for all unique treatments (complexity times predator identity) that a type II functional response explains the data best.

Predator	Complexity	Linear (Q)	Quadratic (Q)	Linear (L)	Type
<i>Ischnura elegans</i>	0	-(n.s.)	+(n.s.)	-(*)	II
<i>Ischnura elegans</i>	1	-(n.s.)	+(n.s.)	-(*)	II
<i>Ischnura elegans</i>	2	-(n.s.)	+(n.s.)	-(***)	II
<i>Ischnura elegans</i>	3	-(n.s.)	+(n.s.)	-(**)	II
<i>Ischnura elegans</i>	4	+(n.s.)	-(n.s.)	-(**)	II
<i>Notonecta glauca</i>	0	-(***)	+(***)	-(***)	II
<i>Notonecta glauca</i>	1	-(***)	+(***)	-(***)	II
<i>Notonecta glauca</i>	2	-(***)	+(**)	-(***)	II
<i>Notonecta glauca</i>	3	-(n.s.)	-(n.s.)	-(***)	II
<i>Notonecta glauca</i>	4	-(*)	-(n.s.)	-(***)	II

We analyzed our data using the so-called the phenomenological test by fitting this test to all ten treatments separately, i.e., two predators with five complexity levels each (Juliano, 2001; Pritchard, Paterson, et al., 2017; Pritchard, Barrios-O'Neill, et al., 2017; Rall et al., 2025b). The only case in which the results suggest a hump-shaped pattern in the proportion data is *Ischnura elegans* at the complexity level of 4, as the linear term is positive, and the quadratic term is negative (table 1). However, both estimates are not significant. The complexity levels 3 and 4 for *Notonecta glauca* show a negative quadratic term, which could also indicate a type III functional response, but both results are not significant. All other treatments have both a negative linear

and a positive quadratic term, indicating in all these cases a declining proportion of eaten prey and therewith type II functional responses (table 1).

Direct shape estimation using the generalized functional response model

Table 2: The significance of the shape parameter q of all ten separately fitted generalized functional response models.

Predator Name	Complexity	q	Significance	Type-o-Response
<i>Ischnura elegans</i>	0	0.116	n.s.	II
<i>Ischnura elegans</i>	1	0.047	n.s.	II
<i>Ischnura elegans</i>	2	-0.001	n.s.	II
<i>Ischnura elegans</i>	3	-0.001	n.s.	II
<i>Ischnura elegans</i>	4	0.193	n.s.	II
<i>Notonecta glauca</i>	0	-0.011	n.s.	II
<i>Notonecta glauca</i>	1	-0.006	n.s.	II
<i>Notonecta glauca</i>	2	0.194	n.s.	II
<i>Notonecta glauca</i>	3	-0.002	n.s.	II
<i>Notonecta glauca</i>	4	-0.001	n.s.	II

We analyzed our data using the generalized functional response model by fitting this model to all ten treatments separately, i.e., two predators with five complexity levels each (Rall et al., 2008; Rosenbaum & Rall, 2018; Vucic-Pestic et al., 2010; Williams & Martinez, 2004). The shape parameter q is not significantly different from zero (see table 2). This means that in all cases, a simpler type II functional response can be used to describe the data properly. This is in line with the phenomenological test shown above, and we will subsequently use the Roger's Random Predator Equation.

Habitat presence, amount, and complexity results

As the type II functional response model is the most appropriate model to describe our data across all treatments (see section “The functional response type” above), we continue our analyses using this functional response model. Based on our hypotheses (see section “Habitat complexity as an independent variable” above), we need to test in total 64 statistical functional response models: 16 models for the Holling-style and 16 models for the Real-style RRPE, resulting in 32 models, and we repeated these 32 models for the two predator species. In the following, we present the description of the 32 models and how habitat affects the functional response parameters:

- Model 01h | 01r: Habitat has no effect on $F_{max} | T_h$, (H_0), and $N_{half} | a$ is also not affected by habitat presence (H_0).
- Model 02h | 02r: Habitat has no effect on $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by habitat presence (H_1).
- Model 03h | 03r: Habitat has no effect on $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by the amount of habitat structure (H_2).
- Model 04h | 04r: Habitat has no effect on $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by complexity (H_3).
- Model 05h | 05r: Habitat presence affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is not affected by habitat presence (H_0).
- Model 06h | 06r: Habitat presence affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by habitat presence (H_1).
- Model 07h | 07r: Habitat presence affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by the amount of habitat structure (H_2).
- Model 08h | 08r: Habitat presence affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by complexity (H_3).

- Model 09h | 09r: The amount of habitat affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is not affected by habitat presence (H_0).
- Model 10h | 10r: The amount of habitat affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by habitat presence (H_1).
- Model 11h | 11r: The amount of habitat affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by the amount of habitat structure (H_2).
- Model 12h | 12r: The amount of habitat affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by complexity (H_3).
- Model 13h | 13r: Complexity affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is not affected by habitat presence (H_0).
- Model 14h | 14r: Complexity affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by habitat presence (H_1).
- Model 15h | 15r: Complexity affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by the amount of habitat structure (H_2).
- Model 16h | 16r: Complexity affects $F_{max} | T_h$, (H_0), and $N_{half} | a$ is affected by complexity (H_3).

The maximum feeding rate, F_{max} , and the handling time, T_h are always interchangeable as $F_{max} = \frac{1}{T_h}$. However, the attack rate, a , is not only a function of the half saturation density, N_{half} , but also a function of the maximum feeding rate: $a = \frac{F_{max}}{N_{half}}$, $N_{half} = \frac{F_{max}}{a}$. This circumstance leads to the fact that the interchangeability of these parameters is context-dependent:

1. Attack rate and half saturation density are interchangeable if the maximum feeding rate is a constant across treatments (models 01 to 04).
2. Attack rate and half saturation density are also interchangeable if we fit a model testing for all complexity levels (H_3) for the half saturation density (models 04, 08, 12, and 16).
3. Attack rate and half saturation density are also interchangeable if we fit a model testing for the same hypothesis (models 01, 06, 11, and 16).

The remaining models (5, 7, 9, 10, 13, 14, 15) will deliver different results.

We will compare all models using common information criteria, the AIC, and the BIC (Akaike, 1974; Schwarz, 1978). The AIC selects models with more parameters, whereas the BIC tends to select models with a lower number of parameters (Schwarz, 1978). Please find the results of all fits saved as *.rds files in the folders `results_hab_ie` and `results_hab_ng` online (<https://github.com/b-c-r/CRITTERstatistics>).

Ischnura elegans results

Table 3: AIC / BIC table of the six most parsimonious out of 32 possible models for *Ischnura elegans*. Find all results below in table .

Model (AIC)	df	dAIC	Model (BIC)	df	dBIC
Model 5r	3	0.000	Model 5r	3	0.000
Model 7r	4	0.265	Model 5h	3	1.583
Model 6h	4	0.952	Model 7r	4	2.731
Model 6r	4	0.952	Model 6h	4	3.418
Model 5h	3	1.583	Model 6r	4	3.418
Model 13r	6	2.107	Model 7h	4	4.718

The most parsimonious model according to AIC and BIC is model 5r (table 3). The maximum feeding rate in the case of no habitat is 28.08 [$\frac{items_{prey}}{day}$] and in the case of habitat present 14.58 [$\frac{items_{prey}}{day}$], which is a drop of about half (table 4). Expressed as handling time, T_h , *I. elegans* predators need 0.04 [days] if no habitat is present and 0.07 [$\frac{days}{items_{prey}}$] if habitat is present to subdue and feed on a prey item. The half saturation density,

N_{half} is not affected by habitat at all ($N_{half} = 57 \frac{\text{items}_{\text{prey}}}{\text{volume}_{\text{arena}}}$, table 4). As the attack rate a depends on both, the maximum feeding rate F_{max} and the half saturation density N_{half} , we can calculate two attack rates for (1) no habitat ($a = 0.49 [\frac{\text{volume}_{\text{arena}}}{\text{days}}]$) and (2) for the case that habitat is present ($a = 0.26 [\frac{\text{volume}_{\text{arena}}}{\text{days}}]$). Note that the change in attack rate matches the change in maximum feeding rate, resulting in the fact that the strength of feeding is influenced equally across the whole range of prey densities (as N_{half} is constant).

We found four more models within a range of two delta units of both information criteria, all with three to four parameters (3), and we will discuss these models below. Please find the full table 18 in the Appendix below.

Table 4: Results of model 5 (Real style) fitted to the data of *Ischnura elegans*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (habitat absent)	28.081	19.398	41.043
F_{max} (habitat present)	14.578	10.515	19.726
N_{half}	57.000	34.380	92.931

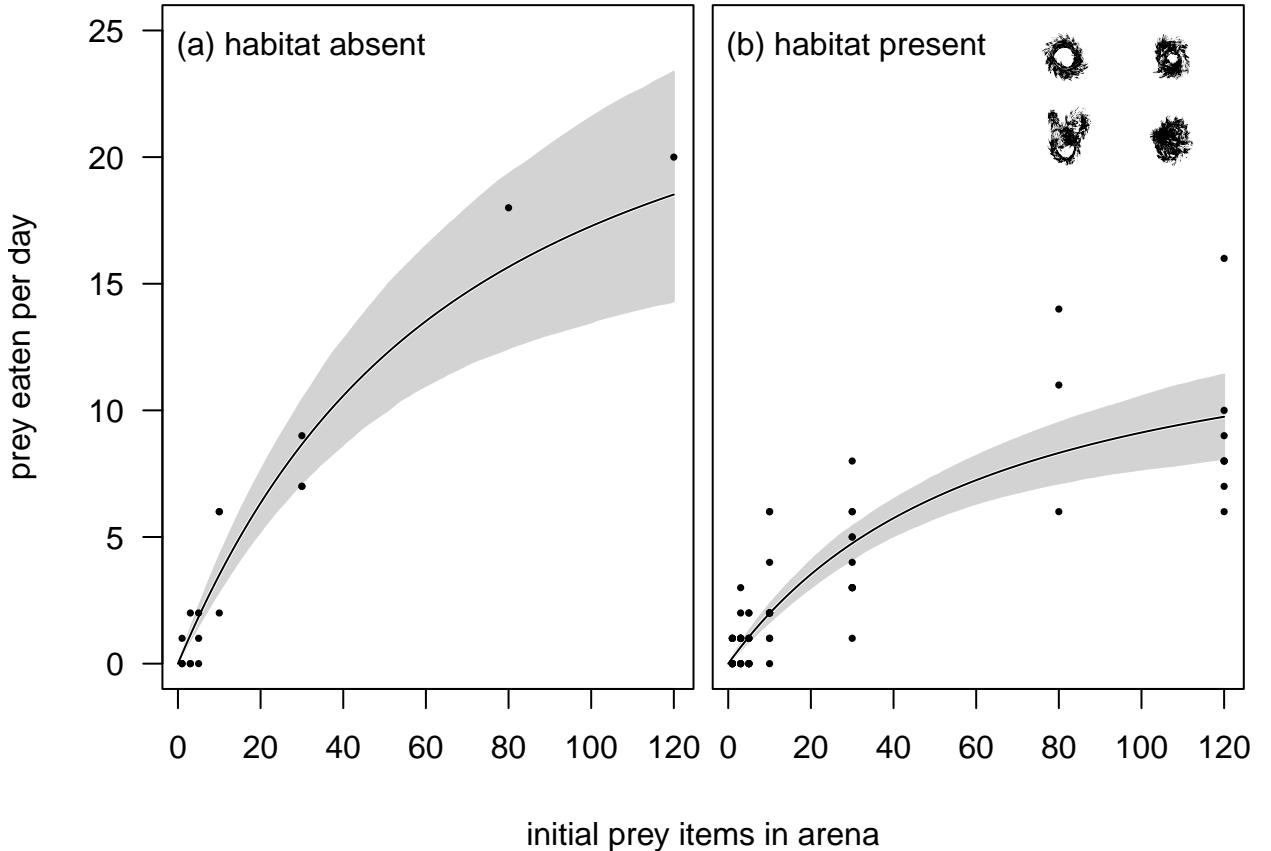


Figure 1: The feeding functional response of *Ischnura elegans* as function of the density of *Asellus aquaticus*. We found that model 5r was the most appropriate to describe the data (table 3). This model includes a unique maximum feeding rate for the cases if habitat is absent (a) or present (b) and a half saturation density that is not affected by habitat (table 4). The regression lines of the best fit point estimates are displayed in black, and the light gray area shows the 95% confidence limits of the best fit.

The models within 2 delta AIC/BIC units

Model 7r (table 5) is more complex than model 5r by one degree of freedom (i.e., one more model parameter). Not only F_{max} depends on the presence of the habitat, but also N_{half} is a negative function of habitat amount (the number of rings). However, the slope of this relationship (-0.09) is not significant ($p = 0.203$). In addition, a likelihood ratio test reveals, that adding this model parameter doesn't make the fit significantly better compared to model 5r ($p = 0.188$).

Table 5: Results of model 7 (Real style) fitted to the data of *Ischnura elegans*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (habitat absent)	36.596	19.848	68.951
F_{max} (habitat present)	13.563	9.823	18.544
$N_{half}(\text{intercept})$	86.008	37.554	203.424
$N_{half}(\text{slope})$	-0.094	-0.239	0.042

Model 6h (table 6) is more complex than model 5r by one degree of freedom. Model 6h is interchangeable with model 6r below. Not only T_h depends on the presence of the habitat but also a . If habitat is present, the attack rate is reduced from $0.42 \frac{\text{items}_{\text{prey}}}{\text{volume}_{\text{arena}}}$ to 0.27. A likelihood ratio test reveals, that adding this model parameter doesn't make the fit significantly better compared to model 5r ($p = 0.306$).

Table 6: Results of model 6 (Holling style) fitted to the data of *Ischnura elegans*.

Parameter Name	Point Estimate	Lower CI	Upper CI
T_h (habitat absent)	0.026	0.012	0.057
T_h (habitat present)	0.075	0.054	0.102
a (habitat absent)	0.419	0.283	0.640
a (habitat present)	0.275	0.208	0.368

Model 6r (table 7) is more complex than model 5r by one degree of freedom. Model 6r is interchangeable with model 6h above. Not only F_{max} depends on the presence of the habitat but also N_{half} . If habitat is present, the half saturation density drops from $90.24 \frac{\text{items}_{\text{prey}}}{\text{volume}_{\text{arena}}}$ to 48.65. A likelihood ratio test reveals, that adding this model parameter doesn't make the fit significantly better compared to model 5r ($p = 0.306$).

Table 7: Results of model 6 (Real style) fitted to the data of *Ischnura elegans*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (habitat absent)	37.807	17.693	81.239
F_{max} (habitat present)	13.361	9.290	18.580
N_{half} (habitat absent)	90.245	31.289	261.984
N_{half} (habitat present)	48.647	26.268	87.922

Model 5h (table 8) is as complex as model 5r, and both have three model parameters. T_h depends on the presence of the habitat, and a is not affected by habitat at all ($0.32 \frac{\text{items}_{\text{prey}}}{\text{volume}_{\text{arena}}}$). The respective half saturation densities are for the case without habitat: $N_{half} = 195.409$; and with habitat: $N_{half} = 38.273$. Especially the half saturation density for the case without habitat seems highly unlikely as it is above the tested range of prey densities. We did not apply a likelihood ratio test, as both models share the same number of parameters.

Table 8: Results of model 5 (Holling style) fitted to the data of *Ischnura elegans*.

Parameter Name	Point Estimate	Lower CI	Upper CI
T_h (habitat absent)	0.016	0.006	0.046
T_h (habitat present)	0.082	0.061	0.110
a	0.317	0.247	0.399

In summary, all models in the range of 2 delta AIC units suggest that (1) the maximum feeding rate drops dramatically by up to 50% when adding habitat structure. The half saturation density is likely to be habitat-independent, according to the most likely model 5r. Eventually, the half saturation density may also decrease by adding habitat (model 6r), or may even decrease as a function of habitat amount (model 7r), which leads to a decrease in attack rates that is less pronounced as the drop of maximum feeding rates (model 6h) or the attack

rate may be constant (model 5h). This result would indicate that the effect of habitat is predominantly acting at high prey densities. However, the alternative models are not contributing significantly to the explanation of the data (see above), leaving this phenomenon open for discussion. The results, however, show, that the higher-order complexity of the habitat structure does not influence the feeding rate of *Ischnura elegans*.

Notonecta glauca results

Table 9: AIC / BIC table of the seven most parsimonious out of 32 possible models for *Notonecta glauca*.

Model (AIC)	df	dAIC	Model (BIC)	df	dBIC
Model 15h	7	0.000	Model 15h	7	0.000
Model 16h	10	1.274	Model 9r	3	1.004
Model 16r	10	1.274	Model 11h	4	1.485
Model 15r	7	1.990	Model 11r	4	1.485
Model 14r	7	4.189	Model 13r	6	1.507
Model 13r	6	4.854	Model 15r	7	1.990
Model 12h	7	8.352	Model 7h	4	2.516

Both, AIC and BIC select for model 15h as the most parsimonious choice (table 9). Within two delta AIC units, models 16h, 16r, and 15r were selected. These models have 7 or more parameters, and in all cases either F_{max} or T_h are affected by habitat complexity. We found the models 9r, 11h, 11r, 13r, and 15r within two delta BIC units, all of them have equal or fewer parameters compared to model 15h (table 9, but see also the full table 19 in the Appendix). These selections highlight the quality of model 15h, as BIC is known to rather select models with fewer parameters (Schwarz, 1978).

Table 10: Results of model 15 (Holling style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
T_h (C0)	0.032	0.028	0.038
T_h (C1)	0.057	0.047	0.068
T_h (C2)	0.036	0.030	0.043
T_h (C3)	0.046	0.037	0.057
T_h (C4)	0.053	0.043	0.065
$a(intercept)$	1.280	1.000	1.599
$a(slope)$	-0.144	-0.192	-0.096

In model 15h, complexity affects the handling time (one measure of handling time per complexity level, table 10). The corresponding maximum feeding rates are $30.84 \left[\frac{items_{prey}}{day} \right]$ (C0), $17.5 \left[\frac{items_{prey}}{day} \right]$ (C1), $28.06 \left[\frac{items_{prey}}{day} \right]$ (C2), $21.65 \left[\frac{items_{prey}}{day} \right]$ (C3), $18.9 \left[\frac{items_{prey}}{day} \right]$ (C4). The maximum feeding rates are generally lower if habitat is present (complexity levels 1-4), but especially at level 2, the value is rather comparable to the case without habitat.

The attack rate, a is a decreasing function of the amount of habitat (table 10) with an intercept of ($a_{intercept} = 1.28 \left[\frac{volume_{arena}}{days} \right]$). The intercept is the attack rate when the habitat is absent. The slope of the attack rate is -0.14, indicating that the successful search and attack of prey at low densities decrease with increasing amounts of habitat.

The half saturation density N_{half} depends on both, the handling time T_h and the attack rate a ($N_{half} = \frac{1}{aT_h}$) leading to five half saturation densities, one for each complexity level: $24.1 \left[\frac{items_{prey}}{volume_{arena}} \right]$ (C0); $26.57 \left[\frac{items_{prey}}{volume_{arena}} \right]$ (C1); $42.6 \left[\frac{items_{prey}}{volume_{arena}} \right]$ (C2); $45.81 \left[\frac{items_{prey}}{volume_{arena}} \right]$ (C3); $39.99 \left[\frac{items_{prey}}{volume_{arena}} \right]$ (C4).

In general, the half saturation densities are increasing with increasing amounts of habitat, highlighting the effect of a decreasing hunting success at lower prey densities.

The models within 2 delta AIC/BIC units

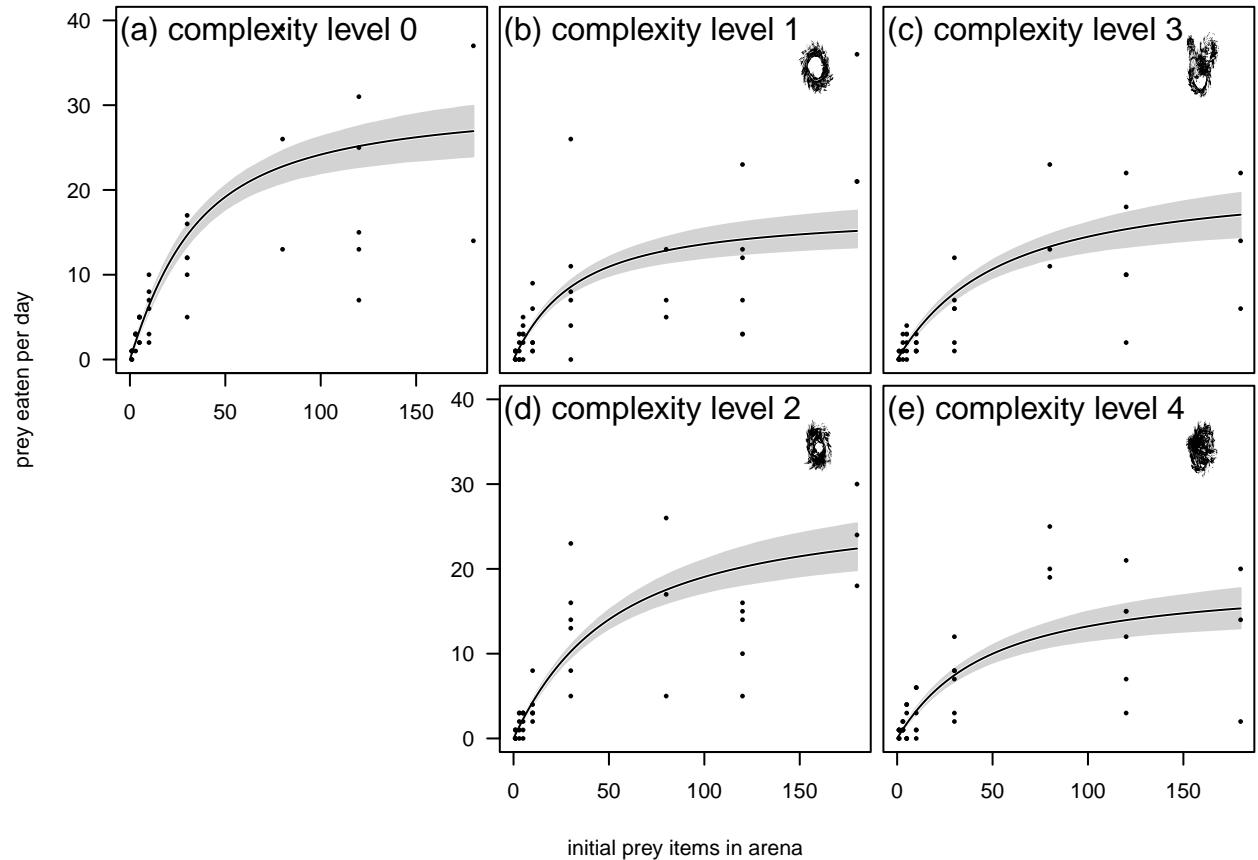


Figure 2: The feeding functional response of *Notonecta glauca* as function of the density of *Asellus aquaticus*. We found that model 15h was the most appropriate to describe the data (table 9). This model includes a unique maximum feeding rate for each complexity level and a decreasing attack rate as a function of the amount of habitat (table 10). The complexity levels (0-4) are displayed in the separate subplots: (a) = 0; (b) = 1; (c) = 3; (d) = 2; and (e) = 4. The amount of habitat structure increases from left to right, whereas the results for 0 rings are displayed in (a), 2 rings are displayed in (b, d), and 3 rings are displayed in (c, e). The regression lines of the best fit point estimates are displayed in black, and the light gray area shows the 95% confidence limits of the best fit.

Model 16h and model 16r are interchangeable and are the most complex models we could fit to data. Both functional response parameters are affected by complexity level (see tables 11 and 12). The patterns of how habitat affects the parameters are similar to model 15h, i.e., handling time increases and maximum feeding decreases with increasing complexity, but we see an up-and-down pattern around this general trend. Attack rates are much higher when habitat is absent, complexity levels 1 and 2 (2 habitat rings in model 15h) show an intermediate attack rate, and complexity levels C3 and C4 have the lowest attack rates (3 rings in model 15h). The effect on half saturation densities is rather neutral, with a slight tendency to increase, in line with the fact that the general decrease in attack rates is more pronounced than the increase in attack rates with an increase in levels of complexity.

Table 11: Results of model 16 (Holling style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
T_h (C0)	0.032	0.028	0.037
T_h (C1)	0.059	0.048	0.072
T_h (C2)	0.038	0.031	0.045
T_h (C3)	0.039	0.029	0.054
T_h (C4)	0.055	0.045	0.069
a (C0)	1.212	0.953	1.575
a (C1)	0.707	0.514	0.975
a (C2)	0.750	0.587	0.949
a (C3)	0.363	0.272	0.480
a (C4)	0.526	0.386	0.712

Table 12: Results of model 16 (Real style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (C0)	31.487	26.737	36.535
F_{max} (C1)	17.046	13.811	20.910
F_{max} (C2)	26.492	22.170	31.762
F_{max} (C3)	25.453	19.158	34.047
F_{max} (C4)	18.057	14.641	22.671
N_{half} (C0)	25.971	18.041	37.123
N_{half} (C1)	24.113	14.999	38.951
N_{half} (C2)	35.334	24.538	52.065
N_{half} (C3)	70.211	41.982	121.140
N_{half} (C4)	34.349	21.218	56.663

Model 15r (table 13) is in line with the above-mentioned models and shows a general increase of F_{max} with the up-and-down pattern with increasing complexity levels as for the models above. The half saturation increases slightly with an increasing amount of habitat. This effect is similar to the effect of complexity in model 16r above.

Table 13: Results of model 15 (Real style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (C0)	30.741	26.589	35.827
F_{max} (C1)	19.646	17.212	22.507
F_{max} (C2)	26.474	23.236	30.071
F_{max} (C3)	20.181	17.248	23.837
F_{max} (C4)	19.703	16.590	23.239
N_{half} (intercept)	24.285	17.027	34.942
N_{half} (slope)	0.081	0.007	0.155

Model 9r (table 14) is the by far the simplest model and chosen by the AIC, and not by the BIC selection. It comprises a decreasing maximum feeding rate with an increasing amount of habitat and a constant half saturation density. The generally decreasing trend of maximum feeding rate with increasing amount of habitat is in line with the models above, only ignoring the up-and-down with complexity levels. We also already saw above (e.g., models 15r and 16r) that the effect of habitat on half saturation is rather weak.

Table 14: Results of model 9 (Real style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (intercept)	34.831	31.027	38.698
F_{max} (slope)	-0.094	-0.110	-0.077
N_{half}	33.937	27.733	41.291

Model 11h and model 11r are interchangeable, and the functional response parameters both depend on the amount of habitat present (tables 15 and 16). Handling time increases, and, of course, maximum feeding rate increases with the same strength. Attack rates decrease, while half saturation densities increase slightly. These results are in line with the above-mentioned models, only missing the up-and-down with complexity levels as in the more complex models.

Table 15: Results of model 11 (Holling style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
T_h (intercept)	0.033	0.028	0.038
T_h (slope)	0.063	0.032	0.099
a (intercept)	1.265	0.992	1.619
a (slope)	-0.144	-0.191	-0.095

Table 16: Results of model 11 (Real style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (intercept)	30.745	26.652	35.446
F_{max} (slope)	-0.063	-0.093	-0.031
N_{half} (intercept)	24.304	17.301	33.955
N_{half} (slope)	0.081	0.005	0.151

Model 13r (table 17) shows the well-known up-and-down pattern of maximum feeding, including a general increase with increasing complexity level. The half saturation density is constant, in line with the rather weak (but significant) positive effect of habitat amount in the models above.

Table 17: Results of model 13 (Real style) fitted to the data of *Notonecta glauca*.

Parameter Name	Point Estimate	Lower CI	Upper CI
F_{max} (C0)	34.784	31.044	38.844
F_{max} (C1)	19.350	16.923	22.318
F_{max} (C2)	26.070	23.323	29.487
F_{max} (C3)	18.371	16.047	21.030
F_{max} (C4)	17.969	15.569	20.620
N_{half}	33.928	28.090	41.710

In summary, all models in the range of 2 delta AIC and BIC units suggest that (1) the handling times increase with increasing amount of habitat available, altered by complexity levels. This leads to a decrease in maximum feeding rates, with the mirrored up-and-down effect of habitat complexity. We compared models 15h (the

most parsimonious model) with model 11h (the next simple model nested in model 15h) and found that if the amount of habitat is medium (2 rings), the results for complexity levels 2 and 3 differ from the prediction of the simpler model (figure 3). The attack rates decrease with increasing amounts of habitat, and this effect is slightly stronger than the effect on handling time, leading to a slightly increasing half saturation density. An even more complex effect of habitat complexity is given as models 16h and 16r are also within 2 delta AIC units, but as the AIC rather selects models that overfit data, we consider this effect as rather irrelevant.

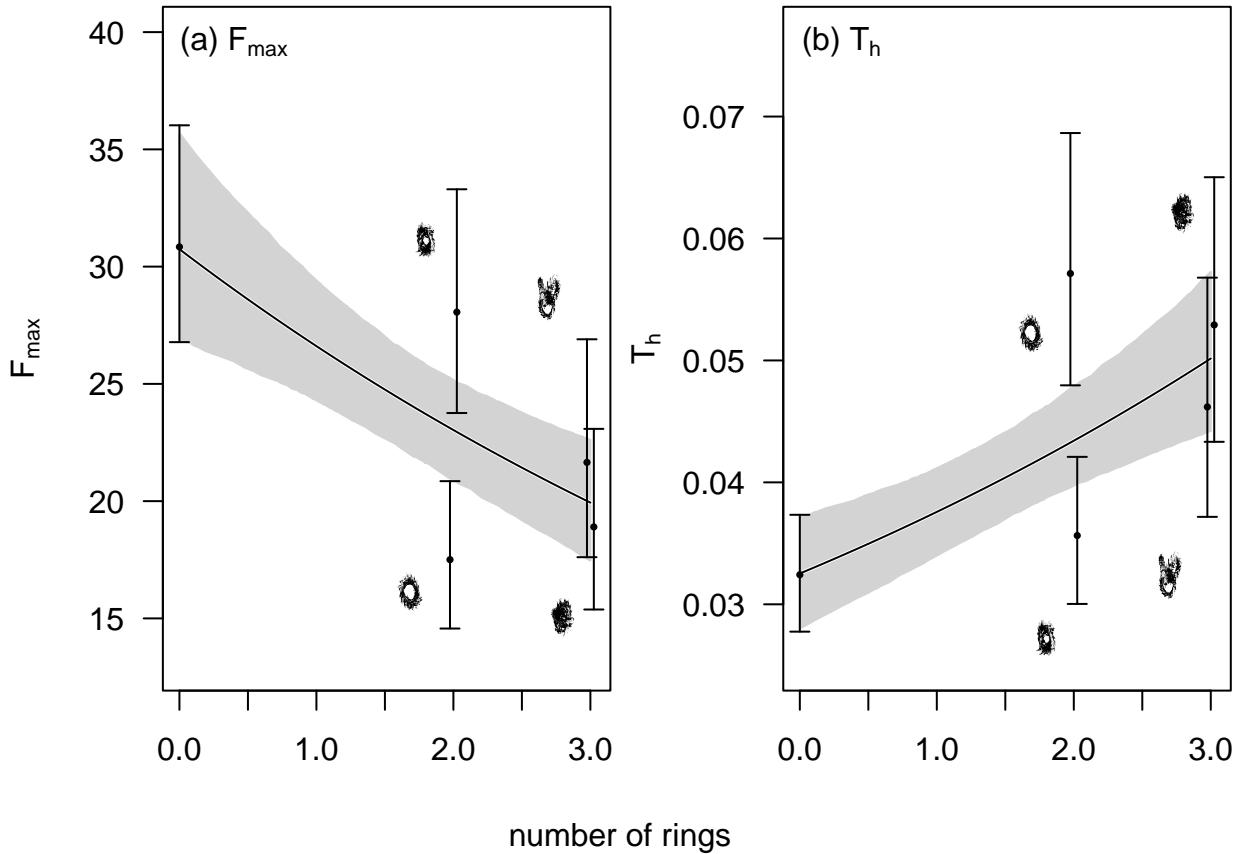


Figure 3: The functional feeding response parameters F_{max} (a) and T_h of *Notonecta glauca* feeding on *Asellus aquaticus*. We found that model 15h was the most appropriate to describe the data (table 9). This model includes a unique maximum feeding rate for each complexity level and a decreasing attack rate as a function of the amount of habitat provided (table 10). The next simpler model, including the decreasing attack rate with ring count, is model 11h (table 15). We consider the complexity levels as variants of the respective ring levels.

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References

- Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, 19(6), 716–723. <https://doi.org/10.1109/TAC.1974.1100705>
- Aranbarri, M., Flores, L., Guzmán, I. de, Larrañaga, A., Elosegi, A., Rall, B. C., & Reiss, J. (2025). Habitat complexity reduces feeding strength of freshwater predators. bioRxiv. <https://doi.org/10.1101/2025.02.22.639633>
- Barcroft, J., & Hill, A. V. (1910). The nature of oxyhaemoglobin, with a note on its molecular weight. *The Journal of Physiology*, 39(6), 411–428. <https://doi.org/10.1113/jphysiol.1910.sp001350>
- Bolker, B. M. (2008). *Ecological models and data in R*. Princeton University Press. <https://math.mcmaster.ca/~bolker/emdbook/index.html>
- Bolker, B. M. (2023). *Emdbook: Support functions and data for "Ecological models and data"*. <https://CRAN.R-project.org/package=emdbook>
- Bolker, B. M., R. Development Core Team, & Giné-Vázquez, I. (2023). *Bbmle: Tools for General Maximum Likelihood Estimation*. <https://doi.org/10.32614/CRAN.package.bbmle>
- Carnell, R. (2024). *Lhs: Latin Hypercube Samples*. <https://doi.org/10.32614/CRAN.package.lhs>
- Corless, R. M., Gonnet, G. H., Hare, D. E. G., Jeffrey, D. J., & Knuth, D. E. (1996). On the LambertW function. *Advances in Computational Mathematics*, 5(1), 329–359. <https://doi.org/10.1007/BF02124750>
- CRAN Team, & Temple Lang, D. (2024). *RCurl: General Network (HTTP/FTP/...) Client Interface for R*. <https://doi.org/10.32614/CRAN.package.RCurl>
- Crawley, M. J. (2012). *The R Book* (2. ed.). Wiley.
- Csárdi, G., Wickham, H., Chang, W., Flight, R., Müller, K., & Hester, J. (2025). *Sessioninfo: R session information*. <https://doi.org/10.32614/CRAN.package.sessioninfo>
- FitzJohn, R. (2024). *Odin: ODE generation and integration*. <https://doi.org/10.32614/CRAN.package.odin>
- Flores, L., Bailey, R. A., Elosegi, A., Larrañaga, A., & Reiss, J. (2016). Habitat complexity in aquatic microcosms affects processes driven by detritivores. *PLOS One*, 11(11), e0165065. <https://doi.org/10.1371/journal.pone.0165065>
- Flores, L., Reiss, J., Larrañaga, A., Rall, B. C., Aranbarri, M., & Guzmán, I. de. (2025). *Habitat complexity reduces feeding strength of freshwater predators (CRITTER) - Data*. Zenodo. <https://doi.org/10.5281/zenodo.14891980>
- Holling, C. S. (1959a). Some characteristics of simple types of predation and parasitism. *The Canadian Entomologist*, 91(7), 385–398. <https://doi.org/10.4039/Ent91385-7>
- Holling, C. S. (1959b). The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. *The Canadian Entomologist*, 91(5), 293–320. <https://doi.org/10.4039/Ent91293-5>
- Jeschke, J. M., Kopp, M., & Tollrian, R. (2002). Predator functional responses: Discriminating between handling and digesting prey. *Ecological Monographs*, 72(1), 95–112. <https://esajournals.onlinelibrary.wiley.com/doi/10.1890/0012-9615%282002%29072%5B0095%3APFRDBH%5D2.0.CO%3B2>
- Juliano, S. A. (2001). Nonlinear curve fitting: Predation and functional response curves. In S. M. Scheiner & J. Gurevitch (Eds.), *Design and analysis of ecological experiments* (2nd Edition, pp. 178–196). Chapman; Hall.
- Kalinkat, G., Rall, B. C., Uiterwaal, S., & Uszko, W. (2023). Empirical evidence of type III functional responses and why it remains rare. *Frontiers in Ecology and Evolution*, 11, 1033818. <https://doi.org/10.3389/fevo.2023.1033818>
- Lyon, N. J. (2024). *supportR: Support functions for wrangling and visualization*. <https://doi.org/10.32614/CRAN.package.supportR>
- Microsoft, & Weston, S. (2022a). *doParallel: Foreach parallel adaptor for the 'parallel' package*. <https://CRAN.R-project.org/package=doParallel>
- Microsoft, & Weston, S. (2022b). *Foreach: Provides foreach looping construct*. <https://doi.org/10.32614/CRAN.package.foreach>
- Müller, K., & Bryan, J. (2020). *Here: A simpler way to find your files*. <https://doi.org/10.32614/CRAN.package.here>
- Pritchard, D. W., Barrios-O'Neill, D., Bovy, H. C., & Paterson, R. A. (2017). *Frair: Tools for Functional Response Analysis*. <https://cran.r-project.org/web/packages/frair/>
- Pritchard, D. W., Paterson, R. A., Bovy, H. C., & Barrios-O'Neill, D. (2017). Frair: An R package for fitting and comparing consumer functional responses. *Methods in Ecology and Evolution*, 8(11), 1528–1534. <https://doi.org/10.1111/2041-210X.12784>
- Rall, B. C., Aranbarri, M., Flores, L., Guzmán, I. de, Larrañaga, A., & Reiss, J. (2025a). *Habitat complexity reduces feeding strength of freshwater predators (CRITTER) - Supplemental Statistics Report*. Zenodo. <https://doi.org/10.5281/zenodo.14898820>
- Rall, B. C., Aranbarri, M., Flores, L., Guzmán, I. de, Larrañaga, A., & Reiss, J. (2025b). *Habitat complexity*

- reduces feeding strength of freshwater predators (CRITTER) - Code.* Zenodo. <https://doi.org/10.5281/zendodo.14894598>
- Rall, B. C., Guill, C., & Brose, U. (2008). Food-web connectance and predator interference dampen the paradox of enrichment. *Oikos*, 117(2), 202–213. <https://doi.org/10.1111/j.2007.0030-1299.15491.x>
- Real, L. A. (1977). The kinetics of functional response. *The American Naturalist*, 111(978), 289–300. <https://doi.org/10.1086/283161>
- Real, L. A. (1979). Ecological determinants of functional response. *Ecology*, 60(3), 481–485. <https://doi.org/10.2307/1936067>
- Ripley, B., Venables, B., Bates, D. M., Hornik, K., Gebhardt, A., & Firth, D. (2025). *MASS: Support Functions and Datasets for Venables and Ripley's MASS*. <https://doi.org/10.32614/CRAN.package.MASS>
- Rogers, D. (1972). Random search and insect population models. *The Journal of Animal Ecology*, 41(2), 369–383. <https://doi.org/10.2307/3474>
- Rosenbaum, B., & Rall, B. C. (2018). Fitting functional responses: Direct parameter estimation by simulating differential equations. *Methods in Ecology and Evolution*, 9(10), 2076–2090. <https://doi.org/10.1111/2041-210X.13039>
- Royama, T. (1971). A comparative study of models for predation and parasitism. *Researches on Population Ecology*, 13(1), 1–91. <https://doi.org/10.1007/BF02511547>
- Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, 6(2), 461–464. <https://doi.org/10.1214/aos/1176344136>
- Urbanej, S. (2022). *Png: Read and write PNG images*. <https://doi.org/10.32614/CRAN.package.png>
- Vonesh, J. R., & Bolker, B. M. (2005). Compensatory larval responses shift trade-offs associated with predator-induced hatching plasticity. *Ecology*, 86(6), 1580–1591. <https://doi.org/10.1890/04-0535>
- Vucic-Pestic, O., Rall, B. C., Kalinkat, G., & Brose, U. (2010). Allometric functional response model: Body masses constrain interaction strengths. *Journal of Animal Ecology*, 79(1), 249–256. <https://doi.org/10.1111/j.1365-2656.2009.01622.x>
- Wickham, H., François, R., Henry, L., Müller, K., & Vaughan, D. (2023). *Dplyr: A grammar of data manipulation*. <https://doi.org/10.32614/CRAN.package.dplyr>
- Wickham, H., & Henry, L. (2025). *Purrr: Functional programming tools*. <https://doi.org/10.32614/CRAN.package.purrr>
- Williams, R. J., & Martinez, N. D. (2004). Stabilization of chaotic and non-permanent food-web dynamics. *The European Physical Journal B: Condensed Matter and Complex Systems*, 38(2), 297–303. <https://doi.org/10.1140/epjb/e2004-00122-1>
- Xie, Y. (2024). *Knitr: A general-purpose package for dynamic report generation in R*. <https://yihui.org/knitr/>
- Xie, Y. (2025). *Bookdown: Authoring books and technical documents with R markdown*. <https://doi.org/10.32614/CRAN.package.bookdown>
- Xie, Y., & Posit Software, PBC. (2025). *Tinytex: Helper Functions to Install and Maintain TeX Live, and Compile LaTeX Documents*. <https://doi.org/10.32614/CRAN.package.tinytex>
- Zar, J. H. (2010). *Biostatistical Analyses* (5th ed.). Prentice Hall. <https://elibrary.pearson.de/book/99.150005/9781292037110>
- Zhu, H. (2024). *kableExtra: Construct complex table with 'kable' and pipe syntax*. <https://doi.org/10.32614/CRAN.package.kableExtra>

Appendix

Phenomenological Test Rationale

Instead of fitting the number eaten prey items as depended variable as a function of the initial prey density, the ratio of prey eaten and initial prey items is used as depended variable (Juliano, 2001; Pritchard, Paterson, et al., 2017; Pritchard, Barrios-O'Neill, et al., 2017). In the case of a type II functional response, the proportion of eaten prey is constantly declining with increasing prey density, whereas in the case of a type III functional response, the proportion of prey eaten increases at low prey densities and declines after reaching a maximum proportion rate. The main trend of any functional response, if looking at the proportion data, is negative. This negative trend is caused by the fact, that initial prey density linearly increases, whereas the eaten prey items are leveling off. Please see Juliano (2001) for a full description. Pritchard, Paterson, et al. (2017) implemented this test using generalized linear models with a binomial distribution, a standard method to analyze proportion data based on yes/no data (i.e., whether a prey item is eaten or not eaten), but see Crawley (2012), chapter 16, for an introduction on this topic.

We use here the customized function `phen_type_test()` which is a wrapper around the `frair_test()` function from the `frair` package (Pritchard, Barrios-O'Neill, et al., 2017). `phen_type_table()` creates a high-quality PDF report table based on the output of `phen_type_test()`. Both functions are located in the project's sub-folder `functions`.

Full AIC / BIC tables

Ischnura elegans

Table 18: AIC / BIC table of all 32 possible models for *Ischnura elegans*.

Model (AIC)	df	dAIC	Model (BIC)	df	dBIC
Model 5r	3	0.000	Model 5r	3	0.000
Model 7r	4	0.265	Model 5h	3	1.583
Model 6h	4	0.952	Model 7r	4	2.731
Model 6r	4	0.952	Model 6h	4	3.418
Model 5h	3	1.583	Model 6r	4	3.418
Model 13r	6	2.107	Model 7h	4	4.718
Model 7h	4	2.252	Model 2h	3	7.001
Model 8h	7	2.446	Model 2r	3	7.001
Model 8r	7	2.446	Model 9r	3	7.189
Model 14r	7	2.928	Model 10h	4	7.768
Model 15r	7	3.495	Model 13r	6	9.505
Model 14h	7	3.834	Model 10r	4	10.128
Model 13h	6	4.026	Model 9h	3	11.069
Model 15h	7	4.039	Model 13h	6	11.424
Model 12h	7	5.271	Model 11h	4	11.468
Model 12r	7	5.271	Model 11r	4	11.468
Model 10h	4	5.303	Model 3h	3	11.887
Model 16h	10	5.945	Model 3r	3	11.887
Model 16r	10	5.945	Model 8h	7	12.309
Model 2h	3	7.001	Model 8r	7	12.309
Model 2r	3	7.001	Model 14r	7	12.791
Model 9r	3	7.189	Model 15r	7	13.358
Model 10r	4	7.663	Model 14h	7	13.697
Model 4h	6	8.317	Model 15h	7	13.902
Model 4r	6	8.317	Model 12h	7	15.135
Model 11h	4	9.002	Model 12r	7	15.135
Model 11r	4	9.002	Model 4h	6	15.715
Model 9h	3	11.069	Model 4r	6	15.715
Model 3h	3	11.887	Model 1h	2	19.128
Model 3r	3	11.887	Model 1r	2	19.128
Model 1h	2	21.594	Model 16h	10	23.206
Model 1r	2	21.594	Model 16r	10	23.206

Notonecta glauca

Table 19: AIC / BIC table of all 32 possible models for *Notonecta glauca*.

Model (AIC)	df	dAIC	Model (BIC)	df	dBIC
Model 15h	7	0.000	Model 15h	7	0.000
Model 16h	10	1.274	Model 9r	3	1.004
Model 16r	10	1.274	Model 11h	4	1.485
Model 15r	7	1.990	Model 11r	4	1.485
Model 14r	7	4.189	Model 13r	6	1.507
Model 13r	6	4.854	Model 15r	7	1.990
Model 12h	7	8.352	Model 7h	4	2.516
Model 12r	7	8.352	Model 14r	7	4.189
Model 8h	7	8.459	Model 10r	4	4.478
Model 8r	7	8.459	Model 7r	4	5.947
Model 14h	7	9.938	Model 12h	7	8.352
Model 11h	4	11.526	Model 12r	7	8.352
Model 11r	4	11.526	Model 8h	7	8.459
Model 7h	4	12.557	Model 8r	7	8.459
Model 9r	3	14.392	Model 14h	7	9.938
Model 10r	4	14.519	Model 3h	3	10.853
Model 7r	4	15.988	Model 3r	3	10.853
Model 4h	6	20.141	Model 16h	10	11.316
Model 4r	6	20.141	Model 16r	10	11.316
Model 10h	4	21.456	Model 10h	4	11.415
Model 3h	3	24.241	Model 5r	3	16.378
Model 3r	3	24.241	Model 4h	6	16.794
Model 6h	4	28.922	Model 4r	6	16.794
Model 6r	4	28.922	Model 6h	4	18.880
Model 5r	3	29.767	Model 6r	4	18.880
Model 13h	6	33.151	Model 13h	6	29.804
Model 2h	3	43.253	Model 2h	3	29.864
Model 2r	3	43.253	Model 2r	3	29.864
Model 9h	3	44.833	Model 9h	3	31.445
Model 5h	3	53.840	Model 5h	3	40.451
Model 1h	2	125.439	Model 1h	2	108.704
Model 1r	2	125.439	Model 1r	2	108.704

All summary including original `bbmle::summary` outputs

The tables below are build using the function `bbmle::summary` from the `bbmle` package (Bolker et al., 2023). This means that all values *except the slopes* are displayed on \log_{10} scale in the column **Orig. Est.** (original estimate). The column **Estimate** displays the values on normal scale. The significance values are all tested against “0”, in the case of the \log_{10} -transformed parameters they are tested against a value of 1 on normal scale. As example, the maximum feeding rate value is tested if it differs significantly from $1 \frac{\text{items}_{\text{prey}}}{\text{day}}$ eaten, not if F_{max} differs between treatments. Therefore, the significance for the \log_{10} -transformed parameters are not relevant. Only the significance for the slopes is of interest as it tells if the model finds a significant effect of the amount of habitat in the experimental trial (0, 2, or 3 ring structures).

Ischnura elegans

Table 20: All 32 summary tables from *Ischnura elegans* model fits.

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
Model 1h							
t_h_log10	-1.204	0.065	-18.648	0.0000	0.063	0.046	0.082
a_log10	-0.510	0.054	-9.505	0.0000	0.309	0.240	0.392
Model 1r							
f_max_log10	1.204	0.065	18.648	0.0000	15.996	12.095	21.237
n_half_log10	1.714	0.107	16.036	0.0000	51.718	32.527	84.610
Model 2h							
t_h_log10	-1.277	0.077	-16.592	0.0000	0.053	0.037	0.075
a_hab0_log10	-0.257	0.085	-3.038	0.0024	0.553	0.381	0.800
a_hab1_log10	-0.643	0.061	-10.541	0.0000	0.228	0.175	0.296
Model 2r							
f_max_log10	1.277	0.077	16.592	0.0000	18.906	13.464	27.077
n_half_hab0_log10	1.534	0.134	11.424	0.0000	34.166	19.200	63.932
n_half_hab1_log10	1.920	0.126	15.274	0.0000	83.088	46.043	152.189
Model 3h							
t_h_log10	-1.254	0.073	-17.191	0.0000	0.056	0.040	0.078
a_intercept_log10	-0.307	0.082	-3.746	0.0002	0.493	0.347	0.717
a_slope	-0.121	0.034	-3.509	0.0005	-0.121	-0.194	-0.050
Model 3r							
f_max_log10	1.254	0.073	17.191	0.0000	17.957	12.824	24.739
n_half_intercept_log10	1.562	0.129	12.102	0.0000	36.451	20.498	63.768
n_half_slope	0.121	0.034	3.509	0.0005	0.121	0.053	0.187
Model 4h							
t_h_log10	-1.277	0.075	-16.930	0.0000	0.053	0.037	0.074
a_0_log10	-0.257	0.084	-3.047	0.0023	0.553	0.380	0.821
a_1_log10	-0.813	0.099	-8.248	0.0000	0.154	0.100	0.240
a_2_log10	-0.554	0.104	-5.319	0.0000	0.279	0.173	0.447
a_3_log10	-0.612	0.094	-6.534	0.0000	0.244	0.162	0.362
a_4_log10	-0.589	0.105	-5.636	0.0000	0.257	0.157	0.395
Model 4r							
f_max_log10	1.277	0.075	16.930	0.0000	18.907	13.607	26.050
n_half_0_log10	1.534	0.132	11.576	0.0000	34.168	19.426	60.184
n_half_1_log10	2.089	0.142	14.724	0.0000	122.880	65.455	232.594
n_half_2_log10	1.831	0.152	12.023	0.0000	67.712	33.472	134.932
n_half_3_log10	1.889	0.140	13.493	0.0000	77.424	40.541	143.389
n_half_4_log10	1.866	0.154	12.150	0.0000	73.468	36.931	145.983
Model 5h							
t_h_hab0_log10	-1.792	0.237	-7.545	0.0000	0.016	0.006	0.049
t_h_hab1_log10	-1.084	0.064	-16.928	0.0000	0.082	0.063	0.111
a_log10	-0.499	0.054	-9.273	0.0000	0.317	0.246	0.401

(continued on next page...)

Table 20: All 32 summary tables from *Ischnura elegans* model fits.
 (continued)

Name	Orig.	Est.	SE	z	p	Estimate	CI low	CI up
Model 5r								
f_max_hab0_log10	1.448	0.083	17.543	0.0000	28.081	19.452	39.818	
f_max_hab1_log10	1.164	0.069	16.839	0.0000	14.578	10.591	19.812	
n_half_log10	1.756	0.111	15.797	0.0000	57.000	34.374	93.267	
Model 6h								
t_h_hab0_log10	-1.578	0.176	-8.959	0.0000	0.026	0.012	0.055	
t_h_hab1_log10	-1.126	0.074	-15.163	0.0000	0.075	0.054	0.107	
a_hab0_log10	-0.378	0.092	-4.091	0.0000	0.419	0.275	0.622	
a_hab1_log10	-0.561	0.065	-8.607	0.0000	0.275	0.203	0.376	
Model 6r								
f_max_hab0_log10	1.578	0.176	8.959	0.0000	37.807	17.042	84.655	
f_max_hab1_log10	1.126	0.074	15.163	0.0000	13.361	9.645	18.744	
n_half_hab0_log10	1.955	0.250	7.837	0.0000	90.245	28.102	281.846	
n_half_hab1_log10	1.687	0.126	13.389	0.0000	48.647	27.119	91.207	
Model 7h								
t_h_hab0_log10	-1.639	0.198	-8.274	0.0000	0.023	0.009	0.053	
t_h_hab1_log10	-1.107	0.070	-15.876	0.0000	0.078	0.057	0.108	
a_intercept_log10	-0.420	0.087	-4.817	0.0000	0.380	0.257	0.573	
a_slope	-0.047	0.040	-1.157	0.2471	-0.047	-0.129	0.027	
Model 7r								
f_max_hab0_log10	1.563	0.133	11.770	0.0000	36.596	20.601	66.645	
f_max_hab1_log10	1.132	0.071	15.910	0.0000	13.563	9.868	19.341	
n_half_intercept_log10	1.935	0.185	10.474	0.0000	86.008	39.215	196.408	
n_half_slope	-0.094	0.074	-1.272	0.2035	-0.094	-0.234	0.049	
Model 8h								
t_h_hab0_log10	-1.578	0.176	-8.959	0.0000	0.026	0.012	0.058	
t_h_hab1_log10	-1.133	0.074	-15.380	0.0000	0.074	0.053	0.103	
a_0_log10	-0.378	0.092	-4.091	0.0000	0.419	0.279	0.637	
a_1_log10	-0.748	0.108	-6.904	0.0000	0.179	0.109	0.294	
a_2_log10	-0.468	0.111	-4.201	0.0000	0.341	0.209	0.559	
a_3_log10	-0.541	0.104	-5.219	0.0000	0.288	0.181	0.449	
a_4_log10	-0.504	0.110	-4.585	0.0000	0.313	0.195	0.505	
Model 8r								
f_max_hab0_log10	1.578	0.176	8.959	0.0000	37.807	17.999	78.220	
f_max_hab1_log10	1.133	0.074	15.380	0.0000	13.569	9.732	19.162	
n_half_0_log10	1.955	0.250	7.837	0.0000	90.243	30.167	258.481	
n_half_1_log10	1.880	0.150	12.570	0.0000	75.896	37.627	157.781	
n_half_2_log10	1.600	0.156	10.243	0.0000	39.837	19.655	82.986	
n_half_3_log10	1.674	0.148	11.291	0.0000	47.174	24.358	94.326	
n_half_4_log10	1.637	0.153	10.687	0.0000	43.351	22.123	85.394	
Model 9h								
t_h_intercept_log10	-1.528	0.132	-11.571	0.0000	0.030	0.017	0.052	
t_h_slope	0.162	0.050	3.261	0.0011	0.162	0.066	0.257	
a_log10	-0.495	0.053	-9.382	0.0000	0.320	0.249	0.403	
Model 9r								
f_max_intercept_log10	1.402	0.082	17.130	0.0000	25.244	17.691	37.535	
f_max_slope	-0.091	0.022	-4.179	0.0000	-0.091	-0.136	-0.049	
n_half_log10	1.750	0.110	15.840	0.0000	56.226	33.839	93.674	
Model 10h								
t_h_intercept_log10	-1.428	0.120	-11.919	0.0000	0.037	0.022	0.063	
t_h_slope	0.096	0.051	1.887	0.0592	0.096	-0.003	0.199	
a_hab0_log10	-0.320	0.087	-3.692	0.0002	0.479	0.328	0.690	

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Table 20: All 32 summary tables from *Ischnura elegans* model fits.
 (continued)

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
a_hab1_log10	-0.598	0.064	-9.422	0.0000	0.252	0.188	0.337
Model 10r							
f_max_intercept_log10	1.339	0.094	14.301	0.0000	21.827	14.042	33.787
f_max_slope	-0.048	0.041	-1.160	0.2461	-0.048	-0.137	0.037
n_half_hab0_log10	1.622	0.153	10.633	0.0000	41.882	20.969	88.757
n_half_hab1_log10	1.834	0.136	13.524	0.0000	68.270	36.925	127.389
Model 11h							
t_h_intercept_log10	-1.440	0.124	-11.641	0.0000	0.036	0.021	0.064
t_h_slope	0.111	0.052	2.135	0.0327	0.111	0.019	0.213
a_intercept_log10	-0.372	0.084	-4.453	0.0000	0.425	0.296	0.619
a_slope	-0.077	0.039	-2.001	0.0454	-0.077	-0.156	0.001
Model 11r							
f_max_intercept_log10	1.440	0.124	11.640	0.0000	27.542	15.688	47.762
f_max_slope	-0.111	0.052	-2.136	0.0327	-0.111	-0.213	-0.010
n_half_intercept_log10	1.812	0.184	9.852	0.0000	64.841	27.763	146.630
n_half_slope	-0.034	0.079	-0.430	0.6669	-0.034	-0.191	0.123
Model 12h							
t_h_intercept_log10	-1.476	0.134	-11.024	0.0000	0.033	0.018	0.059
t_h_slope	0.117	0.055	2.132	0.0330	0.117	0.012	0.226
a_0_log10	-0.339	0.088	-3.863	0.0001	0.458	0.306	0.684
a_1_log10	-0.798	0.100	-7.961	0.0000	0.159	0.100	0.248
a_2_log10	-0.533	0.105	-5.093	0.0000	0.293	0.181	0.471
a_3_log10	-0.536	0.107	-5.010	0.0000	0.291	0.181	0.467
a_4_log10	-0.500	0.113	-4.429	0.0000	0.316	0.193	0.536
Model 12r							
f_max_intercept_log10	1.476	0.134	11.024	0.0000	29.898	15.941	54.162
f_max_slope	-0.117	0.055	-2.132	0.0330	-0.117	-0.230	-0.010
n_half_0_log10	1.815	0.200	9.092	0.0000	65.239	25.574	163.158
n_half_1_log10	2.039	0.138	14.746	0.0000	109.348	63.201	198.027
n_half_2_log10	1.774	0.147	12.083	0.0000	59.458	30.569	115.545
n_half_3_log10	1.660	0.164	10.137	0.0000	45.741	20.943	93.128
n_half_4_log10	1.624	0.168	9.686	0.0000	42.029	18.863	86.956
Model 13h							
t_h_0_log10	-1.765	0.224	-7.883	0.0000	0.017	0.007	0.046
t_h_1_log10	-0.944	0.111	-8.513	0.0000	0.114	0.069	0.203
t_h_2_log10	-1.044	0.117	-8.904	0.0000	0.090	0.052	0.155
t_h_3_log10	-1.056	0.126	-8.379	0.0000	0.088	0.051	0.159
t_h_4_log10	-1.203	0.097	-12.358	0.0000	0.063	0.041	0.097
a_log10	-0.488	0.055	-8.902	0.0000	0.325	0.255	0.418
Model 13r							
f_max_0_log10	1.442	0.082	17.509	0.0000	27.663	19.452	40.501
f_max_1_log10	1.056	0.090	11.759	0.0000	11.369	7.660	16.500
f_max_2_log10	1.185	0.088	13.388	0.0000	15.298	10.294	22.623
f_max_3_log10	1.169	0.091	12.886	0.0000	14.750	9.987	22.212
f_max_4_log10	1.213	0.077	15.704	0.0000	16.325	11.457	23.123
n_half_log10	1.745	0.111	15.673	0.0000	55.625	34.831	89.971
Model 14h							
t_h_0_log10	-1.578	0.176	-8.959	0.0000	0.026	0.012	0.056
t_h_1_log10	-0.981	0.119	-8.209	0.0000	0.104	0.061	0.176
t_h_2_log10	-1.079	0.127	-8.508	0.0000	0.083	0.046	0.148
t_h_3_log10	-1.107	0.142	-7.810	0.0000	0.078	0.043	0.151
t_h_4_log10	-1.240	0.109	-11.393	0.0000	0.058	0.036	0.094
a_hab0_log10	-0.378	0.092	-4.091	0.0000	0.419	0.278	0.643

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Table 20: All 32 summary tables from *Ischnura elegans* model fits.
 (continued)

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
a_hab1_log10	-0.547	0.067	-8.164	0.0000	0.284	0.207	0.373
Model 14r							
f_max_0_log10	1.578	0.176	8.959	0.0000	37.807	17.527	86.106
f_max_1_log10	1.016	0.093	10.869	0.0000	10.364	6.761	15.833
f_max_2_log10	1.143	0.093	12.336	0.0000	13.903	8.885	21.287
f_max_3_log10	1.125	0.095	11.827	0.0000	13.324	8.446	20.219
f_max_4_log10	1.177	0.080	14.628	0.0000	15.038	10.077	21.070
n_half_hab0_log10	1.955	0.250	7.837	0.0000	90.243	29.615	285.469
n_half_hab1_log10	1.672	0.126	13.262	0.0000	46.939	26.024	82.940
Model 15h							
t_h_0_log10	-1.592	0.179	-8.886	0.0000	0.026	0.011	0.057
t_h_1_log10	-0.957	0.113	-8.457	0.0000	0.110	0.067	0.191
t_h_2_log10	-1.057	0.120	-8.806	0.0000	0.088	0.050	0.147
t_h_3_log10	-1.127	0.152	-7.403	0.0000	0.075	0.036	0.150
t_h_4_log10	-1.256	0.117	-10.729	0.0000	0.055	0.032	0.094
a_intercept_log10	-0.389	0.089	-4.357	0.0000	0.409	0.270	0.605
a_slope	-0.060	0.043	-1.411	0.1582	-0.060	-0.148	0.022
Model 15r							
f_max_0_log10	1.526	0.148	10.322	0.0000	33.565	17.490	66.451
f_max_1_log10	1.050	0.090	11.707	0.0000	11.214	7.446	16.498
f_max_2_log10	1.178	0.088	13.332	0.0000	15.083	10.045	21.680
f_max_3_log10	1.120	0.106	10.611	0.0000	13.168	8.049	21.417
f_max_4_log10	1.173	0.089	13.253	0.0000	14.896	10.062	22.204
n_half_intercept_log10	1.878	0.214	8.759	0.0000	75.506	28.006	204.446
n_half_slope	-0.072	0.094	-0.764	0.4447	-0.072	-0.277	0.119
Model 16h							
t_h_0_log10	-1.578	0.176	-8.959	0.0000	0.026	0.012	0.058
t_h_1_log10	-1.145	0.205	-5.593	0.0000	0.072	0.029	0.174
t_h_2_log10	-0.984	0.125	-7.859	0.0000	0.104	0.061	0.178
t_h_3_log10	-1.074	0.167	-6.416	0.0000	0.084	0.041	0.170
t_h_4_log10	-1.266	0.142	-8.913	0.0000	0.054	0.030	0.100
a_0_log10	-0.378	0.092	-4.091	0.0000	0.419	0.281	0.628
a_1_log10	-0.754	0.141	-5.346	0.0000	0.176	0.091	0.338
a_2_log10	-0.377	0.135	-2.790	0.0053	0.420	0.236	0.776
a_3_log10	-0.509	0.138	-3.689	0.0002	0.310	0.169	0.585
a_4_log10	-0.583	0.128	-4.537	0.0000	0.261	0.150	0.458
Model 16r							
f_max_0_log10	1.578	0.176	8.959	0.0000	37.806	16.414	85.984
f_max_1_log10	1.145	0.205	5.593	0.0000	13.955	5.349	36.373
f_max_2_log10	0.984	0.125	7.859	0.0000	9.638	5.548	16.938
f_max_3_log10	1.074	0.167	6.416	0.0000	11.850	5.811	25.567
f_max_4_log10	1.266	0.142	8.913	0.0000	18.439	10.563	34.033
n_half_0_log10	1.955	0.250	7.837	0.0000	90.242	27.965	296.526
n_half_1_log10	1.898	0.319	5.951	0.0000	79.115	17.233	374.193
n_half_2_log10	1.361	0.230	5.906	0.0000	22.968	8.493	63.457
n_half_3_log10	1.582	0.281	5.639	0.0000	38.234	10.865	139.452
n_half_4_log10	1.849	0.248	7.462	0.0000	70.559	24.853	215.002

Notonecta glauca

Table 21: All 32 summary tables from *Notonecta glauca* model fits.

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
Model 1h							
t_h_log10	-1.372	0.020	-67.929	0.0000	0.042	0.039	0.046
a_log10	-0.177	0.028	-6.309	0.0000	0.665	0.580	0.755
Model 1r							
f_max_log10	1.372	0.020	67.929	0.0000	23.560	21.558	25.762
n_half_log10	1.550	0.044	35.545	0.0000	35.447	29.072	43.455
Model 2h							
t_h_log10	-1.397	0.021	-65.700	0.0000	0.040	0.036	0.044
a_hab0_log10	0.180	0.050	3.567	0.0004	1.513	1.196	1.907
a_hab1_log10	-0.308	0.031	-10.011	0.0000	0.493	0.428	0.564
Model 2r							
f_max_log10	1.397	0.021	65.701	0.0000	24.927	22.800	27.691
n_half_hab0_log10	1.217	0.062	19.709	0.0000	16.473	12.407	21.884
n_half_hab1_log10	1.704	0.047	36.543	0.0000	50.605	41.253	63.051
Model 3h							
t_h_log10	-1.398	0.021	-66.503	0.0000	0.040	0.036	0.044
a_intercept_log10	0.185	0.048	3.861	0.0001	1.532	1.221	1.903
a_slope	-0.198	0.019	-10.239	0.0000	-0.199	-0.237	-0.162
Model 3r							
f_max_log10	1.398	0.021	66.503	0.0000	24.980	22.590	27.502
n_half_intercept_log10	1.212	0.060	20.267	0.0000	16.306	12.199	20.933
n_half_slope	0.198	0.019	10.239	0.0000	0.198	0.162	0.237
Model 4h							
t_h_log10	-1.405	0.021	-65.883	0.0000	0.039	0.036	0.043
a_0_log10	0.172	0.050	3.426	0.0006	1.487	1.193	1.871
a_1_log10	-0.329	0.056	-5.873	0.0000	0.469	0.370	0.589
a_2_log10	-0.111	0.050	-2.227	0.0259	0.775	0.609	0.959
a_3_log10	-0.440	0.050	-8.781	0.0000	0.363	0.288	0.455
a_4_log10	-0.404	0.053	-7.639	0.0000	0.395	0.306	0.500
Model 4r							
f_max_log10	1.405	0.021	65.883	0.0000	25.418	22.967	27.947
n_half_0_log10	1.233	0.062	19.975	0.0000	17.098	12.839	22.337
n_half_1_log10	1.734	0.067	25.749	0.0000	54.184	40.704	74.010
n_half_2_log10	1.516	0.060	25.109	0.0000	32.788	25.233	44.082
n_half_3_log10	1.845	0.060	30.740	0.0000	70.047	52.624	94.656
n_half_4_log10	1.809	0.063	28.531	0.0000	64.392	47.671	85.263
Model 5h							
t_h_hab0_log10	-1.616	0.038	-42.110	0.0000	0.024	0.021	0.029
t_h_hab1_log10	-1.291	0.021	-60.565	0.0000	0.051	0.047	0.056
a_log10	-0.162	0.028	-5.689	0.0000	0.689	0.607	0.788
Model 5r							
f_max_hab0_log10	1.543	0.025	61.397	0.0000	34.907	31.061	38.961
f_max_hab1_log10	1.311	0.021	61.828	0.0000	20.471	18.520	22.546
n_half_log10	1.535	0.044	35.142	0.0000	34.239	27.840	41.575
Model 6h							
t_h_hab0_log10	-1.498	0.035	-43.204	0.0000	0.032	0.027	0.037
t_h_hab1_log10	-1.329	0.024	-54.437	0.0000	0.047	0.042	0.052
a_hab0_log10	0.084	0.055	1.510	0.1310	1.212	0.952	1.561
a_hab1_log10	-0.250	0.033	-7.580	0.0000	0.562	0.488	0.660
Model 6r							
f_max_hab0_log10	1.498	0.035	43.204	0.0000	31.487	26.855	36.790

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Table 21: All 32 summary tables from *Notonecta glauca* model fits.
(continued)

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
f_max_hab1_log10	1.329	0.024	54.437	0.0000	21.335	19.142	23.827
n_half_hab0_log10	1.414	0.082	17.338	0.0000	25.971	17.893	37.921
n_half_hab1_log10	1.579	0.052	30.513	0.0000	37.942	30.340	48.200
Model 7h							
t_h_hab0_log10	-1.486	0.033	-45.247	0.0000	0.033	0.028	0.038
t_h_hab1_log10	-1.338	0.024	-54.753	0.0000	0.046	0.041	0.051
a_intercept_log10	0.116	0.051	2.273	0.0230	1.307	1.046	1.646
a_slope	-0.153	0.023	-6.625	0.0000	-0.153	-0.200	-0.111
Model 7r							
f_max_hab0_log10	1.464	0.030	49.125	0.0000	29.114	25.571	33.231
f_max_hab1_log10	1.350	0.024	55.297	0.0000	22.380	20.116	24.949
n_half_intercept_log10	1.318	0.069	19.192	0.0000	20.773	15.411	28.177
n_half_slope	0.124	0.031	4.048	0.0001	0.124	0.059	0.182
Model 8h							
t_h_hab0_log10	-1.498	0.035	-43.204	0.0000	0.032	0.027	0.037
t_h_hab1_log10	-1.342	0.025	-53.876	0.0000	0.045	0.041	0.051
a_0_log10	0.084	0.055	1.510	0.1310	1.212	0.954	1.571
a_1_log10	-0.263	0.060	-4.351	0.0000	0.546	0.412	0.713
a_2_log10	-0.063	0.051	-1.224	0.2209	0.865	0.682	1.092
a_3_log10	-0.396	0.053	-7.411	0.0000	0.402	0.314	0.510
a_4_log10	-0.350	0.056	-6.209	0.0000	0.447	0.351	0.575
Model 8r							
f_max_hab0_log10	1.498	0.035	43.204	0.0000	31.487	26.985	36.417
f_max_hab1_log10	1.342	0.025	53.876	0.0000	21.986	19.649	24.403
n_half_0_log10	1.414	0.082	17.338	0.0000	25.971	17.578	36.119
n_half_1_log10	1.605	0.075	21.508	0.0000	40.242	28.798	56.488
n_half_2_log10	1.405	0.064	21.810	0.0000	25.415	19.147	33.542
n_half_3_log10	1.738	0.066	26.357	0.0000	54.714	40.600	73.305
n_half_4_log10	1.692	0.070	24.294	0.0000	49.227	35.023	66.971
Model 9h							
t_h_intercept_log10	-1.607	0.036	-44.903	0.0000	0.025	0.021	0.029
t_h_slope	0.128	0.014	8.866	0.0000	0.127	0.099	0.154
a_log10	-0.157	0.029	-5.486	0.0000	0.697	0.615	0.798
Model 9r							
f_max_intercept_log10	1.542	0.024	62.993	0.0000	34.831	31.327	38.620
f_max_slope	-0.094	0.009	-11.012	0.0000	-0.094	-0.110	-0.076
n_half_log10	1.531	0.044	35.031	0.0000	33.937	28.074	41.218
Model 10h							
t_h_intercept_log10	-1.510	0.033	-45.322	0.0000	0.031	0.027	0.036
t_h_slope	0.076	0.016	4.826	0.0000	0.076	0.044	0.104
a_hab0_log10	0.072	0.054	1.314	0.1887	1.179	0.915	1.507
a_hab1_log10	-0.241	0.033	-7.353	0.0000	0.574	0.493	0.671
Model 10r							
f_max_intercept_log10	1.513	0.031	48.459	0.0000	32.600	28.107	37.432
f_max_slope	-0.078	0.014	-5.425	0.0000	-0.078	-0.107	-0.050
n_half_hab0_log10	1.445	0.076	19.038	0.0000	27.839	19.529	38.280
n_half_hab1_log10	1.562	0.049	31.601	0.0000	36.444	29.350	45.350
Model 11h							
t_h_intercept_log10	-1.488	0.033	-45.420	0.0000	0.033	0.028	0.037
t_h_slope	0.063	0.016	3.856	0.0001	0.063	0.032	0.096
a_intercept_log10	0.102	0.052	1.947	0.0515	1.265	1.014	1.595
a_slope	-0.144	0.024	-5.956	0.0000	-0.144	-0.191	-0.095

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Table 21: All 32 summary tables from *Notonecta glauca* model fits.
 (continued)

Name	Orig.	Est.	SE	z	p	Estimate	CI low	CI up
Model 11r								
f_max_intercept_log10	1.488	0.033	45.420	0.0000	30.745	26.493	35.571	
f_max_slope	-0.063	0.016	-3.857	0.0001	-0.062	-0.095	-0.033	
n_half_intercept_log10	1.386	0.077	17.998	0.0000	24.304	17.194	34.843	
n_half_slope	0.081	0.036	2.225	0.0261	0.081	0.009	0.150	
Model 12h								
t_h_intercept_log10	-1.493	0.033	-45.054	0.0000	0.032	0.028	0.037	
t_h_slope	0.062	0.017	3.734	0.0002	0.061	0.032	0.095	
a_0_log10	0.089	0.054	1.632	0.1026	1.227	0.972	1.550	
a_1_log10	-0.291	0.058	-5.054	0.0000	0.511	0.382	0.659	
a_2_log10	-0.083	0.050	-1.654	0.0981	0.826	0.650	1.033	
a_3_log10	-0.372	0.056	-6.624	0.0000	0.425	0.334	0.542	
a_4_log10	-0.321	0.059	-5.402	0.0000	0.477	0.372	0.628	
Model 12r								
f_max_intercept_log10	1.493	0.033	45.054	0.0000	31.101	26.770	36.048	
f_max_slope	-0.062	0.017	-3.735	0.0002	-0.061	-0.094	-0.030	
n_half_0_log10	1.404	0.079	17.776	0.0000	25.342	17.522	36.417	
n_half_1_log10	1.661	0.069	24.147	0.0000	45.803	33.604	62.755	
n_half_2_log10	1.452	0.060	24.043	0.0000	28.346	21.643	37.359	
n_half_3_log10	1.680	0.074	22.813	0.0000	47.842	34.843	66.372	
n_half_4_log10	1.629	0.078	20.921	0.0000	42.570	29.916	58.930	
Model 13h								
t_h_0_log10	-1.611	0.038	-42.479	0.0000	0.024	0.021	0.029	
t_h_1_log10	-1.233	0.038	-32.446	0.0000	0.059	0.049	0.070	
t_h_2_log10	-1.435	0.036	-39.612	0.0000	0.037	0.031	0.043	
t_h_3_log10	-1.253	0.039	-32.161	0.0000	0.056	0.047	0.066	
t_h_4_log10	-1.208	0.039	-31.368	0.0000	0.062	0.052	0.073	
a_log10	-0.153	0.029	-5.358	0.0000	0.703	0.610	0.797	
Model 13r								
f_max_0_log10	1.541	0.025	61.458	0.0000	34.784	30.949	38.839	
f_max_1_log10	1.287	0.030	42.422	0.0000	19.350	16.956	22.077	
f_max_2_log10	1.416	0.028	51.411	0.0000	26.070	22.917	29.662	
f_max_3_log10	1.264	0.031	40.568	0.0000	18.371	16.057	21.001	
f_max_4_log10	1.255	0.031	40.067	0.0000	17.969	15.639	20.806	
n_half_log10	1.531	0.044	35.103	0.0000	33.928	28.059	41.379	
Model 14h								
t_h_0_log10	-1.498	0.035	-43.204	0.0000	0.032	0.027	0.037	
t_h_1_log10	-1.267	0.041	-30.789	0.0000	0.054	0.045	0.065	
t_h_2_log10	-1.477	0.041	-35.995	0.0000	0.033	0.028	0.040	
t_h_3_log10	-1.292	0.042	-30.706	0.0000	0.051	0.043	0.062	
t_h_4_log10	-1.241	0.041	-30.172	0.0000	0.057	0.047	0.069	
a_hab0_log10	0.084	0.055	1.510	0.1310	1.212	0.937	1.540	
a_hab1_log10	-0.240	0.033	-7.217	0.0000	0.575	0.498	0.670	
Model 14r								
f_max_0_log10	1.498	0.035	43.204	0.0000	31.487	27.138	36.908	
f_max_1_log10	1.304	0.033	39.997	0.0000	20.122	17.337	23.336	
f_max_2_log10	1.433	0.030	47.723	0.0000	27.122	23.590	31.131	
f_max_3_log10	1.282	0.033	38.276	0.0000	19.133	16.632	22.023	
f_max_4_log10	1.272	0.034	37.905	0.0000	18.699	16.167	21.609	
n_half_hab0_log10	1.414	0.082	17.338	0.0000	25.971	18.069	37.712	
n_half_hab1_log10	1.574	0.052	30.458	0.0000	37.468	30.305	47.220	
Model 15h								
t_h_0_log10	-1.489	0.033	-44.613	0.0000	0.032	0.028	0.038	

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Table 21: All 32 summary tables from *Notonecta glauca* model fits.
 (continued)

Name	Orig. Est.	SE	z	p	Estimate	CI low	CI up
t_h_1_log10	-1.243	0.039	-32.106	0.0000	0.057	0.048	0.067
t_h_2_log10	-1.448	0.037	-38.812	0.0000	0.036	0.030	0.042
t_h_3_log10	-1.335	0.047	-28.329	0.0000	0.046	0.037	0.057
t_h_4_log10	-1.276	0.045	-28.270	0.0000	0.053	0.043	0.065
a_intercept_log10	0.107	0.053	2.036	0.0418	1.280	1.015	1.629
a_slope	-0.144	0.024	-5.938	0.0000	-0.144	-0.191	-0.101
Model 15r							
f_max_0_log10	1.488	0.033	45.165	0.0000	30.741	26.692	35.447
f_max_1_log10	1.293	0.031	42.179	0.0000	19.646	17.042	22.570
f_max_2_log10	1.423	0.028	50.988	0.0000	26.474	23.302	30.134
f_max_3_log10	1.305	0.037	34.849	0.0000	20.181	17.016	23.974
f_max_4_log10	1.295	0.037	34.622	0.0000	19.703	16.463	23.308
n_half_intercept_log10	1.385	0.077	17.965	0.0000	24.285	17.488	34.978
n_half_slope	0.081	0.037	2.220	0.0264	0.081	0.006	0.150
Model 16h							
t_h_0_log10	-1.498	0.035	-43.204	0.0000	0.032	0.027	0.037
t_h_1_log10	-1.232	0.045	-27.187	0.0000	0.059	0.048	0.071
t_h_2_log10	-1.423	0.041	-34.733	0.0000	0.038	0.031	0.046
t_h_3_log10	-1.406	0.066	-21.145	0.0000	0.039	0.030	0.053
t_h_4_log10	-1.257	0.049	-25.651	0.0000	0.055	0.044	0.069
a_0_log10	0.084	0.055	1.510	0.1310	1.212	0.954	1.540
a_1_log10	-0.151	0.073	-2.063	0.0391	0.707	0.512	0.988
a_2_log10	-0.125	0.057	-2.193	0.0283	0.750	0.585	0.978
a_3_log10	-0.441	0.067	-6.611	0.0000	0.363	0.269	0.492
a_4_log10	-0.279	0.068	-4.102	0.0000	0.526	0.385	0.699
Model 16r							
f_max_0_log10	1.498	0.035	43.204	0.0000	31.487	26.657	36.949
f_max_1_log10	1.232	0.045	27.187	0.0000	17.046	13.919	20.963
f_max_2_log10	1.423	0.041	34.733	0.0000	26.492	22.228	32.510
f_max_3_log10	1.406	0.066	21.146	0.0000	25.453	18.474	34.405
f_max_4_log10	1.257	0.049	25.651	0.0000	18.057	14.948	22.500
n_half_0_log10	1.414	0.082	17.338	0.0000	25.971	17.494	38.107
n_half_1_log10	1.382	0.106	12.994	0.0000	24.113	15.028	38.992
n_half_2_log10	1.548	0.088	17.666	0.0000	35.334	24.252	53.009
n_half_3_log10	1.846	0.123	15.060	0.0000	70.211	39.911	123.848
n_half_4_log10	1.536	0.104	14.724	0.0000	34.349	22.416	55.725

Project Settings

We created the statistics in this report and the report itself using R version 4.4.3 (2025-02-28) - Trophy Case on a x86_64 computer with Linux Mint 22.1 as operating system. Find the loaded and attached packages that we used in table 22.

Table 22: All loaded R packages that we used in this report, including base packages and dependencies.

Package Name	Version	Is Package Attached?	Is a Base Package?
base	4.4.3	TRUE	TRUE
datasets	4.4.3	TRUE	TRUE
graphics	4.4.3	TRUE	TRUE
grDevices	4.4.3	TRUE	TRUE
methods	4.4.3	TRUE	TRUE
stats	4.4.3	TRUE	TRUE
utils	4.4.3	TRUE	TRUE
compiler	4.4.3	FALSE	TRUE
grid	4.4.3	FALSE	TRUE
parallel	4.4.3	FALSE	TRUE
stats4	4.4.3	FALSE	TRUE
tools	4.4.3	FALSE	TRUE
dplyr	1.1.4	TRUE	FALSE
foreach	1.5.2	TRUE	FALSE
bbmle	1.0.25.1	FALSE	FALSE
bdsmatrix	1.3-7	FALSE	FALSE
bitops	1.0-9	FALSE	FALSE
bookdown	0.42	FALSE	FALSE
boot	1.3-31	FALSE	FALSE
cli	3.6.3	FALSE	FALSE
coda	0.19-4.1	FALSE	FALSE
codetools	0.2-20	FALSE	FALSE
colorspace	2.1-1	FALSE	FALSE
curl	6.2.0	FALSE	FALSE
digest	0.6.37	FALSE	FALSE
doParallel	1.0.17	FALSE	FALSE
emdbook	1.3.13	FALSE	FALSE
evaluate	1.0.3	FALSE	FALSE
fastmap	1.2.0	FALSE	FALSE
frair	0.5.100	FALSE	FALSE
generics	0.1.3	FALSE	FALSE
gh	1.4.1	FALSE	FALSE
gitcreds	0.1.2	FALSE	FALSE
glue	1.8.0	FALSE	FALSE
here	1.0.1	FALSE	FALSE
htmltools	0.5.8.1	FALSE	FALSE
httr2	1.1.0	FALSE	FALSE
iterators	1.0.14	FALSE	FALSE
jsonlite	2.0.0	FALSE	FALSE
kableExtra	1.4.0	FALSE	FALSE
knitr	1.49	FALSE	FALSE
lamW	2.2.4	FALSE	FALSE
lattice	0.22-5	FALSE	FALSE
lifecycle	1.0.4	FALSE	FALSE
magrittr	2.0.3	FALSE	FALSE

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Table 22: All loaded R packages that we used in this report, including base packages and dependencies. (*continued*)

Package Name	Version	Is Package Attached?	Is a Base Package?
MASS	7.3-65	FALSE	FALSE
Matrix	1.7-3	FALSE	FALSE
munsell	0.5.1	FALSE	FALSE
mvtnorm	1.3-3	FALSE	FALSE
numDeriv	2016.8-1.1	FALSE	FALSE
pillar	1.10.1	FALSE	FALSE
pkgconfig	2.0.3	FALSE	FALSE
plyr	1.8.9	FALSE	FALSE
png	0.1-8	FALSE	FALSE
R6	2.6.1	FALSE	FALSE
rappdirs	0.3.3	FALSE	FALSE
Rcpp	1.0.14	FALSE	FALSE
RcppParallel	5.1.10	FALSE	FALSE
RCurl	1.98-1.16	FALSE	FALSE
rlang	1.1.5	FALSE	FALSE
rmarkdown	2.29	FALSE	FALSE
rprojroot	2.0.4	FALSE	FALSE
rstudioapi	0.17.1	FALSE	FALSE
scales	1.3.0	FALSE	FALSE
sessioninfo	1.2.3	FALSE	FALSE
stringi	1.8.4	FALSE	FALSE
stringr	1.5.1	FALSE	FALSE
supportR	1.4.0	FALSE	FALSE
svglite	2.1.3	FALSE	FALSE
systemfonts	1.2.1	FALSE	FALSE
tibble	3.2.1	FALSE	FALSE
tidyselect	1.2.1	FALSE	FALSE
vctrs	0.6.5	FALSE	FALSE
viridisLite	0.4.2	FALSE	FALSE
withr	3.0.2	FALSE	FALSE
xfun	0.50	FALSE	FALSE
xml2	1.3.6	FALSE	FALSE
yaml	2.3.10	FALSE	FALSE