

# Pumas NCA Tutorial - Single dose ORAL administration 2 formulations and 2 analytes

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using Pumas, PumasTutorials, CSV

## 1 Introduction

In this tutorial, we will cover the fundamentals of performing an NCA analysis with Pumas using an example dataset in which a single oral dose of a capsule formulation and a single oral dose of an oral solution were administered and the concentration of two analytes (parent and metabolite) was measured.

## 2 The dataset

- Single oral dose of a capsule containing 2000 mg was administered to 24 different subjects.
- Washout period
- Single oral dose of an oral solution containing 2000 mg was administered to the same subjects.
- Samples were collected every 30 minutes.

Let's start reading the dataset. By using the `missingstring` option we are specifying how the missing values are labeled in our dataset.

```
data = PumasTutorials.tutorial_data("data/nca","SD_oral_2analytes_2formulations")
data = CSV.read(data,missingstring="NA")
first(data,10)
```

	ID	time	DV	Analyte	BLQ	Type	DOSE	Formulation
	Int64	Float64	Float64	String	Int64	String	Int64	String
1	1	0.0	0.0	Metabolite	0	Capsules	2000	ev
2	1	0.5	0.677881	Metabolite	0	Capsules	0	ev
3	1	1.0	2.13233	Metabolite	0	Capsules	0	ev
4	1	1.5	3.56769	Metabolite	0	Capsules	0	ev
5	1	2.0	4.77554	Metabolite	0	Capsules	0	ev
6	1	2.5	5.94978	Metabolite	0	Capsules	0	ev
7	1	3.0	7.13593	Metabolite	0	Capsules	0	ev
8	1	3.5	6.94463	Metabolite	0	Capsules	0	ev
9	1	4.0	7.32453	Metabolite	0	Capsules	0	ev
10	1	4.5	7.6625	Metabolite	0	Capsules	0	ev

This will be an abbreviated tutorial as the main difference is in the specification of the `read_nca` function. For a complete listing of all NCA options, please check the first tutorial on single oral dose administration

### 3 Defining the units

```
timeu = u"hr"
concu = u"mg/L"
amtu = u"mg"
```

mg

### 4 Defining the population object

The standard requirements of `read_nca` as specified in other tutorials exist. In this example since two different formulations were administered and parent and metabolite concentrations were measured, we need to specify the grouping variable so that the PK parameters are calculated for each formulation and each analyte (`group=`).

```
pop = read_nca(data, id=:ID, time=:time, conc=:DV, amt=:DOSE, ii=24timeu,
  group=[:Type,:Analyte],
  route=:Formulation, timeu=timeu, concu=concu, amtu=amtu, lloq=0.4concu)
```

NCAPopulation (24 subjects):

ID: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]

Group: Array{Pair{String,String},1}[[{"Type"=>"Capsules", "Analyte"=>"Metabolite"}, {"Type"=>"Capsules", "Analyte"=>"Parent"}, {"Type"=>"Solution", "Analyte"=>"Metabolite"}, {"Type"=>"Solution", "Analyte"=>"Parent"}]

```
concentration: mg L^-1
time:         hr
auc:          mg hr L^-1
aumc:         mg hr^2 L^-1
λz:           hr^-1
dose:         mg
```

Key features of the syntax above:

- `route=` is mapped to the `Formulation` column that should specify `ev`

- LLOQ was set to 0.4 by `llq=0.4concu`
- `group=[:Type,:Analyte]` provides a way to perform NCA on two different analytes and formulations at the same time

To check if the grouping works, let's calculate the AUC

```
NCA.auc(pop,auctype=:last,method=:linear)
```

	id	Type	Analyte	auc
	Int64	String	String	Unitful
1	1	Capsules	Metabolite	81.6192 mg hr L <sup>-1</sup>
2	2	Capsules	Metabolite	81.9052 mg hr L <sup>-1</sup>
3	3	Capsules	Metabolite	83.3829 mg hr L <sup>-1</sup>
4	4	Capsules	Metabolite	82.0563 mg hr L <sup>-1</sup>
5	5	Capsules	Metabolite	81.0593 mg hr L <sup>-1</sup>
6	6	Capsules	Metabolite	83.0437 mg hr L <sup>-1</sup>
7	7	Capsules	Metabolite	84.1976 mg hr L <sup>-1</sup>
8	8	Capsules	Metabolite	82.6067 mg hr L <sup>-1</sup>
9	9	Capsules	Metabolite	82.4071 mg hr L <sup>-1</sup>
10	10	Capsules	Metabolite	82.3146 mg hr L <sup>-1</sup>
11	11	Capsules	Metabolite	81.1287 mg hr L <sup>-1</sup>
12	12	Capsules	Metabolite	81.8532 mg hr L <sup>-1</sup>
13	13	Capsules	Metabolite	82.7287 mg hr L <sup>-1</sup>
14	14	Capsules	Metabolite	83.6679 mg hr L <sup>-1</sup>
15	15	Capsules	Metabolite	82.162 mg hr L <sup>-1</sup>
16	16	Capsules	Metabolite	81.5886 mg hr L <sup>-1</sup>
17	17	Capsules	Metabolite	81.3252 mg hr L <sup>-1</sup>
18	18	Capsules	Metabolite	82.517 mg hr L <sup>-1</sup>
19	19	Capsules	Metabolite	83.5749 mg hr L <sup>-1</sup>
20	20	Capsules	Metabolite	83.0247 mg hr L <sup>-1</sup>
21	21	Capsules	Metabolite	82.418 mg hr L <sup>-1</sup>
22	22	Capsules	Metabolite	81.514 mg hr L <sup>-1</sup>
23	23	Capsules	Metabolite	83.5594 mg hr L <sup>-1</sup>
24	24	Capsules	Metabolite	79.7166 mg hr L <sup>-1</sup>
25	1	Capsules	Parent	101.678 mg hr L <sup>-1</sup>
26	2	Capsules	Parent	101.841 mg hr L <sup>-1</sup>
27	3	Capsules	Parent	103.924 mg hr L <sup>-1</sup>
28	4	Capsules	Parent	101.85 mg hr L <sup>-1</sup>
29	5	Capsules	Parent	100.914 mg hr L <sup>-1</sup>
30	6	Capsules	Parent	103.36 mg hr L <sup>-1</sup>
31	7	Capsules	Parent	104.645 mg hr L <sup>-1</sup>
32	8	Capsules	Parent	102.618 mg hr L <sup>-1</sup>
33	9	Capsules	Parent	102.766 mg hr L <sup>-1</sup>
34	10	Capsules	Parent	102.224 mg hr L <sup>-1</sup>
35	11	Capsules	Parent	100.61 mg hr L <sup>-1</sup>
36	12	Capsules	Parent	101.917 mg hr L <sup>-1</sup>
37	13	Capsules	Parent	102.827 mg hr L <sup>-1</sup>
38	14	Capsules	Parent	103.845 mg hr L <sup>-1</sup>
39	15	Capsules	Parent	102.082 mg hr L <sup>-1</sup>
40	16	Capsules	Parent	101.73 mg hr L <sup>-1</sup>
41	17	Capsules	Parent	101.307 mg hr L <sup>-1</sup>
42	18	Capsules	Parent	102.803 mg hr L <sup>-1</sup>
43	19	Capsules	Parent	103.963 mg hr L <sup>-1</sup>
44	20	Capsules	Parent	103.336 mg hr L <sup>-1</sup>
45	21	Capsules	Parent	102.498 mg hr L <sup>-1</sup>
46	22	Capsules	Parent	101.161 mg hr L <sup>-1</sup>
47	23	Capsules	Parent	104.269 mg hr L <sup>-1</sup>
48	24	Capsules	Parent	99.3001 mg hr L <sup>-1</sup>
49	1	Solution	Metabolite	110.772 mg hr L <sup>-1</sup>
50	2	Solution	Metabolite	110.572 <sup>4</sup> mg hr L <sup>-1</sup>
51	3	Solution	Metabolite	110.713 mg hr L <sup>-1</sup>
52	4	Solution	Metabolite	109.459 mg hr L <sup>-1</sup>

All other NCA function work on this grouped variable. Let's directly print the NCA report.

```
report = NCAReport(pop)
report = NCA.to_dataframe(report)
```

	id	Type	Analyte	doseamt	lambda_z	half_life	tmax	tlag	c
	Int64	String	String	Unitful	Unitful	Unitful	Unitful	Unitful	Unitful
1	1	Capsules	Metabolite	2000 mg	0.375321 hr <sup>-1</sup>	1.84681 hr	5.0 hr	0.0 hr	8.375
2	2	Capsules	Metabolite	2000 mg	0.289601 hr <sup>-1</sup>	2.39345 hr	5.5 hr	0.0 hr	8.176
3	3	Capsules	Metabolite	2000 mg	0.193229 hr <sup>-1</sup>	3.58718 hr	5.0 hr	0.0 hr	8.463
4	4	Capsules	Metabolite	2000 mg	0.397353 hr <sup>-1</sup>	1.74441 hr	5.5 hr	0.0 hr	8.007
5	5	Capsules	Metabolite	2000 mg	-0.253963 hr <sup>-1</sup>	-2.72932 hr	6.0 hr	0.0 hr	8.445
6	6	Capsules	Metabolite	2000 mg	0.245656 hr <sup>-1</sup>	2.82162 hr	4.0 hr	0.0 hr	8.358
7	7	Capsules	Metabolite	2000 mg	0.207358 hr <sup>-1</sup>	3.34276 hr	4.0 hr	0.0 hr	8.667
8	8	Capsules	Metabolite	2000 mg	0.369532 hr <sup>-1</sup>	1.87574 hr	6.0 hr	0.0 hr	8.034
9	9	Capsules	Metabolite	2000 mg	0.313687 hr <sup>-1</sup>	2.20968 hr	5.5 hr	0.0 hr	7.945
10	10	Capsules	Metabolite	2000 mg	0.278758 hr <sup>-1</sup>	2.48655 hr	5.5 hr	0.0 hr	8.106
11	11	Capsules	Metabolite	2000 mg	-0.796943 hr <sup>-1</sup>	-0.869758 hr	4.0 hr	0.0 hr	7.867
12	12	Capsules	Metabolite	2000 mg	0.282085 hr <sup>-1</sup>	2.45722 hr	4.0 hr	0.0 hr	8.273
13	13	Capsules	Metabolite	2000 mg	0.22053 hr <sup>-1</sup>	3.1431 hr	4.5 hr	0.0 hr	8.522
14	14	Capsules	Metabolite	2000 mg	0.179082 hr <sup>-1</sup>	3.87057 hr	4.0 hr	0.0 hr	7.935
15	15	Capsules	Metabolite	2000 mg	0.147145 hr <sup>-1</sup>	4.71066 hr	5.0 hr	0.0 hr	8.252
16	16	Capsules	Metabolite	2000 mg	0.888041 hr <sup>-1</sup>	0.780535 hr	5.5 hr	0.0 hr	8.007
17	17	Capsules	Metabolite	2000 mg	0.377237 hr <sup>-1</sup>	1.83743 hr	6.0 hr	0.0 hr	8.086
18	18	Capsules	Metabolite	2000 mg	0.16821 hr <sup>-1</sup>	4.12072 hr	4.5 hr	0.0 hr	7.883
19	19	Capsules	Metabolite	2000 mg	0.333248 hr <sup>-1</sup>	2.07998 hr	5.0 hr	0.0 hr	8.739
20	20	Capsules	Metabolite	2000 mg	0.36101 hr <sup>-1</sup>	1.92002 hr	4.0 hr	0.0 hr	7.795
21	21	Capsules	Metabolite	2000 mg	0.221688 hr <sup>-1</sup>	3.12667 hr	4.5 hr	0.0 hr	7.993
22	22	Capsules	Metabolite	2000 mg	1.11474 hr <sup>-1</sup>	0.621802 hr	6.0 hr	0.0 hr	7.573
23	23	Capsules	Metabolite	2000 mg	0.800884 hr <sup>-1</sup>	0.865478 hr	5.0 hr	0.0 hr	8.169
24	24	Capsules	Metabolite	2000 mg	-0.890666 hr <sup>-1</sup>	-0.778235 hr	4.5 hr	0.0 hr	7.785
25	1	Capsules	Parent	2000 mg	0.376974 hr <sup>-1</sup>	1.83871 hr	3.0 hr	0.0 hr	10.30
26	2	Capsules	Parent	2000 mg	0.287911 hr <sup>-1</sup>	2.4075 hr	3.5 hr	0.0 hr	10.03
27	3	Capsules	Parent	2000 mg	0.195978 hr <sup>-1</sup>	3.53686 hr	3.0 hr	0.0 hr	10.81
28	4	Capsules	Parent	2000 mg	0.394215 hr <sup>-1</sup>	1.7583 hr	3.5 hr	0.0 hr	9.859
29	5	Capsules	Parent	2000 mg	0.133014 hr <sup>-1</sup>	5.21108 hr	5.0 hr	0.0 hr	10.01
30	6	Capsules	Parent	2000 mg	0.245908 hr <sup>-1</sup>	2.81873 hr	4.0 hr	0.0 hr	10.79
31	7	Capsules	Parent	2000 mg	0.208447 hr <sup>-1</sup>	3.32529 hr	4.0 hr	0.0 hr	11.2
32	8	Capsules	Parent	2000 mg	0.366268 hr <sup>-1</sup>	1.89246 hr	4.0 hr	0.0 hr	10.24
33	9	Capsules	Parent	2000 mg	0.312375 hr <sup>-1</sup>	2.21896 hr	3.5 hr	0.0 hr	10.63
34	10	Capsules	Parent	2000 mg	0.277981 hr <sup>-1</sup>	2.4935 hr	3.0 hr	0.0 hr	10.40
35	11	Capsules	Parent	2000 mg	-0.756411 hr <sup>-1</sup>	-0.916364 hr	4.0 hr	0.0 hr	10.22
36	12	Capsules	Parent	2000 mg	0.280981 hr <sup>-1</sup>	2.46688 hr	4.0 hr	0.0 hr	10.81
37	13	Capsules	Parent	2000 mg	0.175111 hr <sup>-1</sup>	3.95834 hr	4.0 hr	0.0 hr	11.10
38	14	Capsules	Parent	2000 mg	0.18069 hr <sup>-1</sup>	3.83611 hr	3.0 hr	0.0 hr	10.83
39	15	Capsules	Parent	2000 mg	0.150714 hr <sup>-1</sup>	4.59908 hr	5.0 hr	0.0 hr	10.13
40	16	Capsules	Parent	2000 mg	0.864551 hr <sup>-1</sup>	0.801742 hr	4.0 hr	0.0 hr	10.09
41	17	Capsules	Parent	2000 mg	0.375308 hr <sup>-1</sup>	1.84688 hr	3.5 hr	0.0 hr	10.32
42	18	Capsules	Parent	2000 mg	0.171226 hr <sup>-1</sup>	4.04815 hr	3.5 hr	0.0 hr	10.20
43	19	Capsules	Parent	2000 mg	0.329593 hr <sup>-1</sup>	2.10304 hr	3.0 hr	0.0 hr	11.22
44	20	Capsules	Parent	2000 mg	0.355591 hr <sup>-1</sup>	1.94928 hr	3.0 hr	0.0 hr	10.55
45	21	Capsules	Parent	2000 mg	0.222483 hr <sup>-1</sup>	3.1155 hr	4.0 hr	0.0 hr	10.15
46	22	Capsules	Parent	2000 mg	1.08696 hr <sup>-1</sup>	0.637695 hr	3.5 hr	0.0 hr	9.998
47	23	Capsules	Parent	2000 mg	0.783621 hr <sup>-1</sup>	0.884544 hr	4.0 hr	0.0 hr	10.30
48	24	Capsules	Parent	2000 mg	-0.841545 hr <sup>-1</sup>	-0.823661 hr	3.5 hr	0.0 hr	10.09
49	1	Solution	Metabolite	2000 mg	0.46133 hr <sup>-1</sup>	1.5025 hr	5.5 hr	0.0 hr	11.01
50	2	Solution	Metabolite	2000 mg	0.208627 hr <sup>-1</sup>	3.32243 hr	4.5 hr	0.0 hr	11.06

Finally, we can save this data frame as a csv file if desired.

```
CSV.write("./tutorials/nca/report_SD_oral_2analytes_2formulations.csv", report)

using PumasTutorials
PumasTutorials.tutorial_footer(WEAVE_ARGS[:folder],WEAVE_ARGS[:file])
```

## 4.1 Appendix

These tutorials are part of the PumasTutorials.jl repository, found at: <https://github.com/JuliaDiffEq/Di>

To locally run this tutorial, do the following commands:

```
using PumasTutorials
PumasTutorials.weave_file("nca","SD_ORAL_2ANALYTES_2FORMULATIONS.jmd")
```

Computer Information:

```
Julia Version 1.1.1
Commit 55e36cc308 (2019-05-16 04:10 UTC)
Platform Info:
  OS: Windows (x86_64-w64-mingw32)
  CPU: Intel(R) Core(TM) i7-8550U CPU @ 1.80GHz
  WORD_SIZE: 64
  LIBM: libopenlibm
  LLVM: libLLVM-6.0.1 (ORCJIT, skylake)
Environment:
  JULIA_EDITOR = "C:\Users\accou\AppData\Local\atom\app-1.38.2\atom.exe" -a
  JULIA_NUM_THREADS = 4
```

Package Information:

```
Status `C:\Users\accou\.julia\environments\v1.1\Project.toml`
[621f4979-c628-5d54-868e-fcf4e3e8185c] AbstractFFTs 0.4.1
[c52e3926-4ff0-5f6e-af25-54175e0327b1] Atom 0.8.8
[f0abef60-9ec0-11e9-27de-db6506a91768] AutoOffload 0.1.0
[6e4b80f9-dd63-53aa-95a3-0cdb28fa8baf] BenchmarkTools 0.4.2
[4ece37e6-a012-11e8-38cd-91247efc2c34] Bioequivalence 0.1.0
[336ed68f-0bac-5ca0-87d4-7b16caf5d00b] CSV 0.5.9
[c5f51814-7f29-56b8-a69c-e4d8f6be1fde] CUDAdrv 3.0.1
[be33ccc6-a3ff-5ff2-a52e-74243cff1e17] CUDAnative 2.2.1
[49dc2e85-a5d0-5ad3-a950-438e2897f1b9] Calculus 0.5.0
[7057c7e9-c182-5462-911a-8362d720325c] Cassette 0.2.5
[34da2185-b29b-5c13-b0c7-acf172513d20] Compat 2.1.0
[3a865a2d-5b23-5a0f-bc46-62713ec82fae] CuArrays 1.1.0
[667455a9-e2ce-5579-9412-b964f529a492] Cubature 1.4.0
[a93c6f00-e57d-5684-b7b6-d8193f3e46c0] DataFrames 0.18.4
[82cc6244-b520-54b8-b5a6-8a565e85f1d0] DataInterpolations 0.2.0
```

[31a5f54b-26ea-5ae9-a837-f05ce5417438] Debugger 0.5.0  
 [bcd4f6db-9728-5f36-b5f7-82caef46ccdb] DelayDiffEq 5.9.1  
 [2b5f629d-d688-5b77-993f-72d75c75574e] DiffEqBase 5.16.3  
 [ebbdde9d-f333-5424-9be2-dbf1e9acfb5e] DiffEqBayes 1.2.0  
 [31c91b34-3c75-11e9-0341-95557aab0344] DiffEqBenchmarks 0.1.0  
 [459566f4-90b8-5000-8ac3-15dfb0a30def] DiffEqCallbacks 2.5.2+  
 [f3b72e0c-5b89-59e1-b016-84e28bfd966d] DiffEqDevTools 2.13.0  
 [01453d9d-ee7c-5054-8395-0335cb756afa] DiffEqDiffTools 0.14.0  
 [aae7a2af-3d4f-5e19-a356-7da93b79d9d0] DiffEqFlux 0.6.0  
 [071ae1c0-96b5-11e9-1965-c90190d839ea] DiffEqGPU 0.1.0  
 [c894b116-72e5-5b58-be3c-e6d8d4ac2b12] DiffEqJump 6.1.1+  
 [8f2b45d5-b17b-5532-9e92-98ae0077e2e3] DiffEqMachineLearning 0.1.0  
 [78ddff82-25fc-5f2b-89aa-309469cbf16f] DiffEqMonteCarlo 0.15.1  
 [77a26b50-5914-5dd7-bc55-306e6241c503] DiffEqNoiseProcess 3.3.1  
 [9fdde737-9c7f-55bf-ade8-46b3f136cc48] DiffEqOperators 3.5.0  
 [055956cb-9e8b-5191-98cc-73ae4a59e68a] DiffEqPhysics 3.2.0  
 [a077e3f3-b75c-5d7f-a0c6-6bc4c8ec64a9] DiffEqProblemLibrary 4.3.0  
 [41bf760c-e81c-5289-8e54-58b1f1f8abe2] DiffEqSensitivity 3.3.0  
 [6d1b261a-3be8-11e9-3f2f-0b112a9a8436] DiffEqTutorials 0.1.0  
 [0c46a032-eb83-5123-abaf-570d42b7fbaa] DifferentialEquations 6.6.0  
 [31c24e10-a181-5473-b8eb-7969acd0382f] Distributions 0.20.0  
 [e30172f5-a6a5-5a46-863b-614d45cd2de4] Documenter 0.23.0  
 [587475ba-b771-5e3f-ad9e-33799f191a9c] Flux 0.8.3  
 [f6369f11-7733-5829-9624-2563aa707210] ForwardDiff 0.10.3+  
 [ba82f77b-6841-5d2e-bd9f-4daf811aec27] GPUifyLoops 0.2.5  
 [c91e804a-d5a3-530f-b6f0-dfbca275c004] Gadfly 1.1.0  
 [bc5e4493-9b4d-5f90-b8aa-2b2bcaad7a26] GitHub 5.1.1  
 [7073ff75-c697-5162-941a-fcdaad2a7d2a] IJulia 1.18.1  
 [42fd0dbc-a981-5370-80f2-aaf504508153] IterativeSolvers 0.8.1  
 [033835bb-8acc-5ee8-8aae-3f567f8a3819] JLD2 0.1.2  
 [e5e0dc1b-0480-54bc-9374-aad01c23163d] Juno 0.7.0  
 [2d691ee1-e668-5016-a719-b2531b85e0f5] LIBLINEAR 0.5.1  
 [7f56f5a3-f504-529b-bc02-0b1fe5e64312] LSODA 0.4.0  
 [6f1fad26-d15e-5dc8-ae53-837a1d7b8c9f] Libtask 0.3.0  
 [c7f686f2-ff18-58e9-bc7b-31028e88f75d] MCMCChains 0.3.10  
 [33e6dc65-8f57-5167-99aa-e5a354878fb2] MKL 0.0.0  
 [cc2ba9b6-d476-5e6d-8eaf-a92d5412d41d] MLDataUtils 0.5.0  
 [eb30cadb-4394-5ae3-aed4-317e484a6458] MLDatasets 0.3.0  
 [961ee093-0014-501f-94e3-6117800e7a78] ModelingToolkit 0.5.0  
 [4886b29c-78c9-11e9-0a6e-41e1f4161f7b] MonteCarloIntegration 0.0.1  
 [2774e3e8-f4cf-5e23-947b-6d7e65073b56] NLSolve 4.0.0  
 [872c559c-99b0-510c-b3b7-b6c96a88d5cd] NNlib 0.6.0  
 [8faf48c0-8b73-11e9-0e63-2155955bfa4d] NeuralNetDiffEq 0.1.0  
 [09606e27-ecf5-54fc-bb29-004bd9f985bf] ODEInterfaceDiffEq 3.3.1  
 [1dea7af3-3e70-54e6-95c3-0bf5283fa5ed] OrdinaryDiffEq 5.12.0  
 [65888b18-ceab-5e60-b2b9-181511a3b968] ParameterizedFunctions 4.2.0  
 [14b8a8f1-9102-5b29-a752-f990bacb7fe1] PkgTemplates 0.6.1  
 [91a5bcdd-55d7-5caf-9e0b-520d859cae80] Plots 0.25.3  
 [92933f4c-e287-5a05-a399-4b506db050ca] ProgressMeter 1.0.0



[d7b8c89e-ad89-52e0-b9fd-d0ed321fa021] Pumas 0.1.0  
[b7b41870-aa11-11e9-048a-09266ec4a62f] PumasTutorials 0.0.1  
[438e738f-606a-5dbb-bf0a-cddfbfd45ab0] PyCall 1.91.2  
[d330b81b-6aea-500a-939a-2ce795aea3ee] PyPlot 2.8.1  
[1fd47b50-473d-5c70-9696-f719f8f3bcd] QuadGK 2.1.0  
[612083be-0b0f-5412-89c1-4e7c75506a58] Queryverse 0.3.1  
[6f49c342-dc21-5d91-9882-a32aef131414] RCall 0.13.3  
[731186ca-8d62-57ce-b412-fbd966d074cd] RecursiveArrayTools 0.20.0  
[37e2e3b7-166d-5795-8a7a-e32c996b4267] ReverseDiff 0.3.1  
[295af30f-e4ad-537b-8983-00126c2a3abe] Revise 2.1.6  
[2b6d1eac-7baa-5078-8adc-e6a3e659f14f] SingleFloats 0.1.3  
[47a9eef4-7e08-11e9-0b38-333d64bd3804] SparseDiffTools 0.5.0  
[90137ffa-7385-5640-81b9-e52037218182] StaticArrays 0.11.0  
[4c63d2b9-4356-54db-8cca-17b64c39e42c] StatsFuns 0.8.0  
[f3b207a7-027a-5e70-b257-86293d7955fd] StatsPlots 0.11.0  
[9672c7b4-1e72-59bd-8a11-6ac3964bc41f] SteadyStateDiffEq 1.5.0  
[789caeaf-c7a9-5a7d-9973-96adeb23e2a0] StochasticDiffEq 6.6.0  
[c3572dad-4567-51f8-b174-8c6c989267f4] Sundials 3.6.1  
[fd094767-a336-5f1f-9728-57cf17d0bbfb] Suppressor 0.1.1  
[6fc51010-71bc-11e9-0e15-a3fcc6593c49] Surrogates 0.1.0  
[9f7883ad-71c0-57eb-9f7f-b5c9e6d3789c] Tracker 0.2.2  
[fce5fe82-541a-59a6-adf8-730c64b5f9a0] Turing 0.6.18  
[1986cc42-f94f-5a68-af5c-568840ba703d] Unitful 0.16.0  
[44d3d7a6-8a23-5bf8-98c5-b353f8df5ec9] Weave 0.9.1  
[e88e6eb3-aa80-5325-afca-941959d7151f] Zygote 0.3.2