Dynamics of acute oil toxicity in different life stages of the copepod Calanus finmarchicus

Tjalling Jager, Bjørn Henrik Hansen, Dag Altin, Ida B. Øverjordet, Iurgi Salaberria, Mathijs Smit, Anders J. Olsen, Cecilie Miljeteig, Trond Nordtug

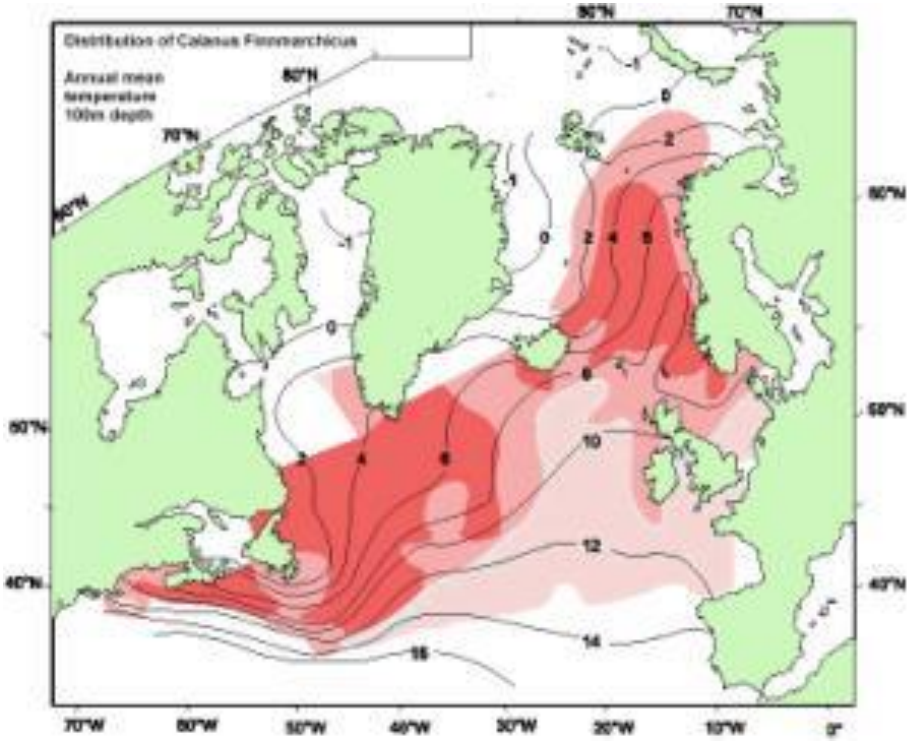
DEBtox Research

SINTEF

NTNU
Norwegian University of Science and Technology

Introduction

- *Calanus finmarchicus* (Copepoda)
- Widely distributed in North Atlantic
- Need to assess impacts of oil activities



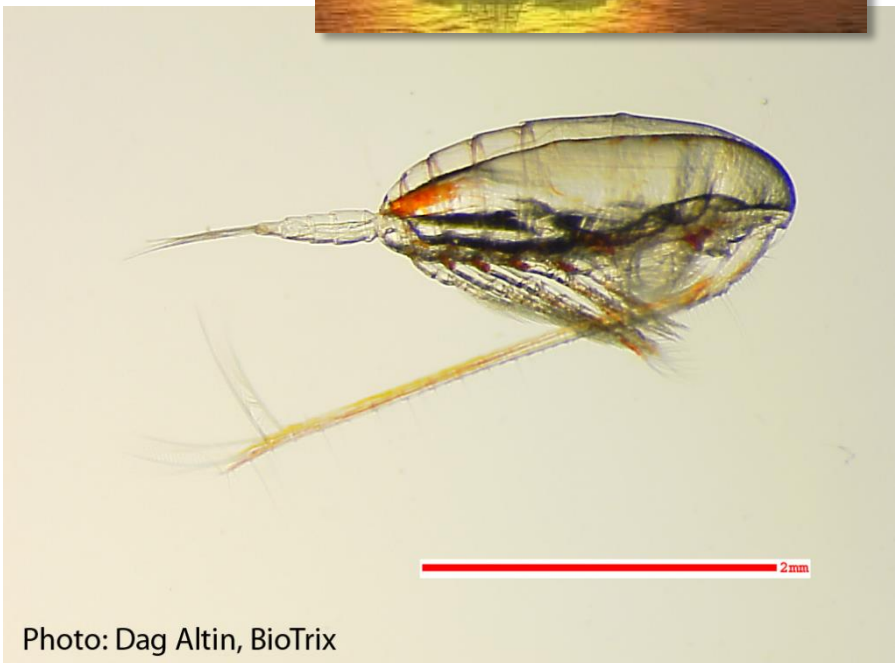
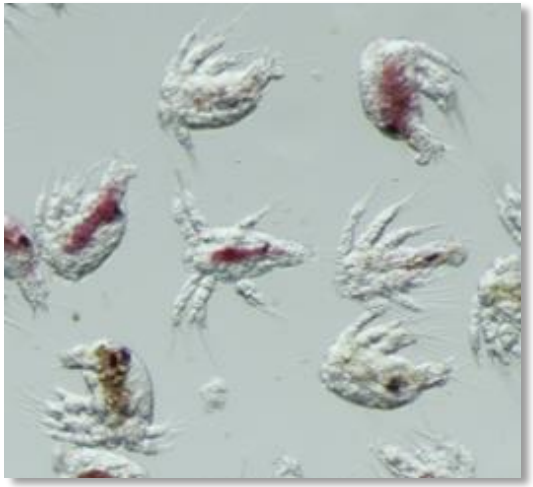


Photo: Dag Altin, BioTrix

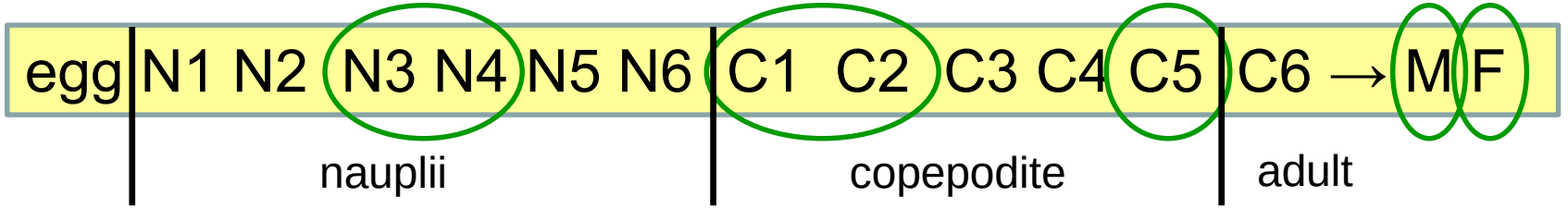
Calanus life cycle

egg	N1 N2 N3 N4 N5 N6	C1 C2 C3 C4 C5	C6
	nauplii	copepodite	adult

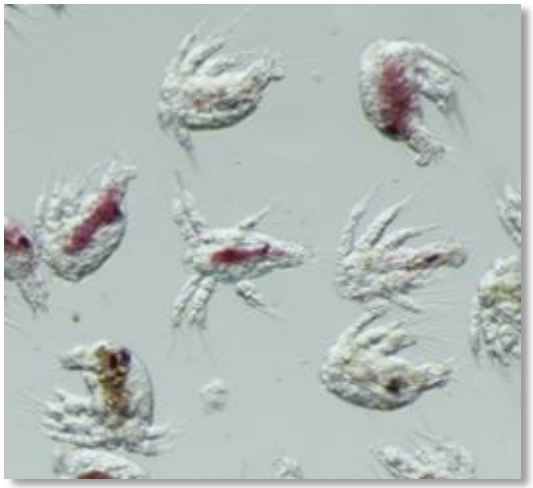
- Stages differ in size, shape, lipids etc.
- How does sensitivity to oil vary between stages?



Experimental setup



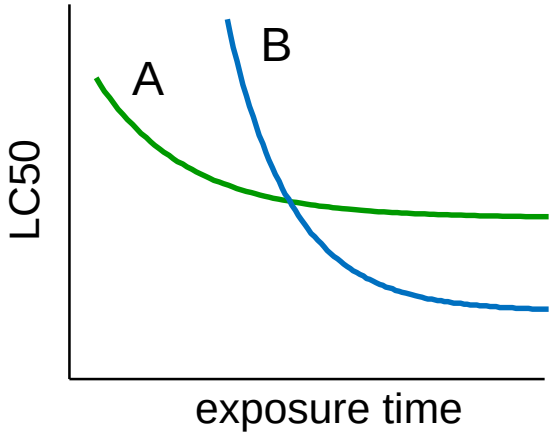
- Acute toxicity tests, 5 life stages
- Fresh and weathered oil WSFs



What is 'sensitivity'?

LC50: estimated concentration for 50% mortality after specified exposure duration

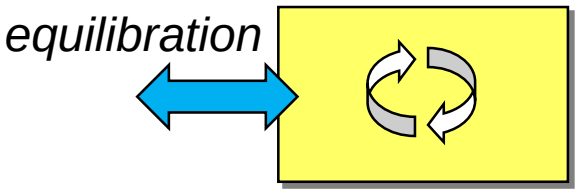
- However ….
  - LC50 changes over time
  - *how* it changes with time depends on chemical, life stage, …

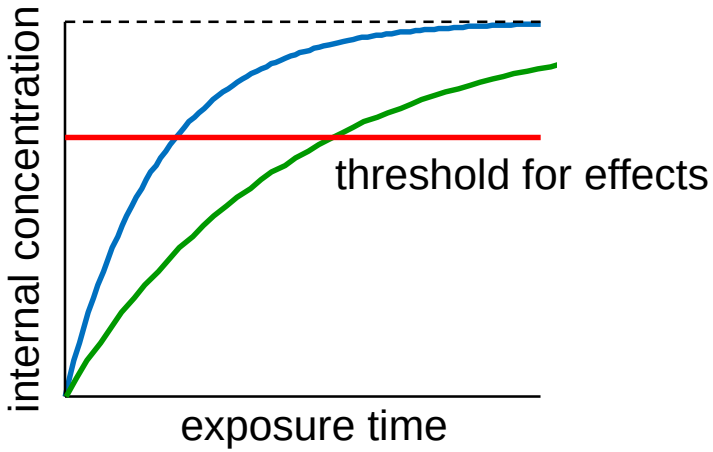


What is 'sensitivity'?

LC50: estimated concentration for 50% mortality after specified exposure duration

- However ….
  - LC50 changes over time
  - *how* it changes with time depends on chemical, life stage, …
- Part of the story is toxicokinetics (TK) …





Dynamic modelling

- Toxicokinetic-toxicodynamic modelling
  - explicitly model effects over time
  - for survival: GUTS

Environmental Science & Technology

2011

CRITICAL REVIEW

pubs.acs.org/est

General Unified Threshold Model of Survival - a Toxicokinetic-Toxicodynamic Framework for Ecotoxicology

Tjalling Jager,[†] Carlo Albert,[‡] Thomas G. Preuss,[§] and Roman Ashauer[‡,*]

[†]Department of Theoretical Biology, Vrije Universiteit, de Boelelaan 1085, NL-1081 HV, Amsterdam, The Netherlands

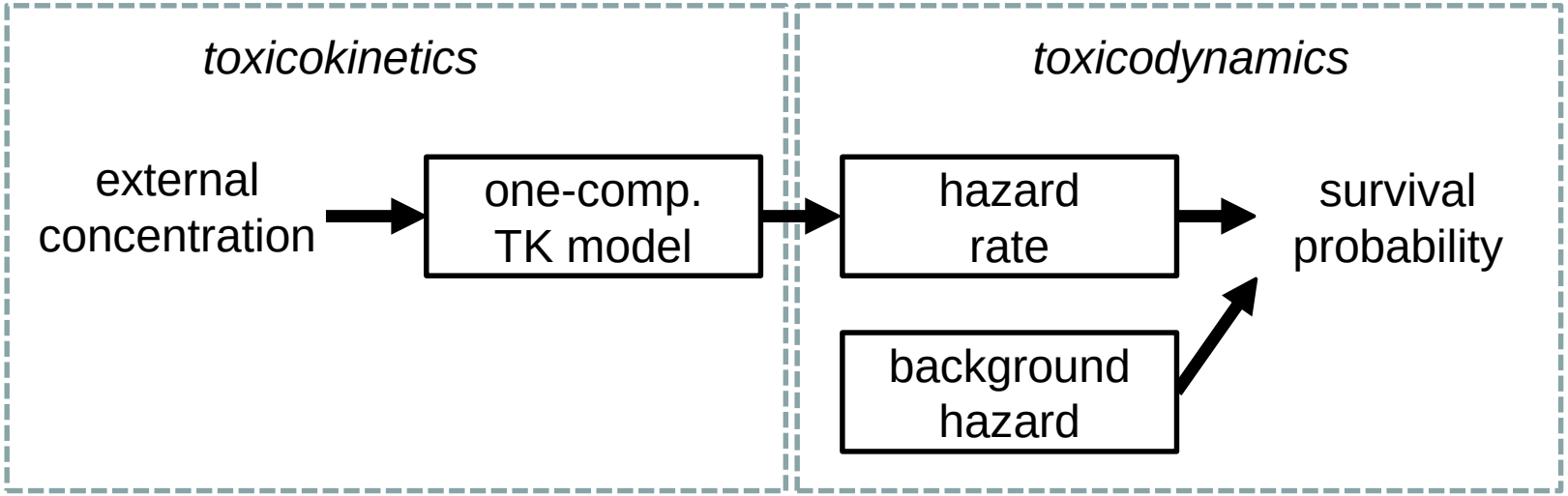
[‡]Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland

[§]Institute for Environmental Research, RWTH Aachen University, Worringerweg 1, D-52064, Aachen, Germany

Supporting Information

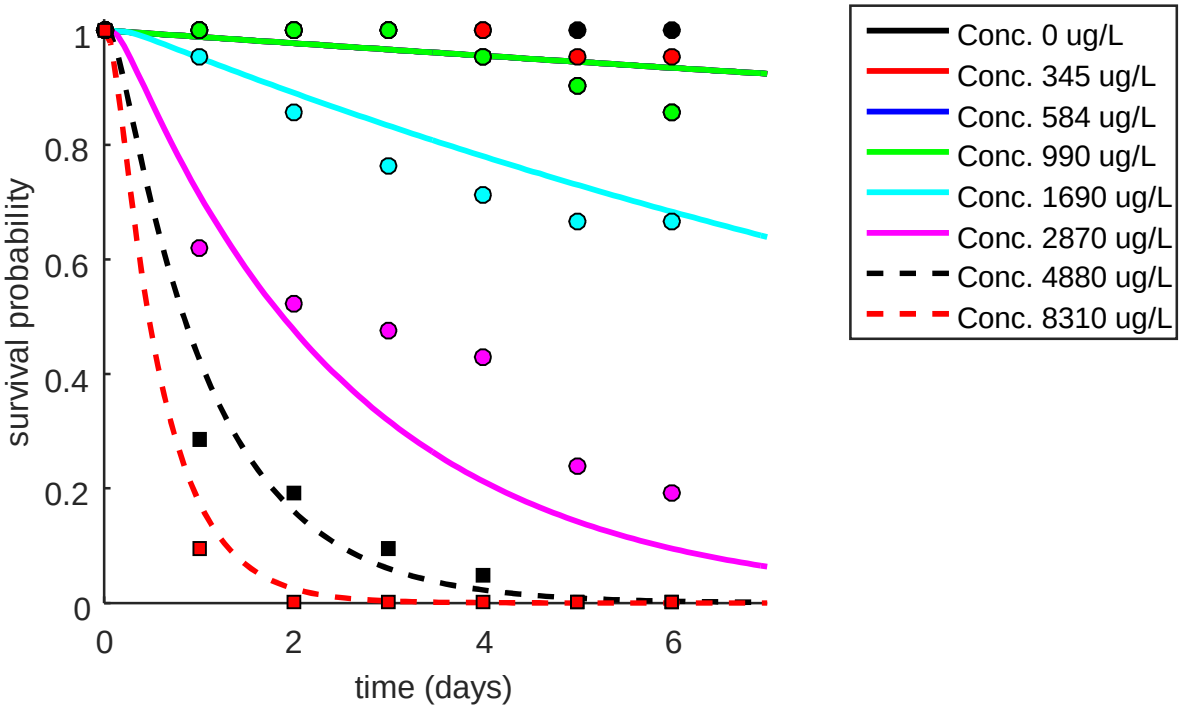
Dynamic modelling

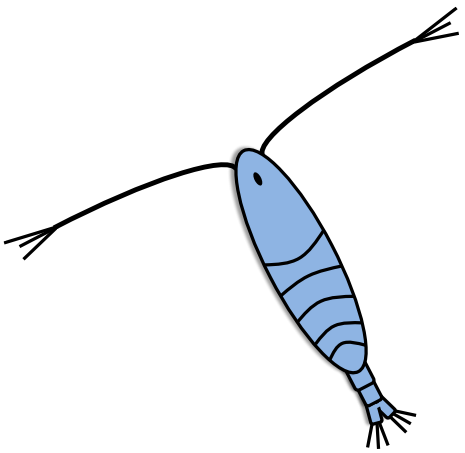
- Toxicokinetic-toxicodynamic modelling
  - explicitly model effects over time
  - for survival: GUTS
  - here: simple hazard model with scaled TK



Dynamic modelling

- Example: female copepods and fresh oil
- Typical misfit in lower doses ...

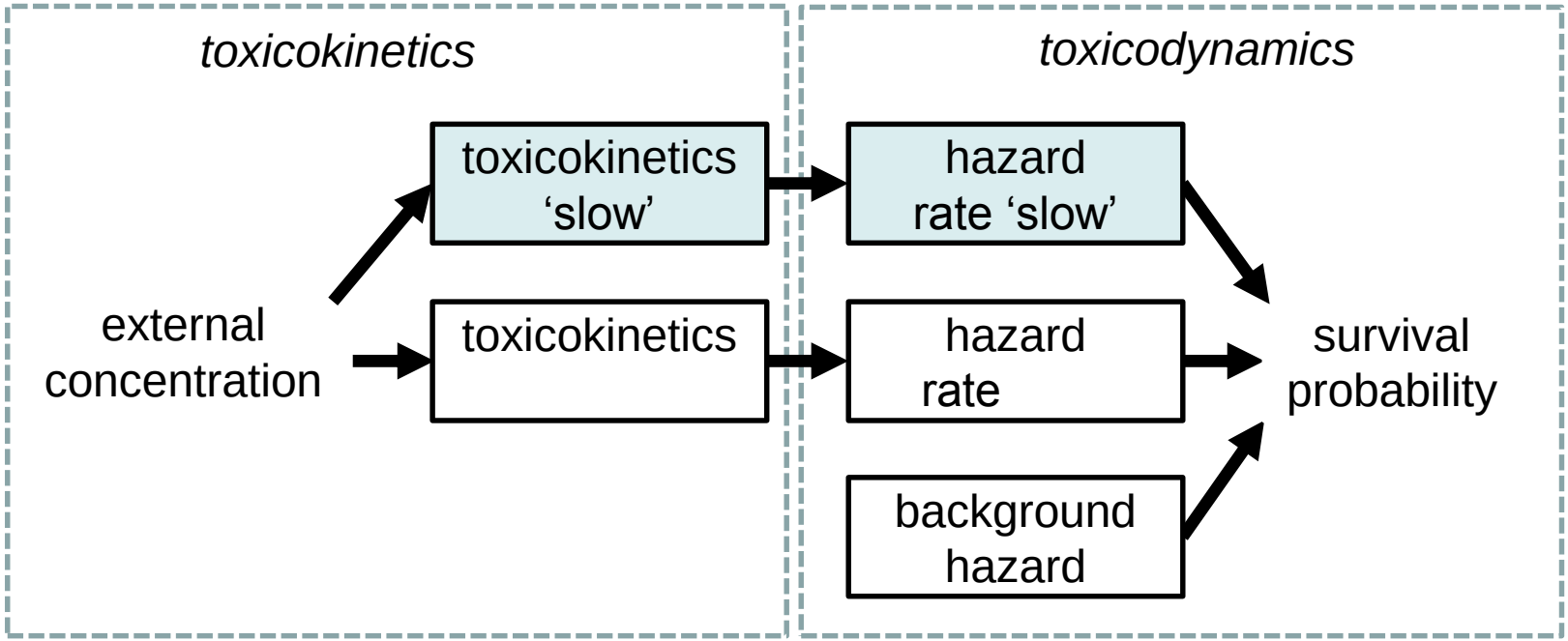




Dynamic modelling

Oil is a mixture of many compounds …

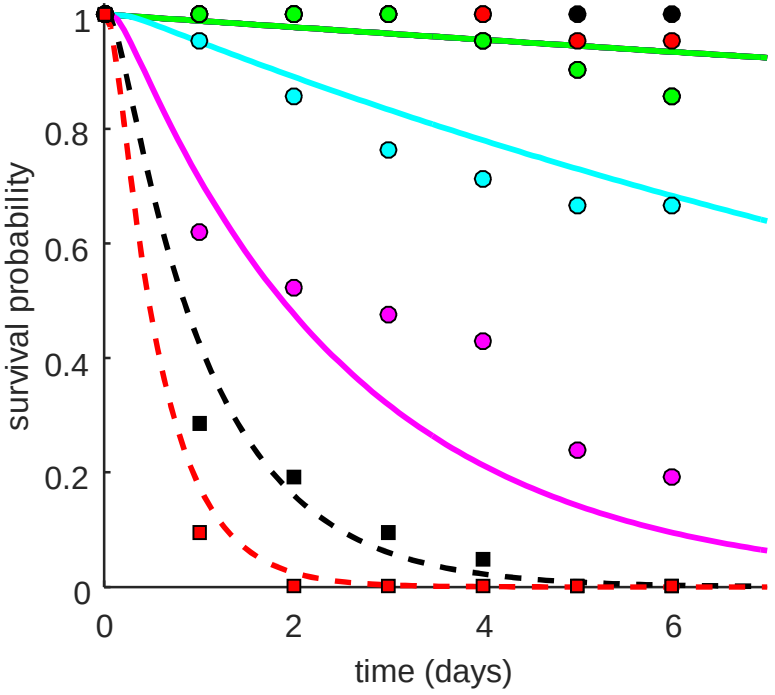
- Treat oil as two hypothetical component blocks
- Assume independent causes of death



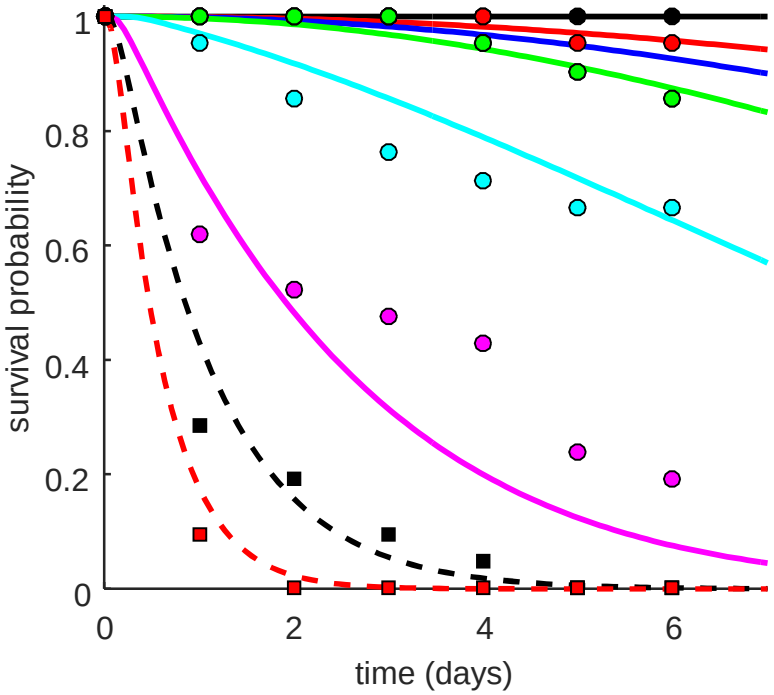
Dynamic modelling

- Example: female copepods and fresh oil
- From 4 parameters to 7 …

one mechanism



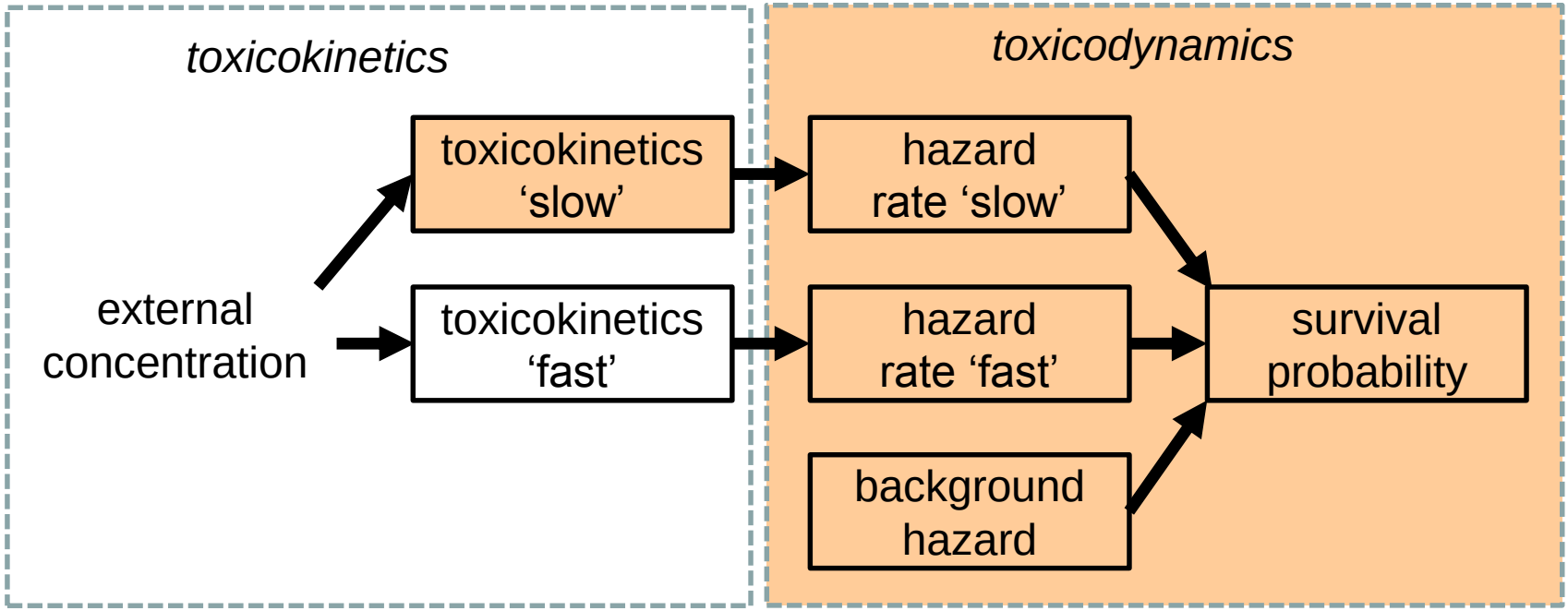
two mechanisms



Simultaneous fitting

We have 10 data sets (5 stages and 2 oil types)

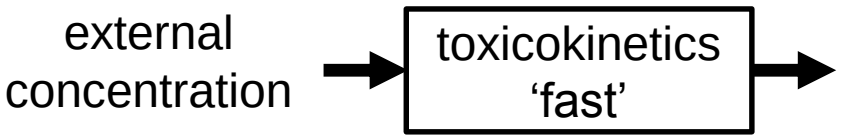
- Which parameters stay the same for all oils/stages?
- Expect same mechanism of action ...
- Insufficient info in data for slow TK ...



Simultaneous fitting

Toxicokinetics may depend on oil and life stage

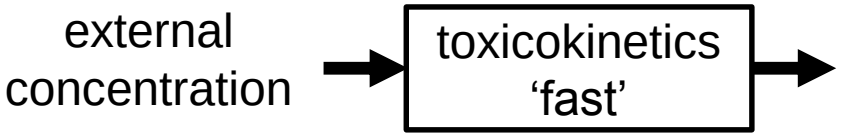
- Note: no body-residue data ... (scaled TK)
  - TK parameters inferred from survival patterns

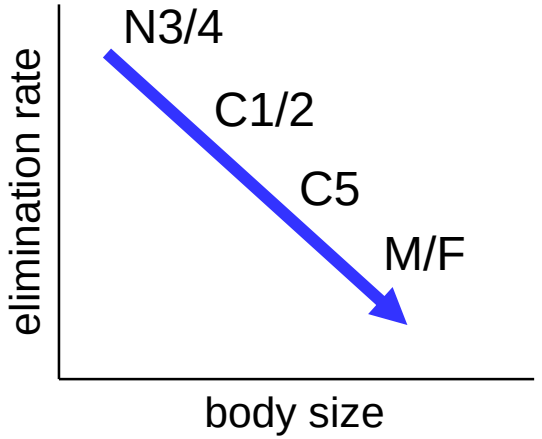


Simultaneous fitting

‘Elimination’ rate

- Determines how rapidly mortality starts
  - may include transformation processes etc.

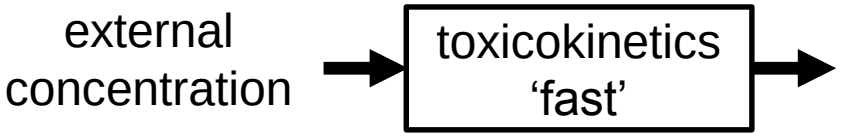


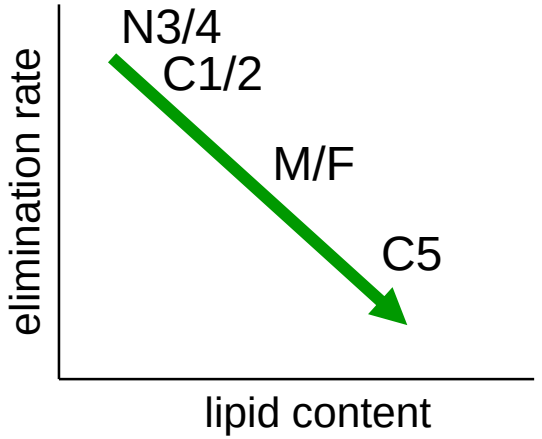


Simultaneous fitting

‘Elimination’ rate

- Determines how rapidly mortality starts
  - may include transformation processes etc.



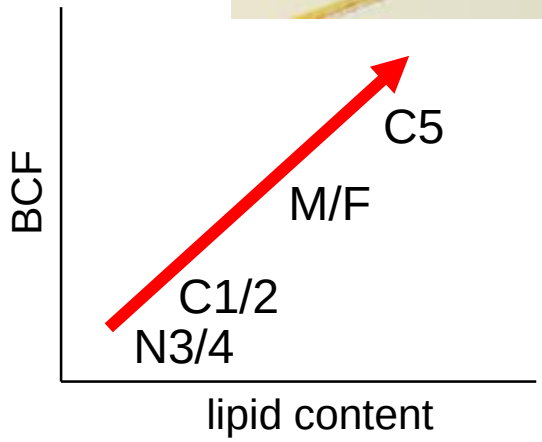


Simultaneous fitting

‘Sensitivity’ factor

- Determines relation exposure & magnitude of effect
  - reflects differences in BCF etc.
  - reference: nauplii/fresh oil

external concentration → toxicokinetics ‘fast’ →



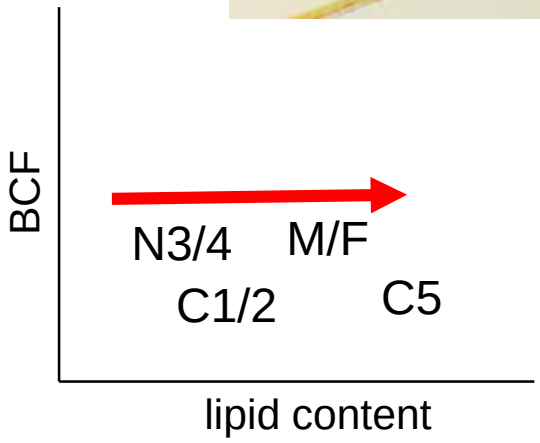
Simultaneous fitting

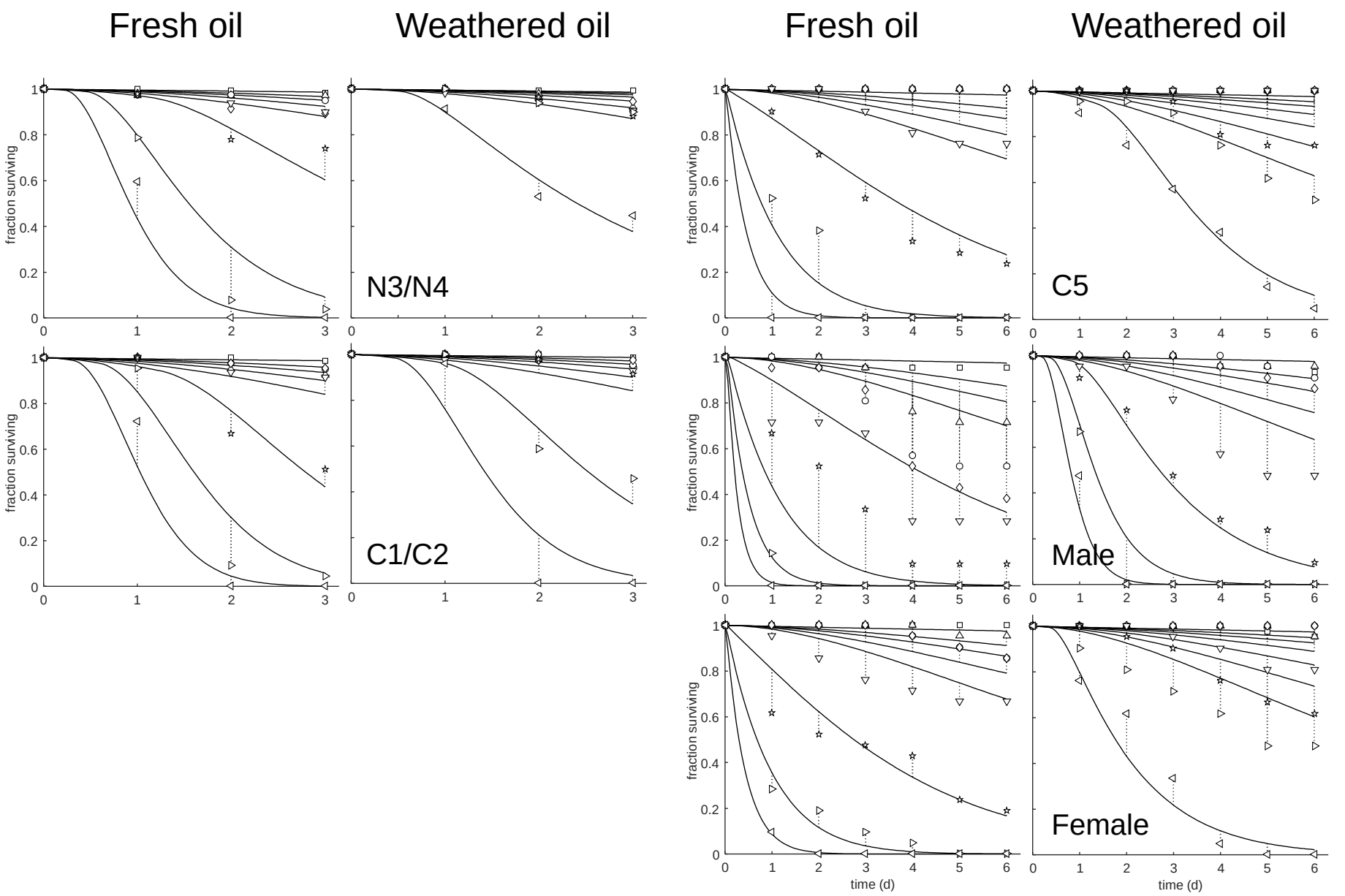
‘Sensitivity’ factor

- Determines relation exposure & magnitude of effect
  - reflects differences in BCF etc.
  - reference: nauplii/fresh oil

25 parameters for 10 data sets

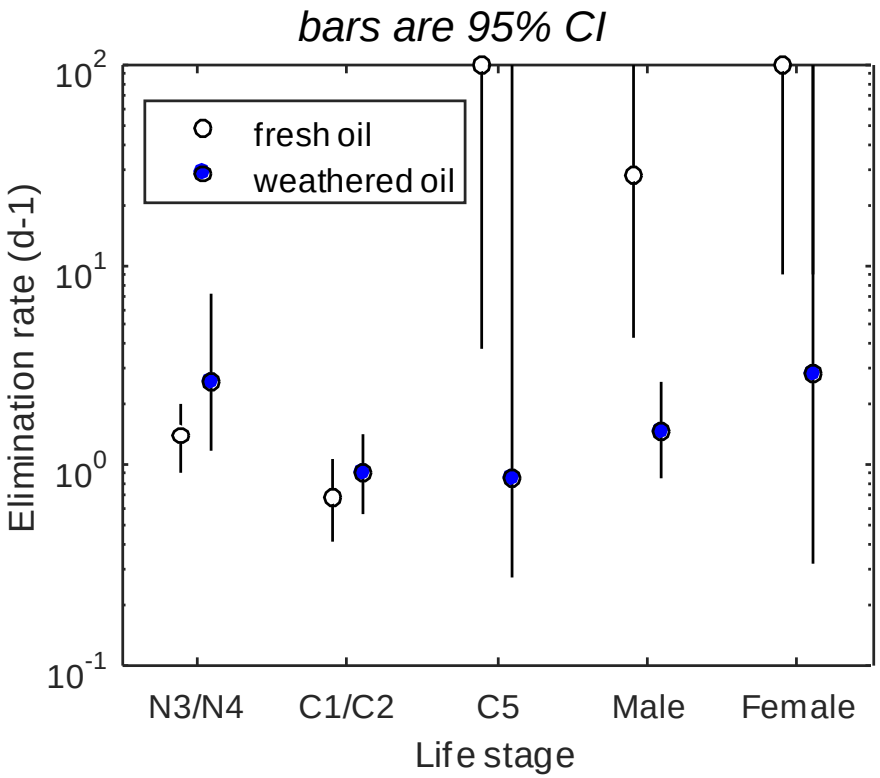
external concentration → toxicokinetics ‘fast’ →

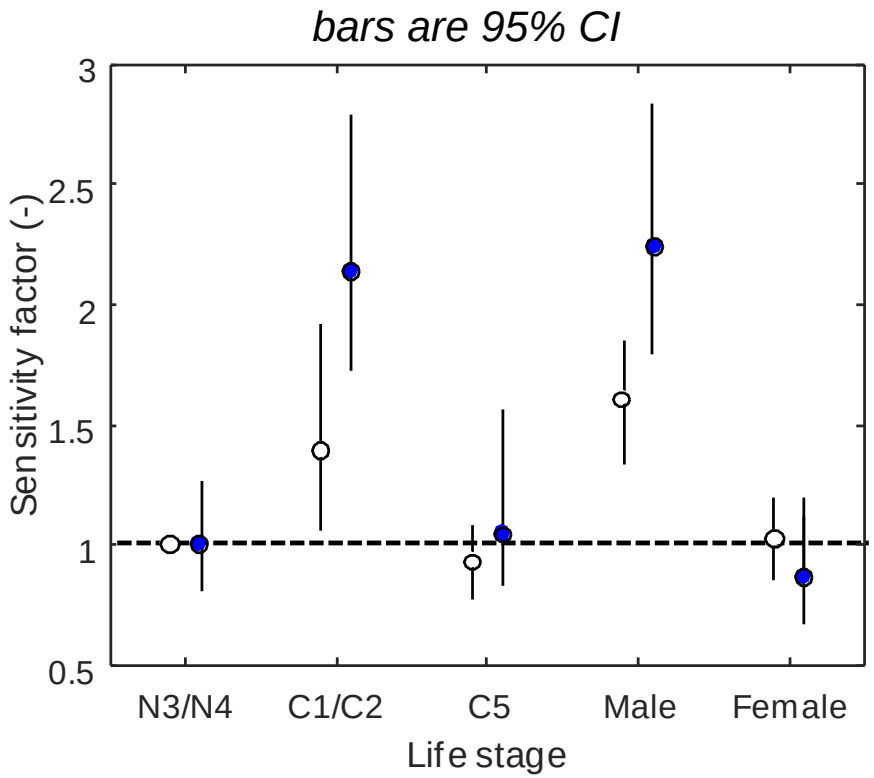



Fresh oil
Weathered oil
Fresh oil
Weathered oil
fraction surviving
N3/N4
C5
C1/C2
Male
Female
time (d)
time (d)

Parameters

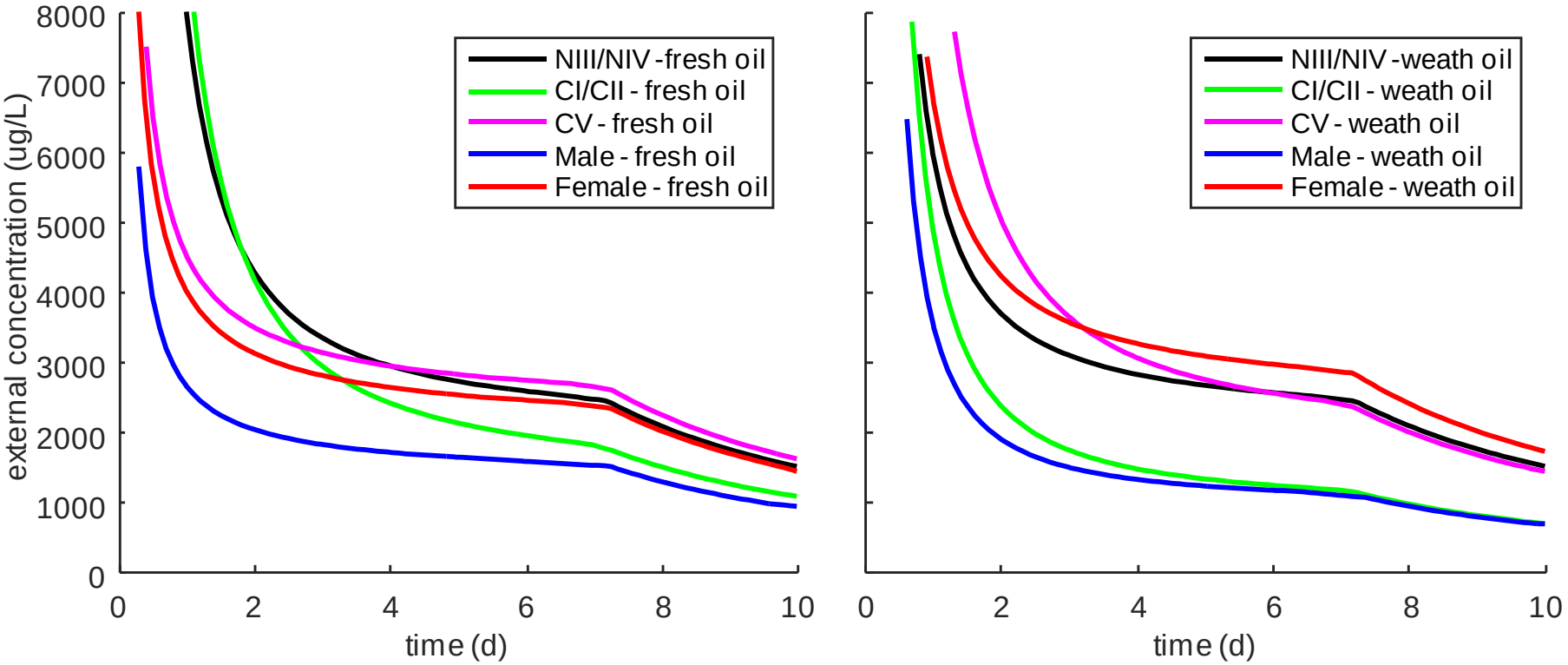
- No decrease in elimination rate with size/lipid content
- Males and early copepodites higher ‘sensitivity factor’





LC50 vs. time

- LC50(*t*) predicted from estimated model parameters



Take home

- Oil toxicity in *C. finmarchicus* displays two MoA's
  - fast mechanism, distinct threshold
  - slow mechanism, possibly no threshold
- Elimination rates do *not* follow expected patterns
  - influence of biotransformation?
- Nauplii are *not* particularly vulnerable
  - males and early copepodites show higher 'sensitivity'
- For accurate predictions, mechanistic work needed
  - e.g., test single components and measure body residues

Funding

196711/S40

225314/E40

The Research Council of Norway

Statoil

More information

on DEBtox/GUTS: **www.debtox.info**

summercourse on dynamic modelling of toxic effects, August 2016 (DK)

International Network of Expertise on Dynamic Energy Budgets

DEBnet