UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Pesticides
Federal Insecticide, Fungicide & Rodenticide Act
(FIFRA)

≈2,000

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Chemicals under Federal Food, Drug, and Cosmetic Act
(FFDCA)
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Industrial chemicals under Toxic Substances Control Act (TSCA)
≈84,000

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UNITED STATES • ENVIRONMENTAL PROTECTION AGENCY •

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This is a lot of chemicals to evaluate

We need models

96hr Lethal Concentration at 50% mortality (LC50) takes 4 days to complete per chemical

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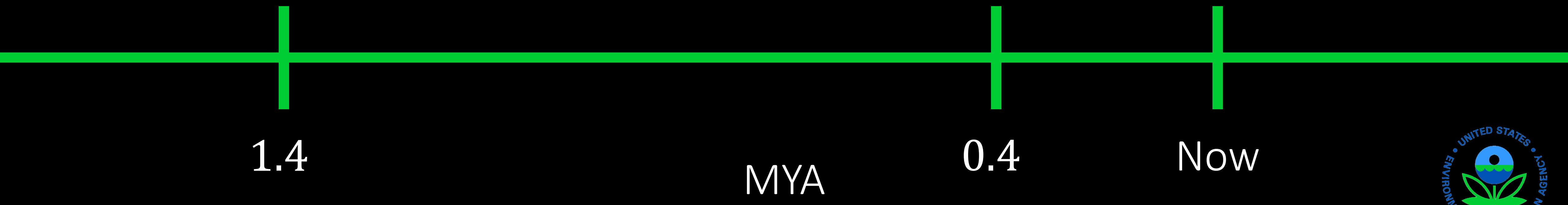
There are currently around 1600 threatened or endangered species in the US

Evaluating chemicals for listed species in this way will take

1,472,000 years



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Homo erectus learned how to use fire

Homo sapiens

1.4

MYA

0.4

Now

Homo sapiens

1.4

MYA

0.4

Now

We need models

for the number of chemicals, chemical mixtures, population & community level impacts, cross-species extrapolation, non-animal testing, predictive MOA and AOP assessments, predicting exposure

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The Fish Toxicity Translator

A Next Generation Tool for Population Modeling to Support Ecological Risk Assessment

Nate Pollesch[1,2], Sarah Kadlec[1], Kevin Flynn[1], Sandy Raimondo[1], and Matt Etterson[1]
[1]University of Wisconsin – Madison
[2]USEPA Office of Research and Development

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UNIVERSITY OF WISCONSIN–MADISON

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Abstract

Populations of aquatic organisms are exposed to diverse natural and anthropogenic stressors. Traditional toxicity testing provides endpoints that need to be interpreted and extrapolated in order to understand impacts of exposure on wildlife populations. The Fish Toxicity Translator is a mechanistic population model developed by the USEPA that uses life history characteristics of fish, laboratory derived measures of acute and chronic toxicity, and ecotoxicological theory to estimate population level effects of chemical exposure scenarios. The Fish Toxicity Translator uses a novel modeling approach, size-structured integral projection modeling, that allows for the incorporation of size-dependent acute and chronic effects of chemical and non-chemical stressors. Model development has taken place in the open source R language has been developed into an R package with an accompanying graphical user interface using R Shiny. In this talk I will describe the modeling theory supporting the Fish Toxicity Translator and give a demonstration of the Fish Toxicity Translator tool that is being developed to support ecological risk assessors.

The Fish Toxicity Translator

Toxicity Translation

Toxicity Translation

The process of predicting population-level impacts of contaminant exposure for wild animals based on data derived from laboratory toxicity studies.

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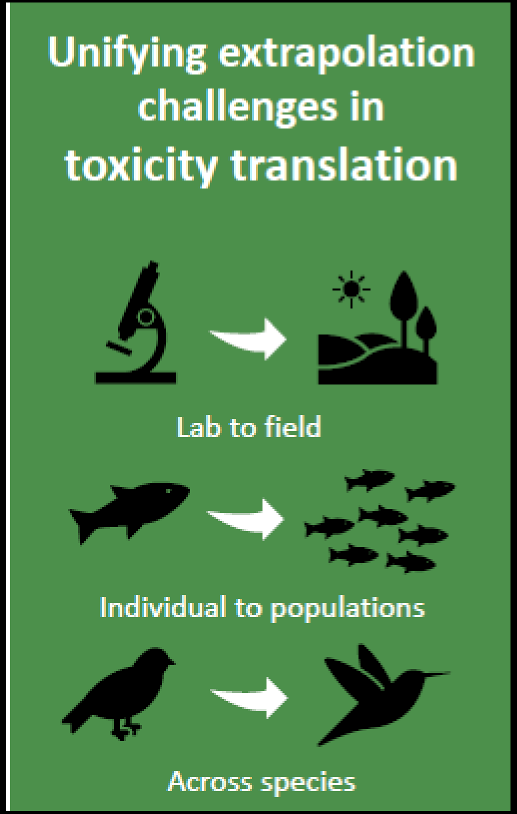
Toxicity translation
of laboratory derived data is needed to estimate effects of contaminant exposure across species, at population-level endpoints, and in realistic exposure settings.



The Fish Toxicity Translator

Size-structured integral projection model (IPM)

For fish, size is important toxicologically and ecologically

- IPMs link size to dynamics of growth, reproduction, and survival
- Most size measures are non-destructive and accessible in both the laboratory and the field
- Our approach uses ***realistic exposure profiles (EPA's PWC Model)*** interpreted by different effect models (***GUTS TK-TD, simple threshold)*** to predict ***population-level impacts*** of exposures and stressors

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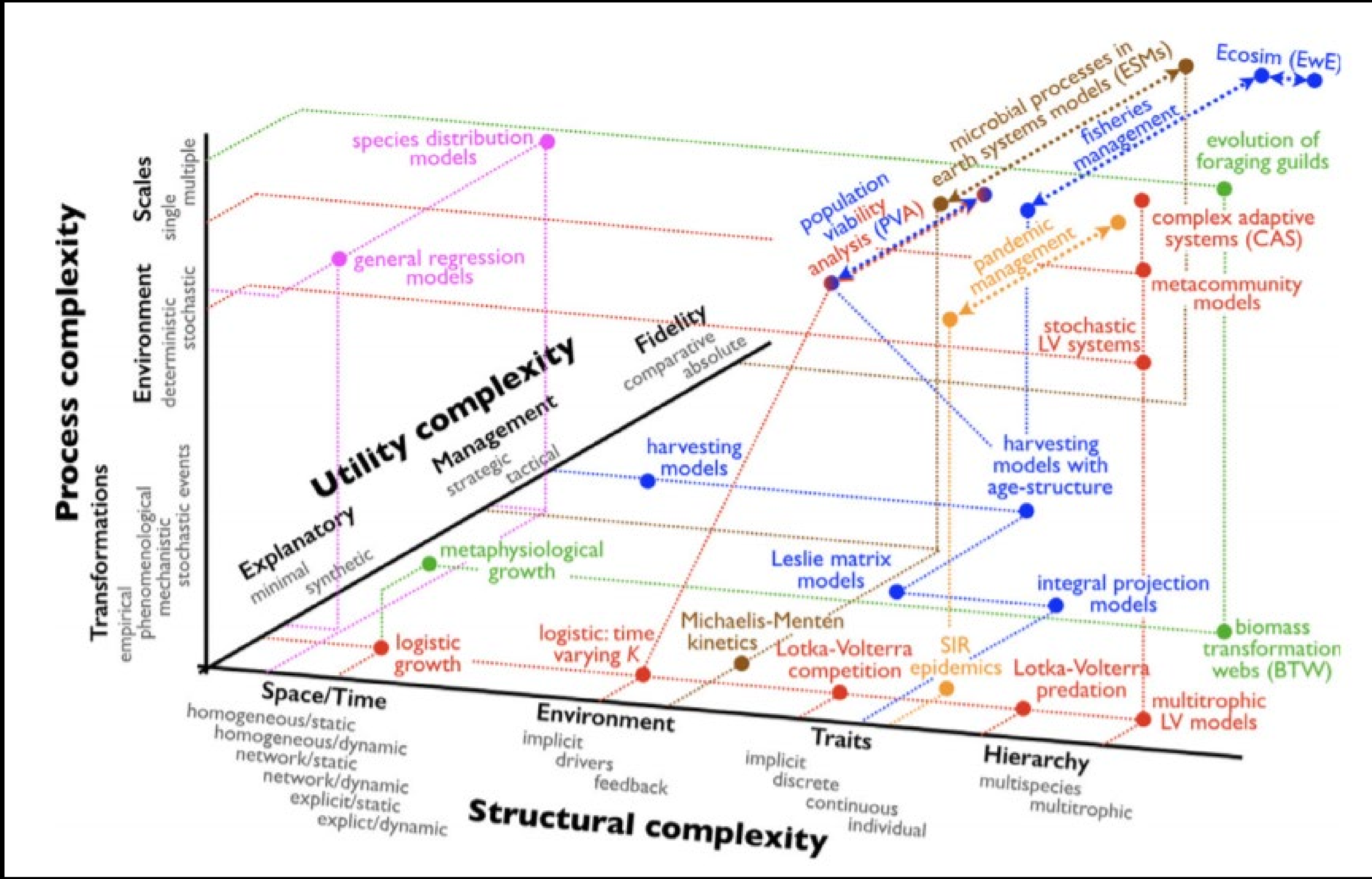
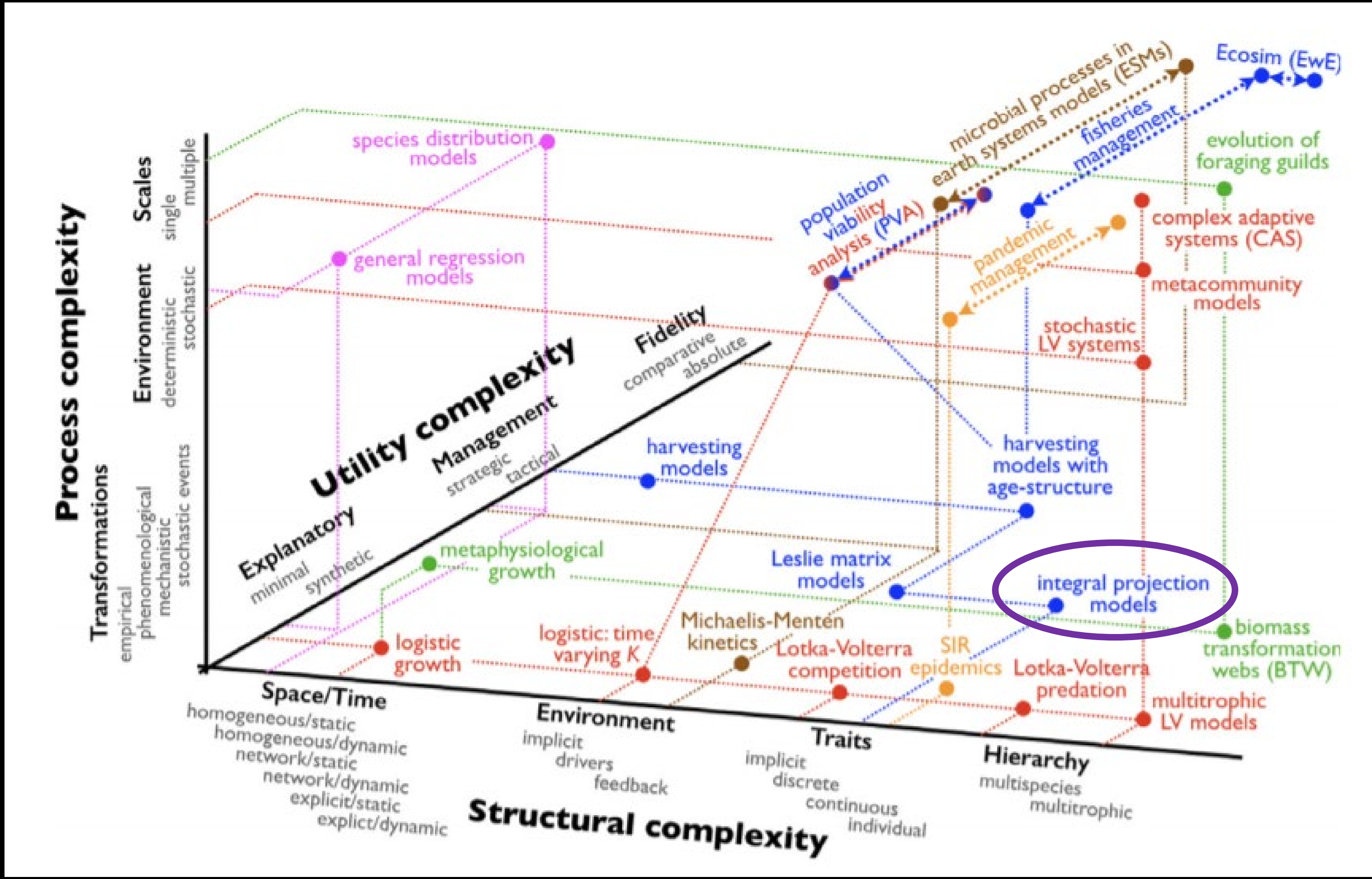


Discrete time
Continuous Trait

Model Typology from Getz et al., 2018 *Making ecological models adequate*

Size-structured integral projection model (IPM)



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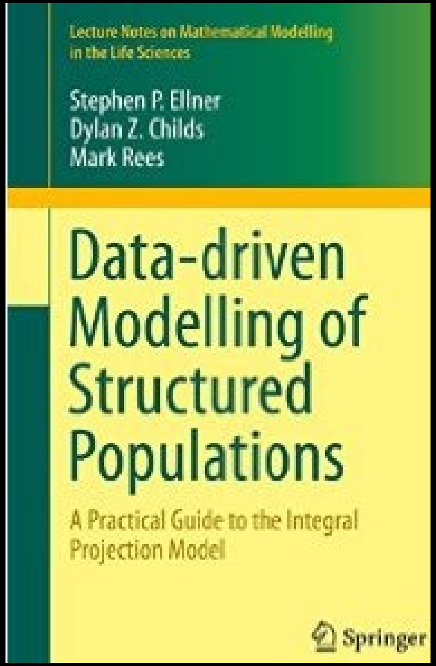
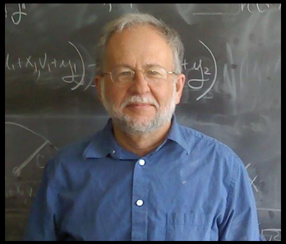
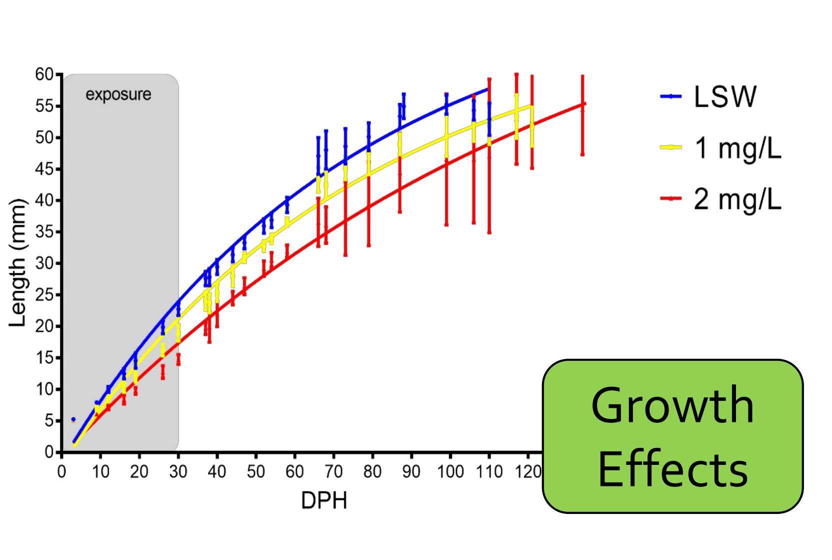


Ellner et al., 2016

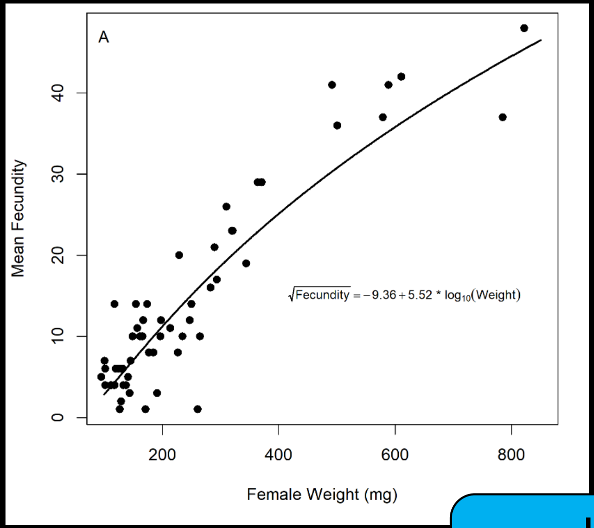


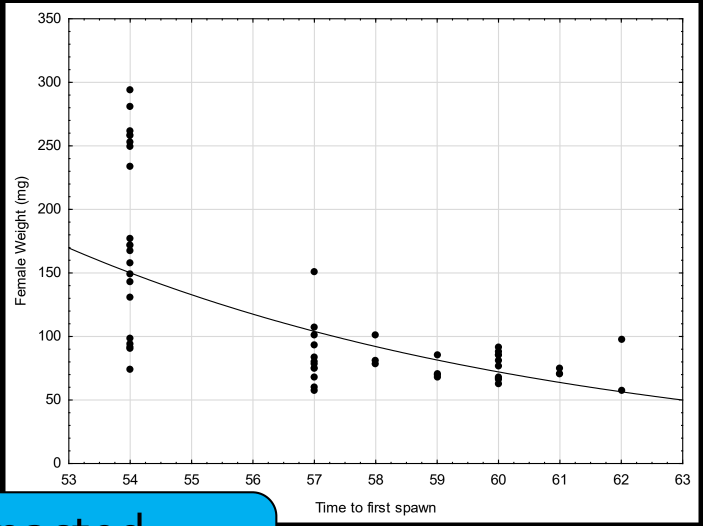
Steve Ellner, Cornell

Growth and Reproductive Effects of Exposure

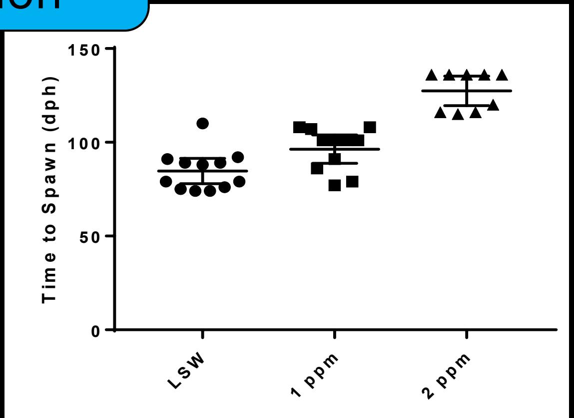


Growth Effects





Impacted Reproduction

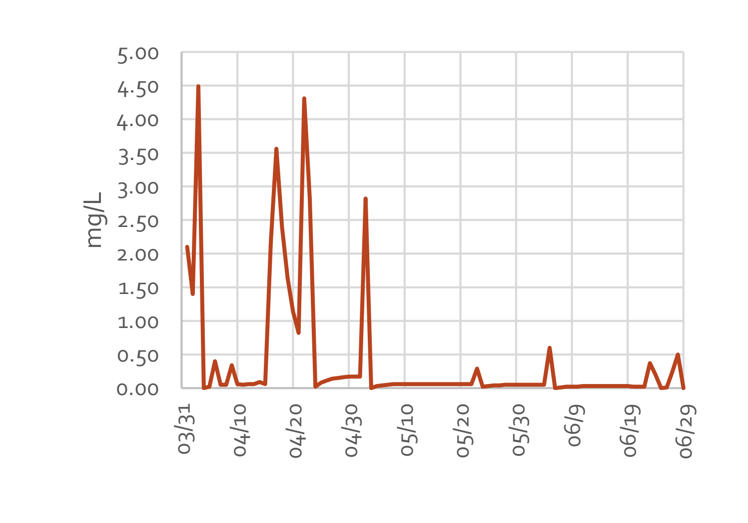


Exposure reduces growth

- Effects are persistent even after exposure ends
- Effects can be direct or indirect (food availability)
- Size is related to survival (ex., predation, over-winter)
- Size is related to fecundity, time to 1st spawn (i.e., spawning season)

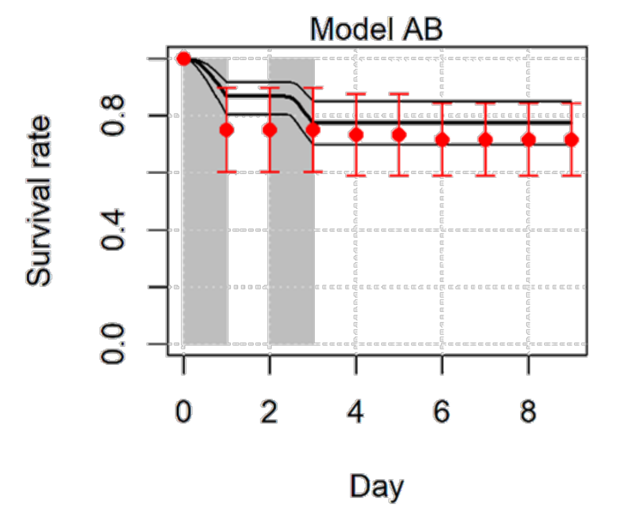
Pulsed exposure survival modeling

Realistic Chemical Exposure



Predicted environmental concentrations can vary based on timing of use, precipitation, etc.

Survival Studies



Grey bars: Exposure periods
Black lines: Model-predicted survival
Red dots: Laboratory-observed survival

Toxicokinetic-toxicodynamic (TK-TD) models

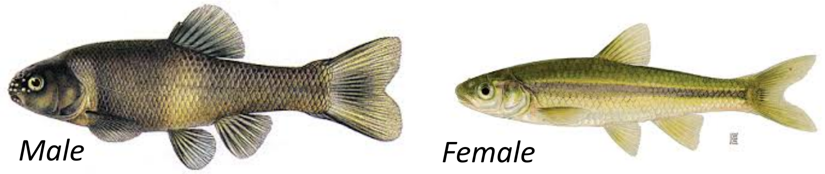
- Are effects of time-variable exposures different than constant exposures of the same average concentration?
- Simplified TK-TD models
  - Are calibrated with standard toxicity test data (constant exposure concentrations)
  - Can predict effects of simple and complex time-variable exposure scenarios

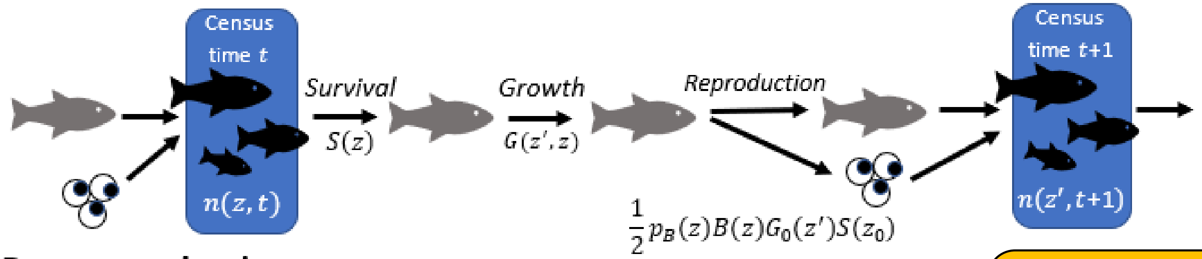
Scenario Building

- Parameterizable growth, reproduction, and survival functions for different species
- Different reproductive strategies
- Non-chemical stressors
  - Over-winter survival
- Chemical stressors
  - Type, magnitude, and timing of exposure
  - Multiple approaches for modeling chemical effects (eg TKTD or Threshold)

Fathead minnow

Pimephales promelas

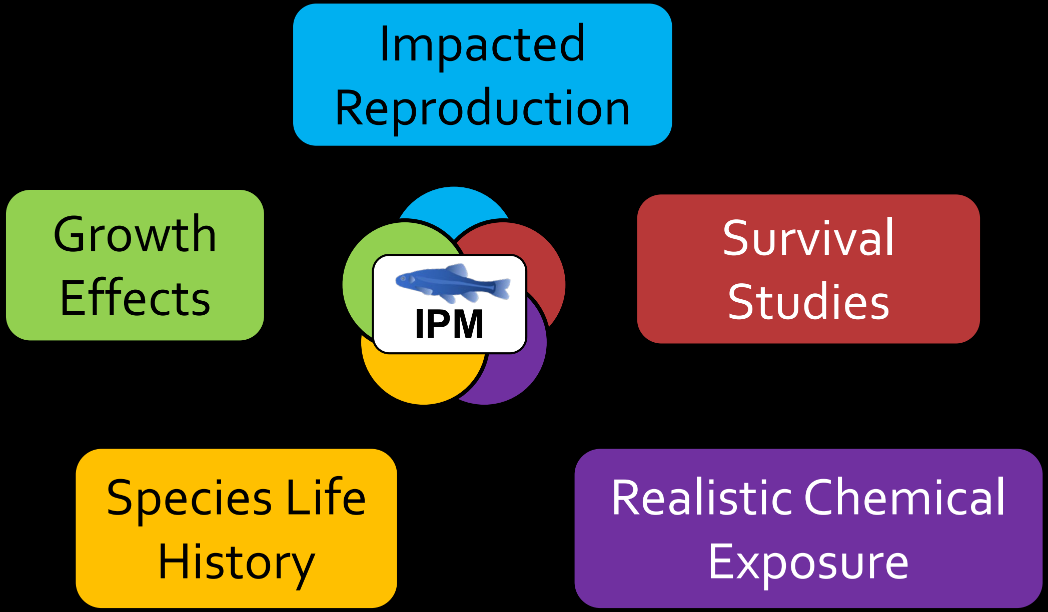




Post-reproductive census structure

Species Life History

Fish Toxicity Translator Integral Projection Model



IPM: 101

Impacted Reproduction

Growth Effects

Survival Studies

Species Life History

Realistic Chemical Exposure

$K(z', z)$ The transition Kernel

$$n(z', t+1) = \int_L^U \left(\overbrace{G(z', z)S(z) + \frac{1}{2} p_B(z)B(z)G_0(z')s(z_0)}^{} \right) n(z, t)dz$$

New population size-distribution

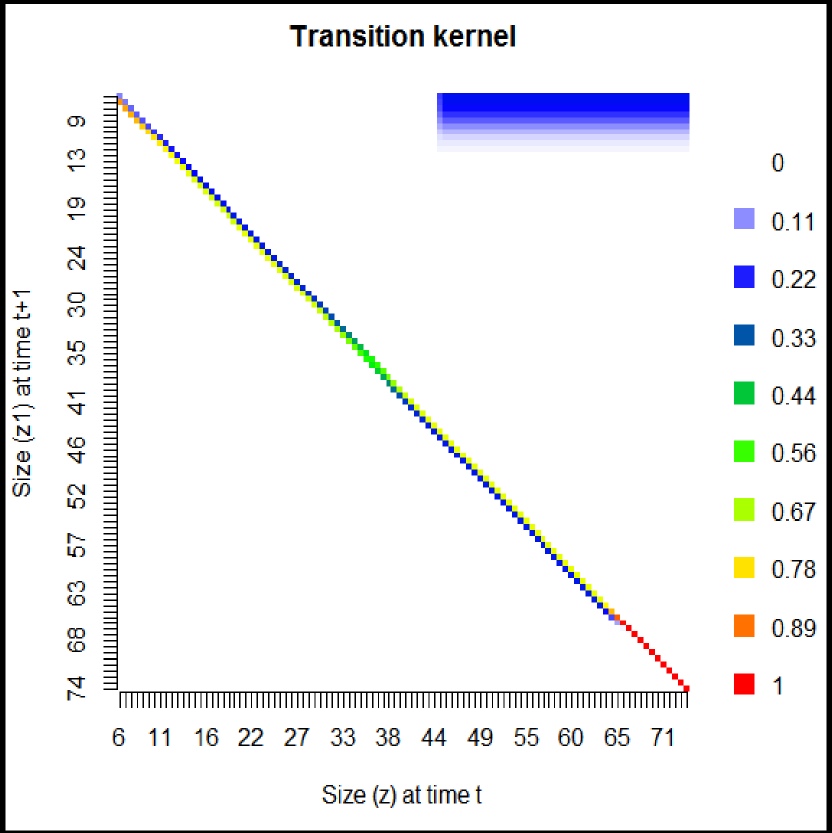
Growth and Survival Kernel

Reproduction Kernel

Population size-distribution

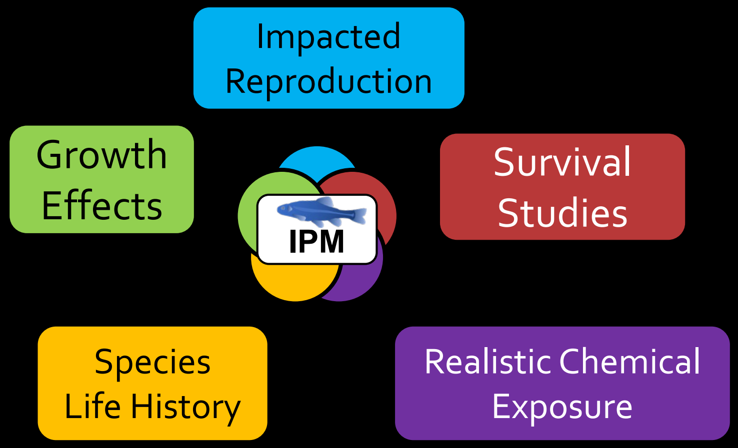
Where z and z' are size, t is time

U and L are the upper and lower limits of size.



$$\begin{bmatrix} f_0 & f_1 & f_2 & \cdots & f_{\omega-2} & f_{\omega-1} \\ s_0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & s_1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & s_2 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & s_{\omega-2} & 0 \end{bmatrix}$$

IPM: 101



$$n(z',t+1) = \int_L^U \Big(\overbrace{G(z',z)S(z) + \frac{1}{2} p_B(z)B(z)G_0(z')s(z_0)}^{K(z',z)\text{ The transition Kernel}} \Big) n(z,t)dz$$

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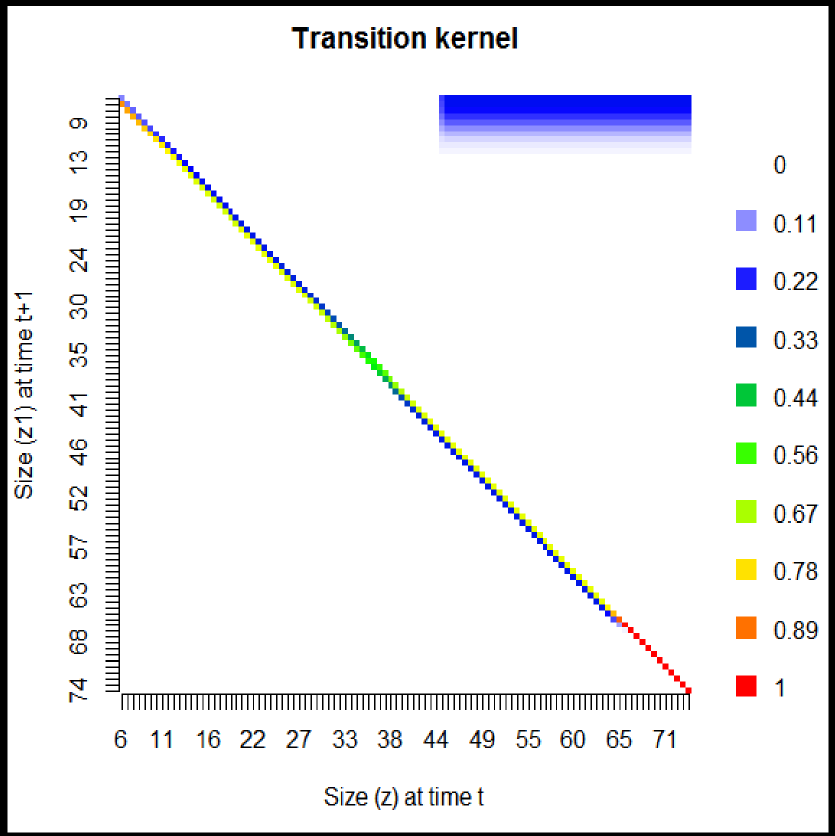

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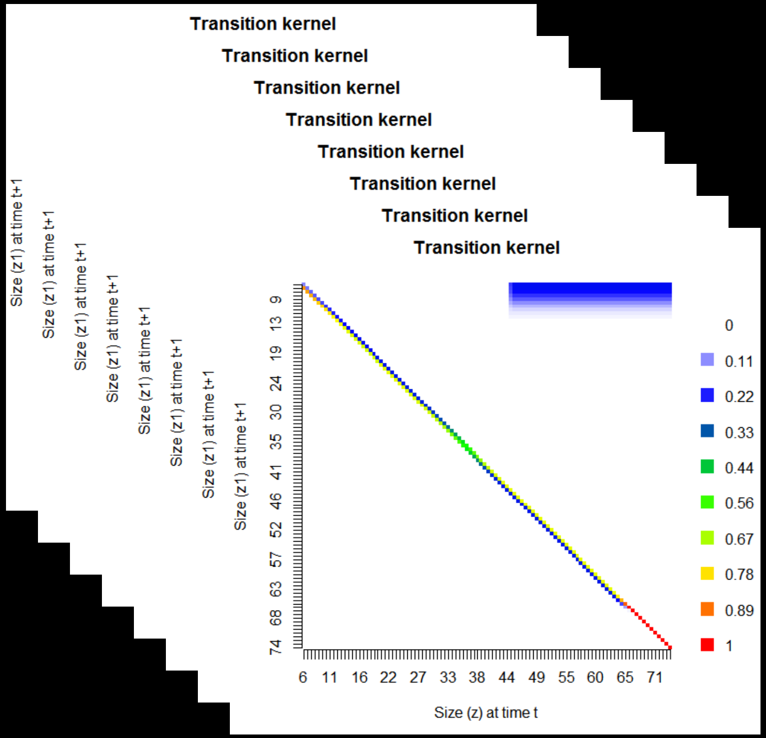
In Practice…



IPM: 101

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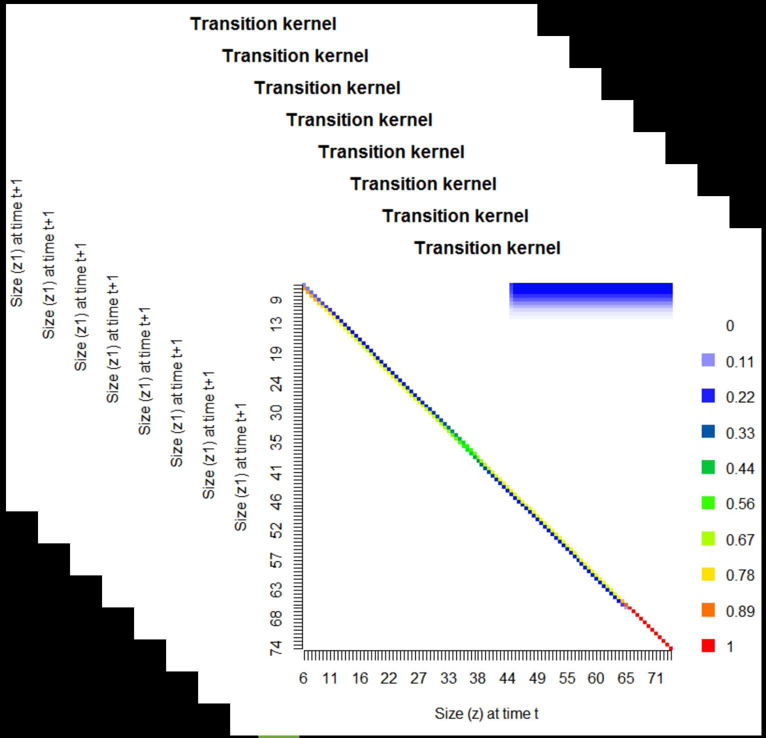
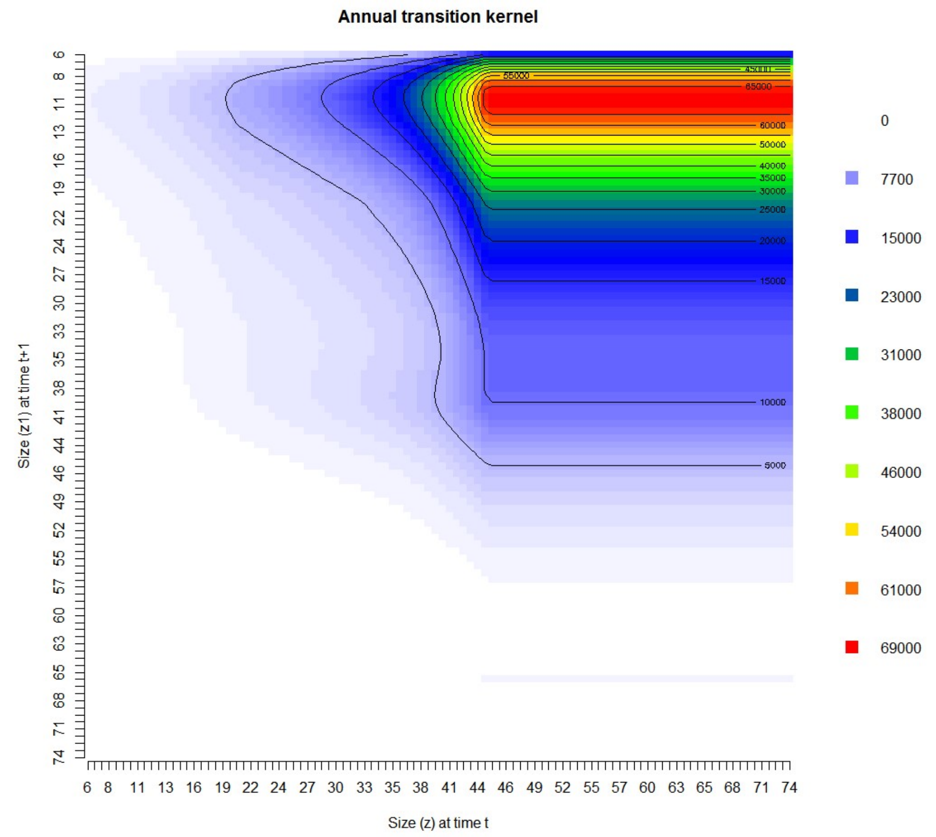
In Practice…



Which can be analyzed for:

- Asymptotic growth rate (λ)
- Stable size distribution
- Annual class size-transitions



IPM: 101

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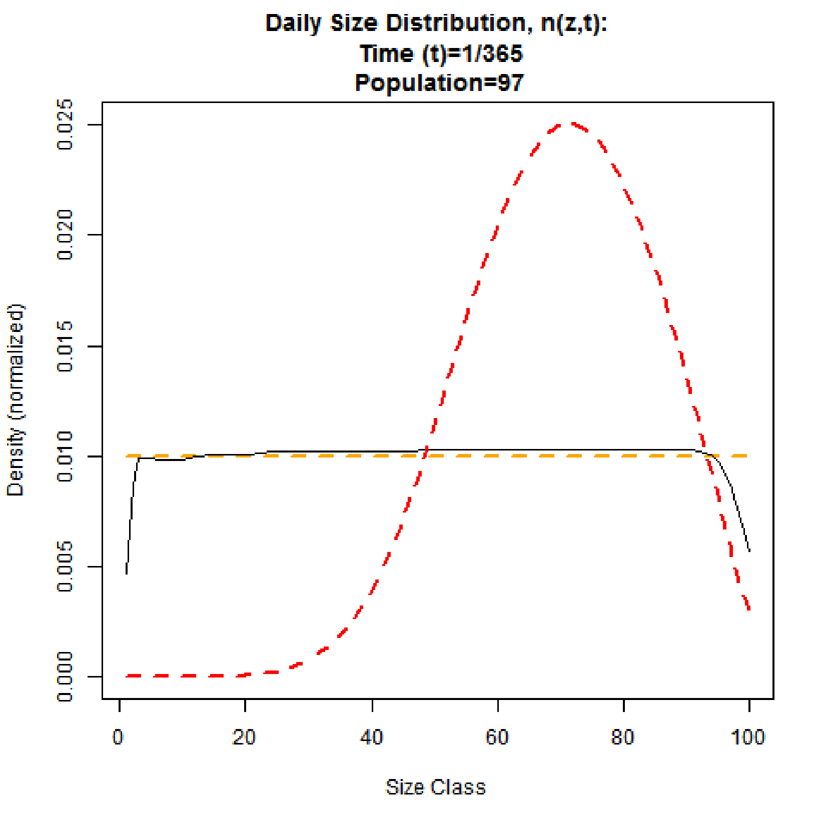
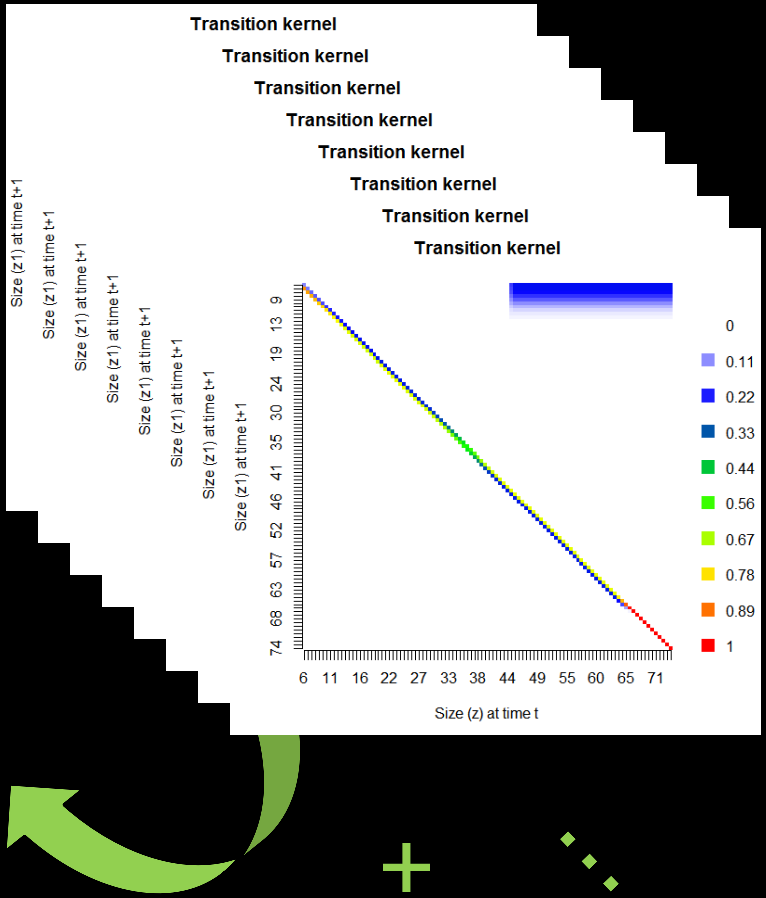
These can be combined for daily and asymptotic behavior.

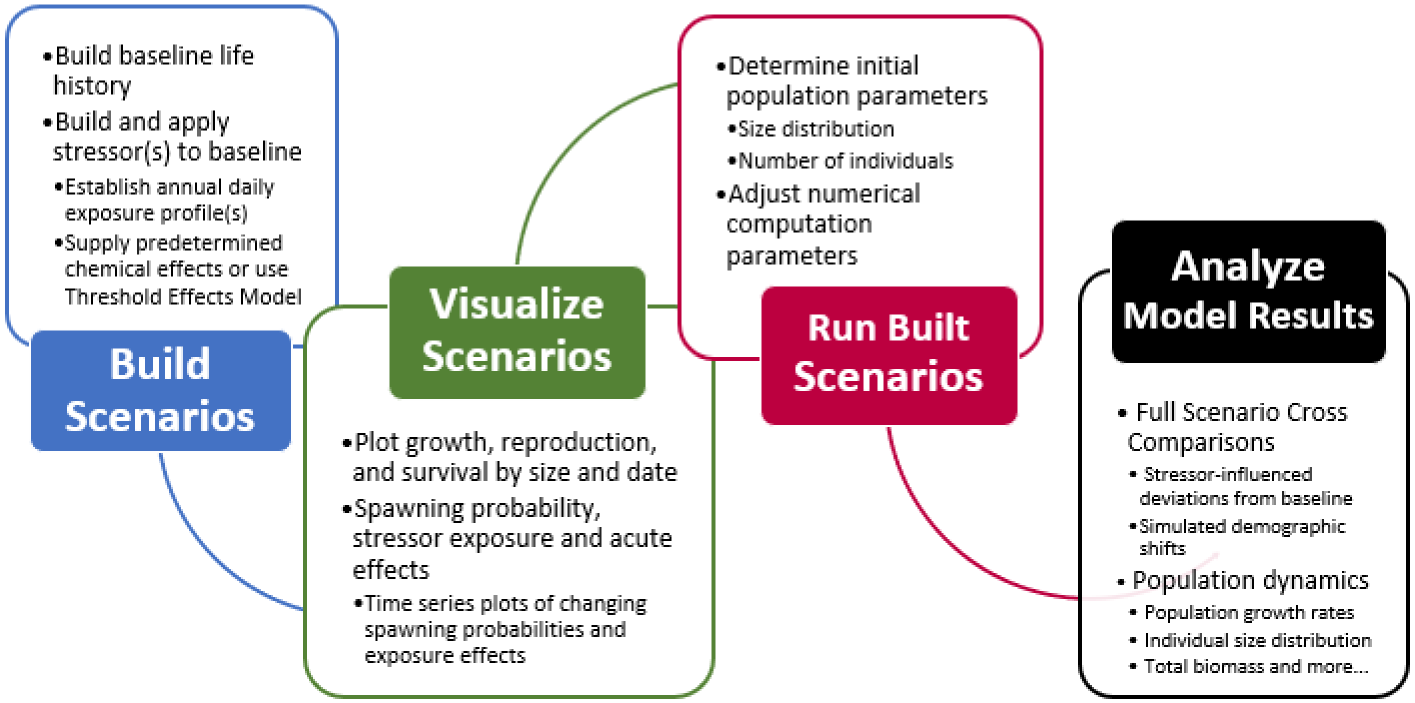


In Practice…



\+ Initial dist.

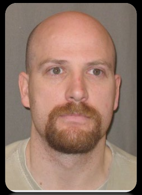
Model Demo



GUI Team: W. Melendez - GDIT, J. Frisch - GDIT

FISH TOXICITY TRANSLATOR
Integral Projection Model Team

J. Swintek



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