



# BUILDING AN R PACKAGE, R SHINY APPLICATION, AND QUARTO BOOK FOR CUMULATIVE EFFECT ASSESSMENTS IN BC (CEMPRA)

**Matthew Bayly**

M.J. Bayly Analytics Ltd.

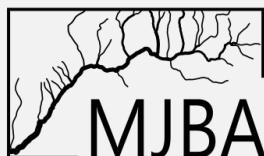
Whistler – British Columbia

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[mjbayly.com](http://mjbayly.com)

# Talk Overview

- Putting larger R projects together...
- Overview of the CEMPRA R package and R Shiny application (*case study*)
- How we apply principles of software development within the R universe:
  - *e.g., Separation of concern, modularity, single responsibility principle, encapsulation, don't repeat yourself, KISS (keep it simple buddy), etc.*
- Useful workflows
- Applying novel/special tools to larger projects
  - *e.g., Quarto, Google Analytics, etc.,*



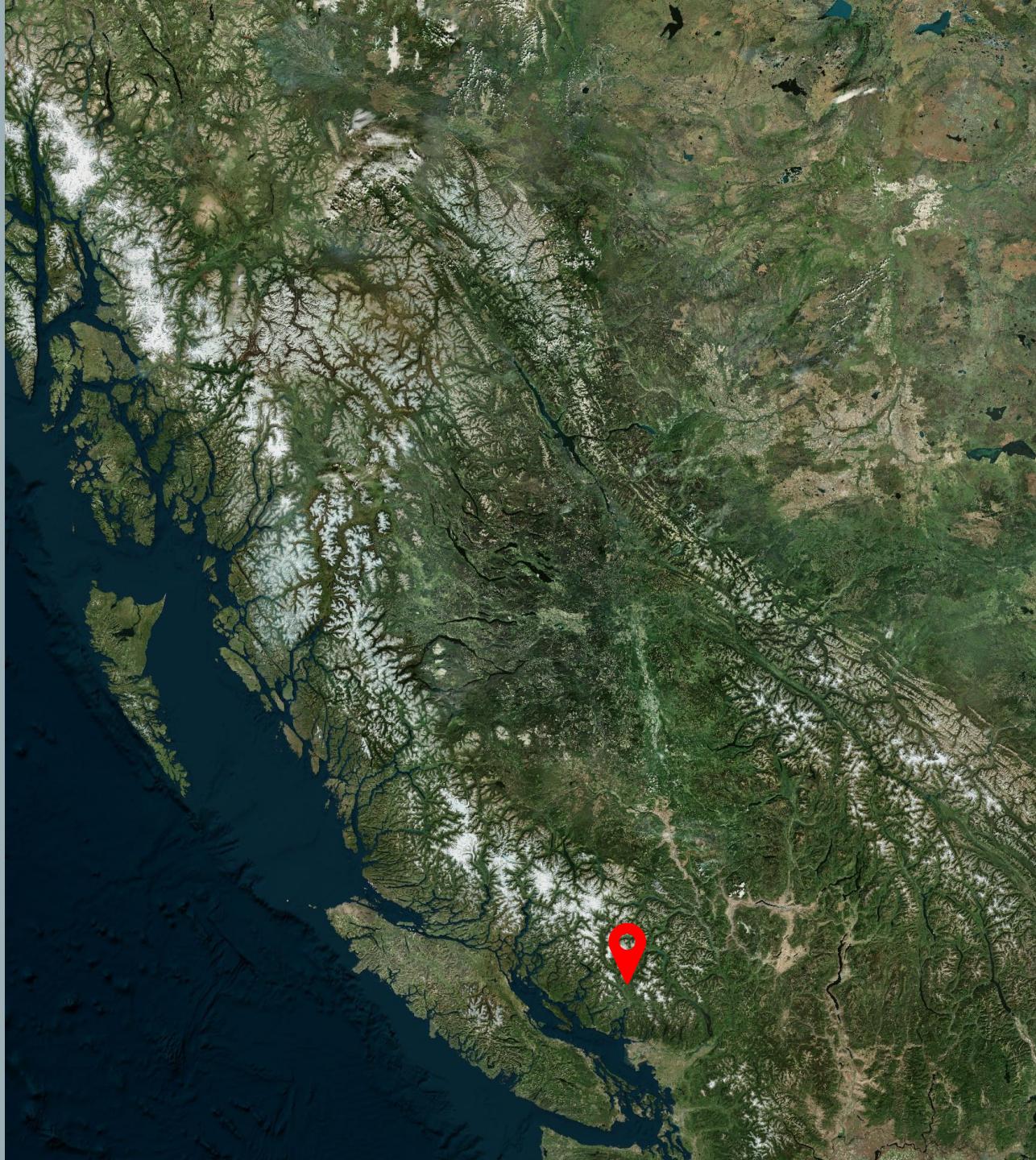
## MY BACKGROUND

I work as a Quantitative Biologists:  
*Watershed restoration, hydrology, salmon ecosystems etc.*

I have been R heavily for about 14 years.

Also work as a general web developer  
(databases/servers, PHP, JavaScript, Python, etc.).

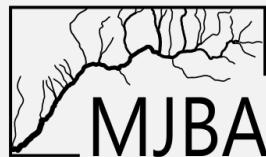
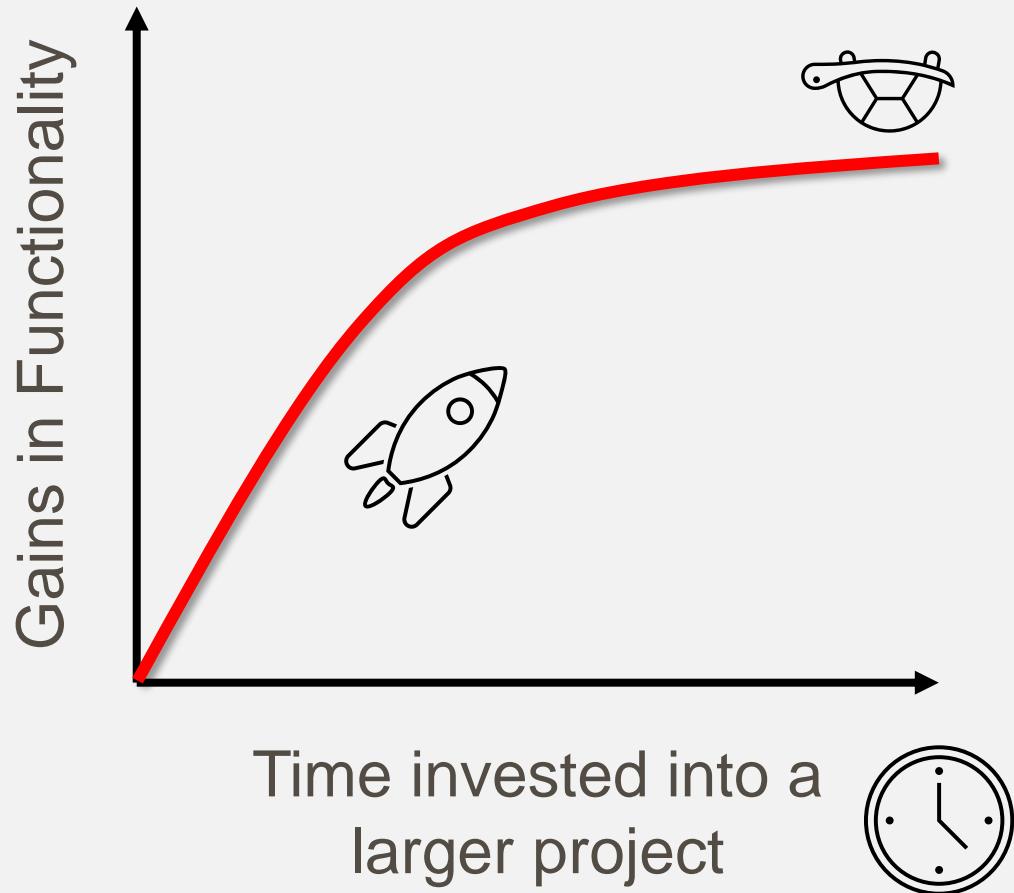
Passionate about re-usable tools,  
systems, & frameworks to support environmental management.



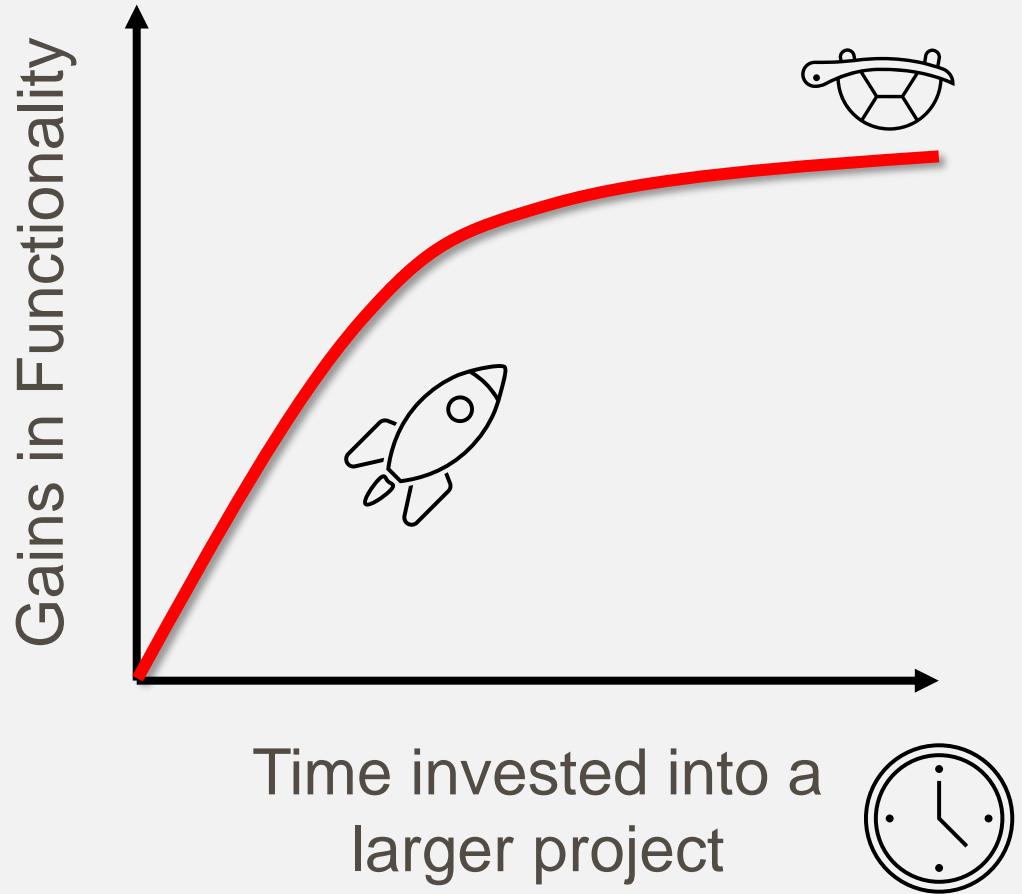
# Why even worry about organizational structures and systems in R...?



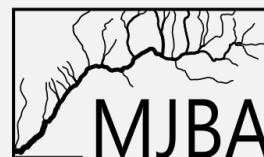
# Why even worry about organizational structures and systems in R...?



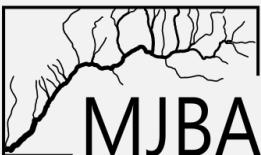
# Why even worry about organizational structures and systems in R...?



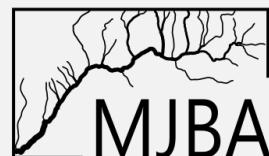
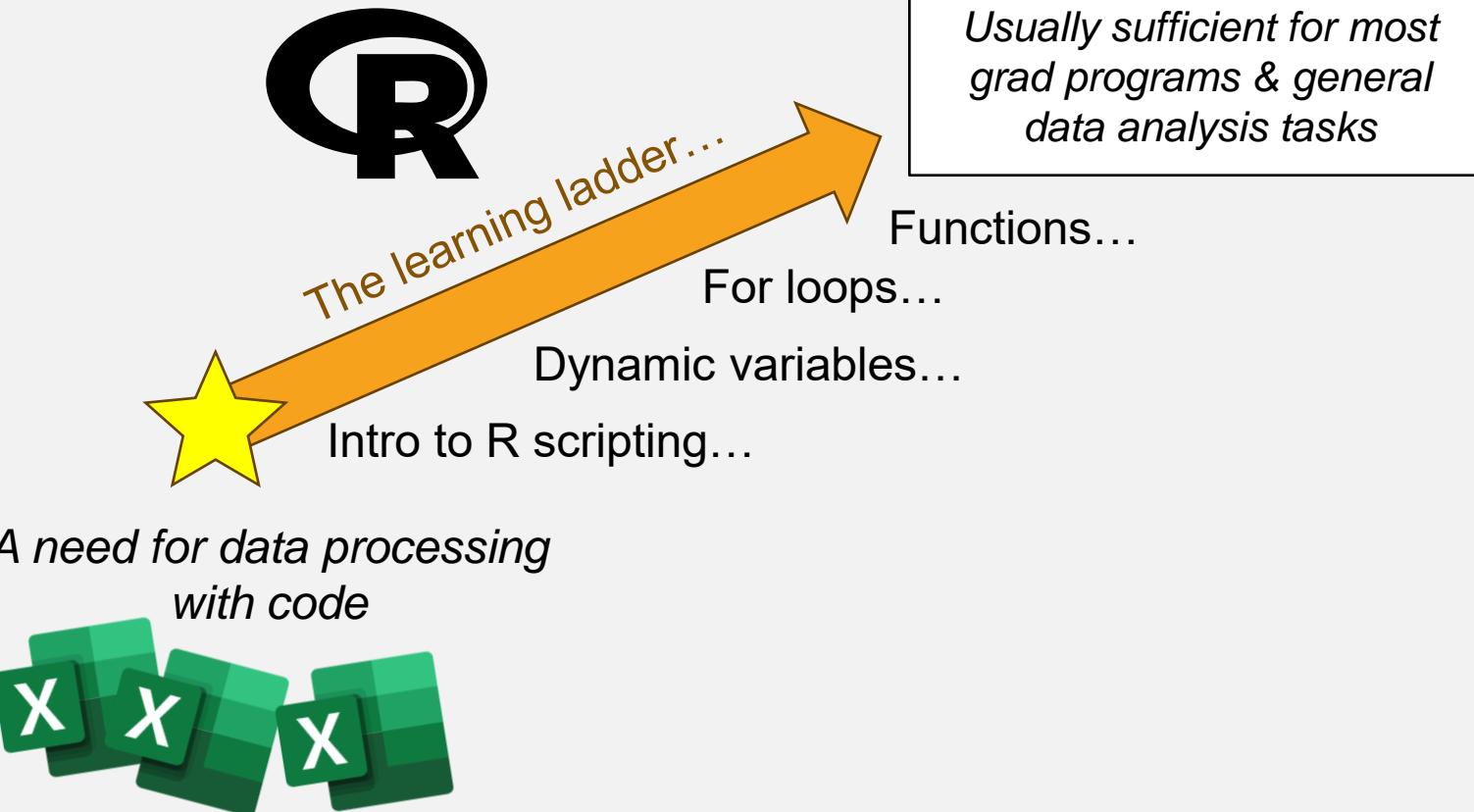
*The dread of revisiting older code bases...*



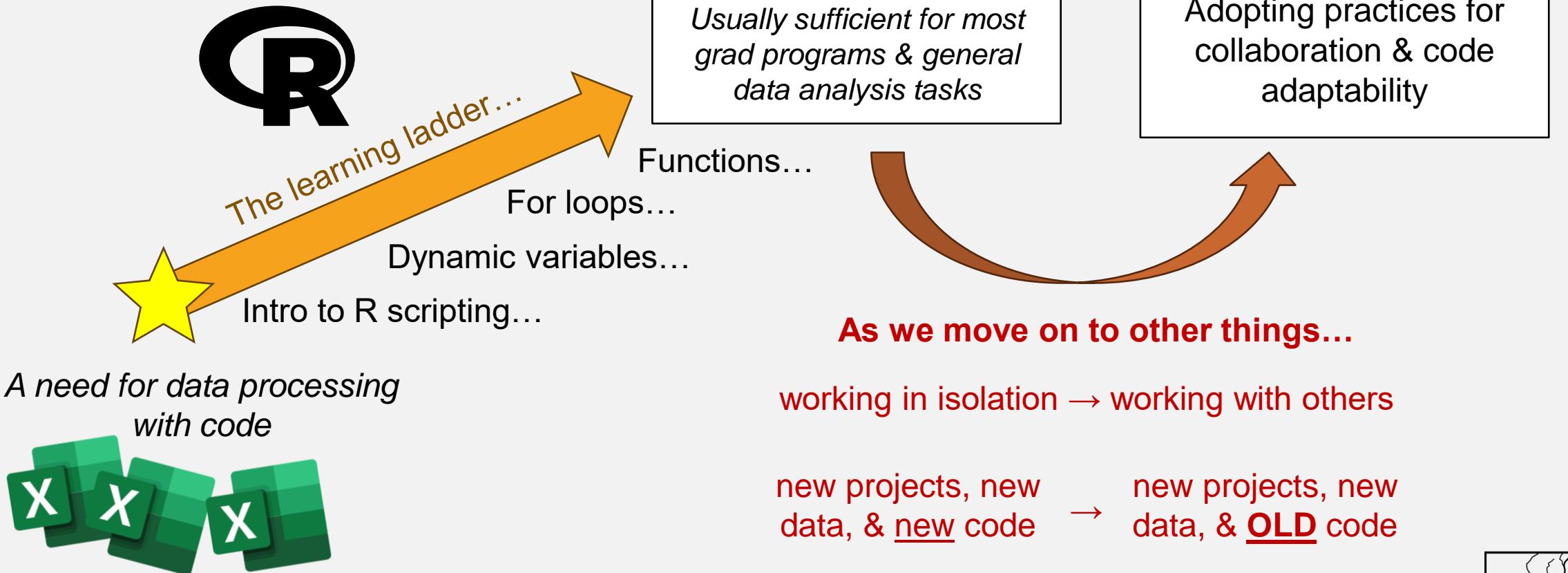
Do all large software projects (in any language) become messy & complex...?

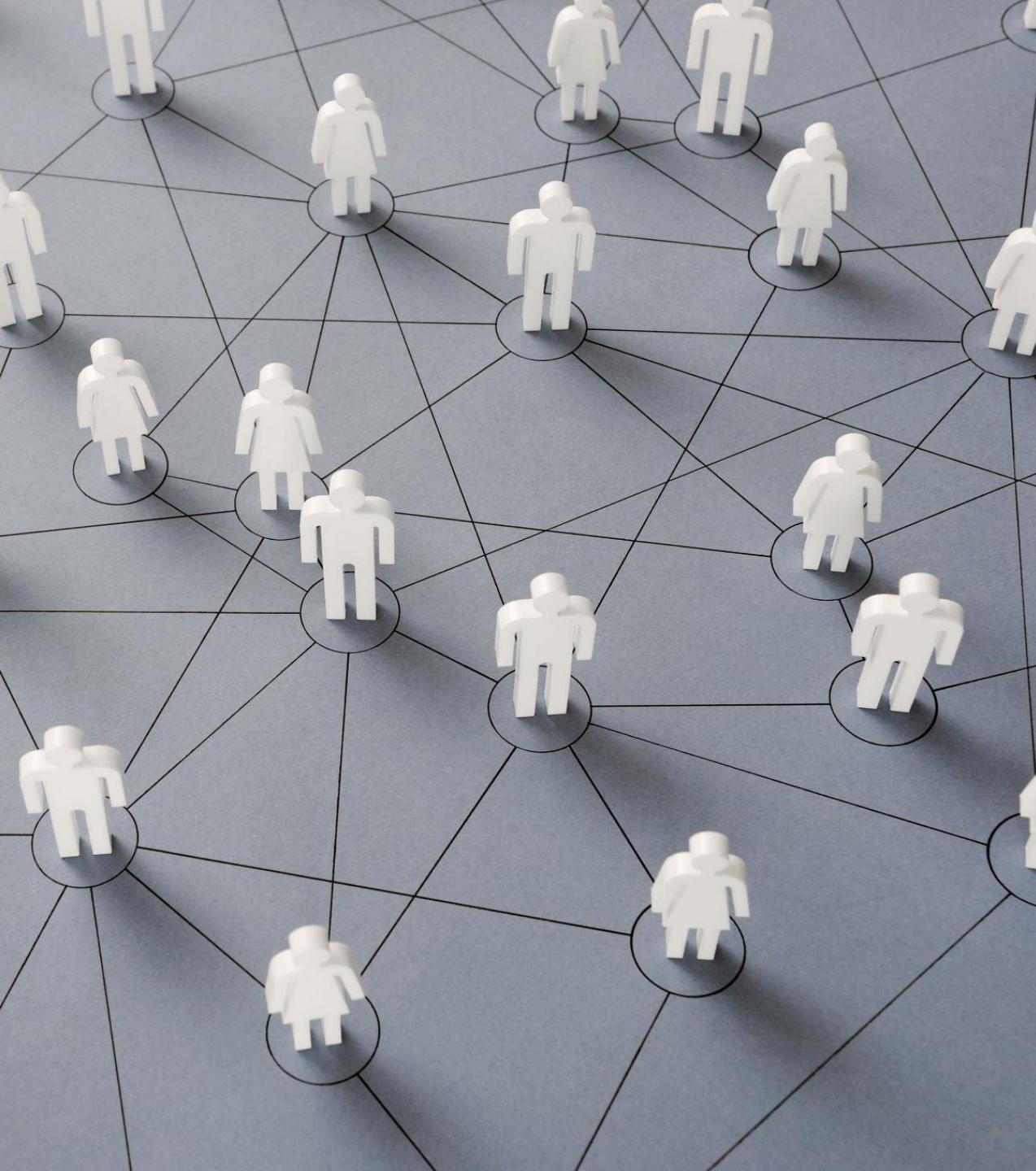


# Do all large software projects (in any language) become messy & complex...?



# Do all large software projects (in any language) become messy & complex...?



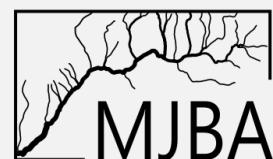


- R: massive surge in popularity over the past 15 years.
- Brings people together
- However,... larger collaborative projects still struggle with good structure



I don't think the answer is imposing more overhead everyone, but instead having pathways for structured development that encourages maintainability & scalability

If you're here at this conference you're probably one of the individuals in your organization to lead the charge in acting as the critical link & organizing individual



# **CEMPRA**

## Cumulative Effects Model for Prioritizing Recovery Actions

- Case study application: R package & R Shiny application
- Developed in collaboration with multiple individuals across different organizations.

Matthew Bayly: MJBA, Core application development.

Alexandra Tekatch: ESSA, Core application development.

Jordan Rosenfeld: Project design and coordination; ECCS Aquatic Ecologist

Lauren Jarvis: Collaborator; AEP Research Scientist

Andrew Paul: Collaborator; AEP Research Scientist

Eva Enders: Project Lead; DFO Research Scientist

Kyle Wilson: Population model development.

Sierra Sullivan: UBC

Isuru Dharmasena: Core Shiny app development

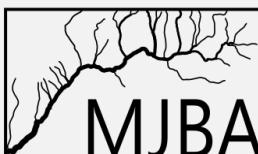
Alejandra Urcelay: ESSA

Pedro Gonzalez, ESSA

Marc Porter, PSF

Julian Heavyside: ESSA

*+ guidance and support from others...*



# CEMPRA

## Cumulative Effects Model for Prioritizing Recovery Actions

- Cumulative effects risk calculators, statistics, & spatial data processing
- Life cycle matrix population model & scenario projections
- <https://github.com/essatech/CEMPRA>

The Cumulative Effects Model for Prioritizing Recovery Actions (CEMPRA) is a cumulative effects modeling framework. The CEMPRA tool uses a series of standardized stressor-response functions to accommodate the complexity of the system capacity and productivity of a target species system. This framework deals with generalization, simplification, and scale as possible so that users can apply the model to various geographic regions, contexts, systems, and species, and as possible so that users can apply the model to various geographic regions, contexts, systems, and species-at-risk. As the name suggests, the CEMPRA tool helps prioritize recovery actions for data-limited species and species-at-risk, with the flexibility to accommodate both data-rich and data-poor study systems. The CEMPRA tool is accessible as an open-source R package (<https://github.com/essatech/CEMPRA>) and R shiny interactive web application (<https://github.com/essatech/CEMPRAshiny>).

**Project Components**

- GitHub Repository for R-Package (<https://github.com/essatech/CEMPRA>)
- GitHub Repository for R-Shiny Application (<https://github.com/essatech/CEMPRAshiny>)
- LIVE (online R-Shiny Application) (<https://essa.shinyapps.io/CEMPRAshiny/>)
- R-Package Tutorials (<https://essatech.github.io/CEMPRA/index.html>)
- Guidance Document: ([https://mattbayly.github.io/CEMPRA\\_documentation/](https://mattbayly.github.io/CEMPRA_documentation/))

**Shiny App Tutorial Video** access the tool <https://essa.shinyapps.io/CEMPRAshiny/>

**Package 'CEMPRA'**  
March 15, 2024

**About**

**Map Overview**

**Population Model**

**Socio-Economic**

**Upload Data**

**Download Data**

**CEMPRA - Cumulative Effects Model for Prioritizing Recovery Actions**

Stressor-Response Relationship: Foot flow

Use the table below to edit and define the stressor-response (stress-response) relationship for Aquatic Flow rate. Click on cells in the table to edit their values. The graph shows the stressor-response relationship between the raw stressor values (x-axis) and the mean system capacity (y-axis). The red line shows the mean value, and the shading represents uncertainty in the relationship. The red shading represents one standard deviation, and the grey shading represents the upper and lower bounds of min and max values. Click and drag within the graph area to zoom in or out, or click the graph to zoom out to full view.

HUC Values: Mean: 10.6 (Min: 0, Max: 29.2)

Stressor-Response curve for Foot flow

Mean System Capacity (%)

Raw Stressor Values

| Raw Value | Mean System Capacity (0-100) | SD (0-100) | Lower Limit (0) | Upper Limit (100) |
|-----------|------------------------------|------------|-----------------|-------------------|
| 100       | 20                           | 0          | 0               | 100               |
| 90        | 20                           | 0          | 0               | 100               |
| 80        | 24                           | 0          | 0               | 100               |
| 70        | 30                           | 0          | 0               | 100               |

Double-click a cell to edit its value.

Legend: Topo, Imagery, Grey

Stressors Variables

- Show raw values on mouse hover (slow)

preview all SR curves

Avg flow, Barrier dams, BKTR, Feb flow, Foot flow, Fragmentation, Habitat loss, Nat lm other, NN RNR, Phosphorus, Sediment, Selenium, Custom Stressor

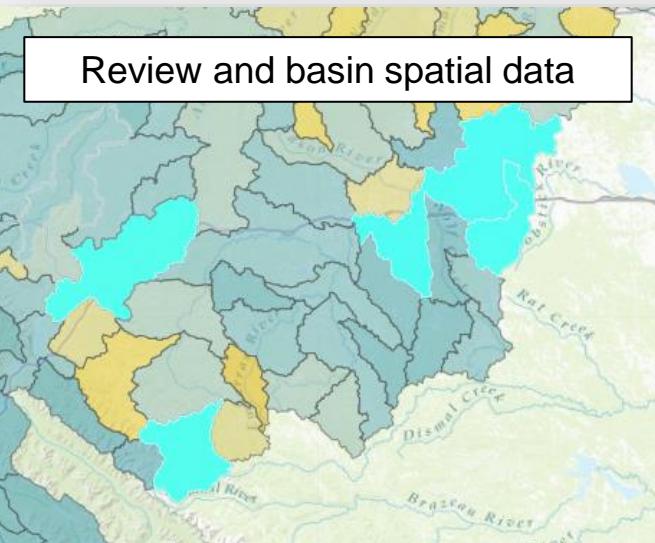
Leaflet | Tess © Esri — Esri, DeLorme, NAVTEQ, TomTom, Intermap, i-bis, USGS, NPS, NoCEN, GeoBase, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

(0) ICS selected - click on a unit on the map to select



<https://github.com/essatech/CEMPRA>

| Stressor        | Mean  | SD  | Distribution | Low_Limit | Up_Limit | SysCap |
|-----------------|-------|-----|--------------|-----------|----------|--------|
| Aug_flow        | 99.99 | 0   | normal       | 100       | 0        | 100    |
| Barrier_dams    | 0     | 0   | normal       | 0         | 5        | 100    |
| BKTR            | 0     | 0   | normal       | 0         | 100      | 100    |
| Feb_flow        | 99.54 | 0   | normal       | 100       | 0        | 99.9   |
| Foot_flow       | 24.11 | 0   | normal       | 0         | 100      | 95.9   |
| Fragmentation   | 0.09  | 0   | normal       | 0         | 0.32     | 74.1   |
| Habitat_loss    | 0     | 0   | normal       | 0         | 100      | 100    |
| Nat_lim_other   | 35    | 0   | normal       | 20        | 50       | 35     |
| NN_RNTR         | 0     | 0   | normal       | 0         | 100      | 100    |
| Phosphorus      | 0.77  | 0   | normal       | 0.01      | 978      | 56.3   |
| Sediment        | 7.34  | 0   | normal       | 1         | 10.8     | 10.8   |
| Selenium        | 0     | 0   | normal       | 0         | 31       | 100    |
| Spring_flow_sub | 305   | 187 | normal       | 0         | 800      | 100    |



# CE summary statistics

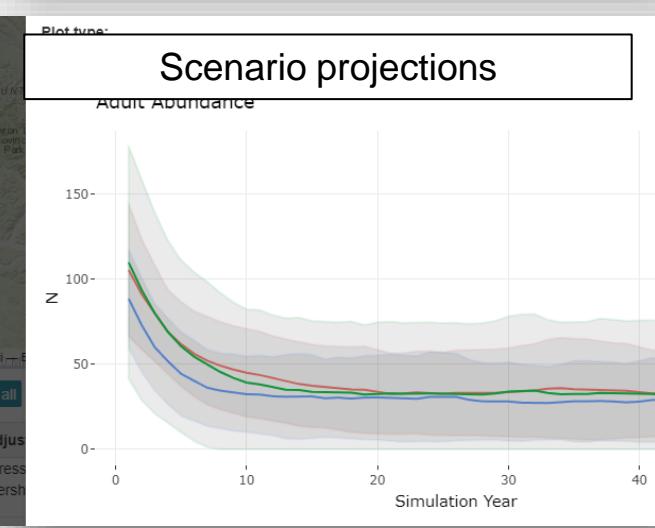
# Edit and customize relationships

standard deviation, and the grey shading represents the upper and lower bounds of min and max values. Click and drag within the graph window to zoom in on particular trends; double-click the graph to zoom out to full view.

HUC Values, Mean: 9.63 (Min: 2, Max: 17)

The graph displays a stressor-response curve for Temperature parr. The x-axis is labeled "Raw Stressor Values" and ranges from 0 to 16. The y-axis is labeled "Mean System Capacity (%)" and ranges from 0 to 100. A red line represents the mean response, starting at 0% capacity for stressor values below 4, rising sharply to 100% capacity between 4 and 6, and then gradually decreasing to approximately 10% capacity at a stressor value of 17. A light grey shaded area surrounds the red line, representing the standard deviation. A legend at the top right indicates that the grey line represents "msc" and the red line represents "Mean Sys. Cap.".

| Raw Value | Mean System Capacity (0-100) | SD (0-100) | Lower Limit (0) | Upper Limit (100) |
|-----------|------------------------------|------------|-----------------|-------------------|
| 0         | 0                            | 10         | 0               | 100               |
| 1         | 0                            | 10         | 0               | 100               |
| 2         | 0                            | 10         | 0               | 100               |



**CEMPRA - Cumulative Effects Model for Prioritizing Recovery Actions**

# Excel data upload & download

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**Up**  
Click  
watershed polygons must all be validated externally, or you will experience errors. Please see notes below to ensure proper data format. See sample data at the link below to help map.

[See Guidance Document Help Section](#)

[Download Example Datasets Here](#)

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**Stressor Response Workbook**

**Stressor Response Workbook (xlsx)**

---

**Watershed GIS Polygons or Lines (Spatial) [ .gpkg or .shp ]**

---

**Optional Additional Inputs**

**Population Model Vital Rates**

Upload life cycle profiles with for target species within the Population Model tab.

---

**Socio-economic Input Workbook**

**Socio-economic Input Workbook (xlsx)**

struc



**Population Model**  
See guidance document help section: Life Cycle Matrix Model

## Life cycle matrix model dashboard

Population Model Inputs (vital rates)  
Load Data From Existing Life Cycles Profile  
life\_cycles.csv

Browse... No file selected Nstage (# Stages) 4

Survival Parameters  
Define the individual survival probabilities for each stage class evaluated on annual time steps in the simulation.

|                           |                           |                           |
|---------------------------|---------------------------|---------------------------|
| SE (Egg Survival)         | SO (YOY Survival)         | surv_1 (Stage 1 Survival) |
| 0.1                       | 0.3                       | 0.3                       |
| surv_2 (Stage 2 Survival) | surv_3 (Stage 3 Survival) | surv_4 (Stage 4 Survival) |
| 0.3                       | 0.9                       | 0.9                       |

Interannual stochasticity is introduced into the model. Mortality also correlates intra-annually among size classes and over time (correlation diminishes as distance between stages increases).

M\_cv (Coefficient of variation in stage-specific mortality) 0.1 M\_rho (Correlation in mortality through time) 0.1

Growth Parameters  
Growth is represented as a constant rate of increase in body mass for all species in the model.

year\_1 (Years as Stage 1) 1 year\_2 (Years as Stage 2) 1 year\_3 (Years as Stage 3) 1 year\_4 (Years as Stage 4) 1

Sample Time Series

## Scenarios

Plot type:  
 Plot Stage Classes    Lambda    All Life Stages

Select stages to plot:  
 Stage 4    Stage 3    Stage 2    Stage 1

Abundance

Simulation  
Current  
Previous

mat\_1 (Maturity as Stage 1) 0 mat\_2 (Maturity as Stage 2) 0 mat\_3 (Maturity as Stage 3) 0 mat\_4 (Maturity as Stage 4) 1

**CEMPRA - Cumulative Effects Model for Prioritizing Recovery Actions**

## Sensitivity Tests

Full Matrix Eigen

The following tables represent outputs from an eigen analysis of the stage-structured matrix model. Note that these values are only relevant for density-independent growth conditions and will be misleading if not interpreted alongside density-dependent constraints.

Lambda: 0.81

The Lambda value represents the intrinsic population growth rate (at stable stage & equilibrium conditions). Lambda values greater than 1.0 indicate the population will increase and lambda values less than one indicate the population will decrease.

The following table shows the transition matrix for density-independent growth. The values represented here are adjusted for survival, growth, reproduction & the sex ratio, but they do not consider density-dependent constraints on population growth.

Transition matrix

|      | Stage 1 | Stage 2 | Stage 3 | Stage 4 |       |
|------|---------|---------|---------|---------|-------|
| Comp | Stage 1 | 0       | 0       | 0       | 15    |
| Proj | Stage 2 | 0.3     | 0.298   | 0       | 0     |
| Proj | Stage 3 | 0       | 0.002   | 0.756   | 0     |
| Proj | Stage 4 | 0       | 0       | 0.144   | 0.756 |

The next table shows the sensitivities matrix. What effect does an absolute change in a vital rate have on lambda? For example, if we change first-year survival by 0.001, how much will that affect the population growth rate?

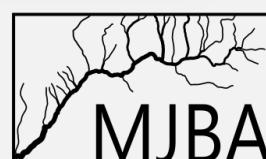
Sensitivity Matrix

|      | Stage 1 | Stage 2 | Stage 3 | Stage 4 |       |
|------|---------|---------|---------|---------|-------|
| Den  | Stage 1 | 0.03    | 0.017   | 0.001   | 0.002 |
| Hab  | Stage 2 | 0.08    | 0.047   | 0.002   | 0.004 |
| Hab  | Stage 3 | 23.841  | 14.041  | 0.462   | 1.284 |
| Mear | Stage 4 | 8.574   | 5.05    | 0.166   | 0.462 |

The next table shows the elasticities matrix. What effect does a proportional change in vital rate have on population growth. For example, if we increase first-year survival by 1%, how much will that affect the population growth rate?

Elasticities Matrix

|     | Stage 1 | Stage 2 | Stage 3 | Stage 4 |       |
|-----|---------|---------|---------|---------|-------|
| Low | Stage 1 | 0.03    | 0.017   | 0.001   | 0.002 |
| Low | Stage 2 | 0.08    | 0.047   | 0.002   | 0.004 |
| Low | Stage 3 | 23.841  | 14.041  | 0.462   | 1.284 |
| Low | Stage 4 | 8.574   | 5.05    | 0.166   | 0.462 |



# PROJECT LAYOUT

## R PACKAGE

*“Biology and core data processing here”*

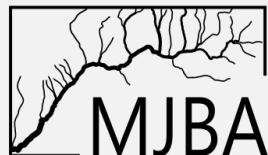
- Population ecology code
- Matrix math
- Complex data manipulations
- Import/export functionality

## R SHINY APPLICATION

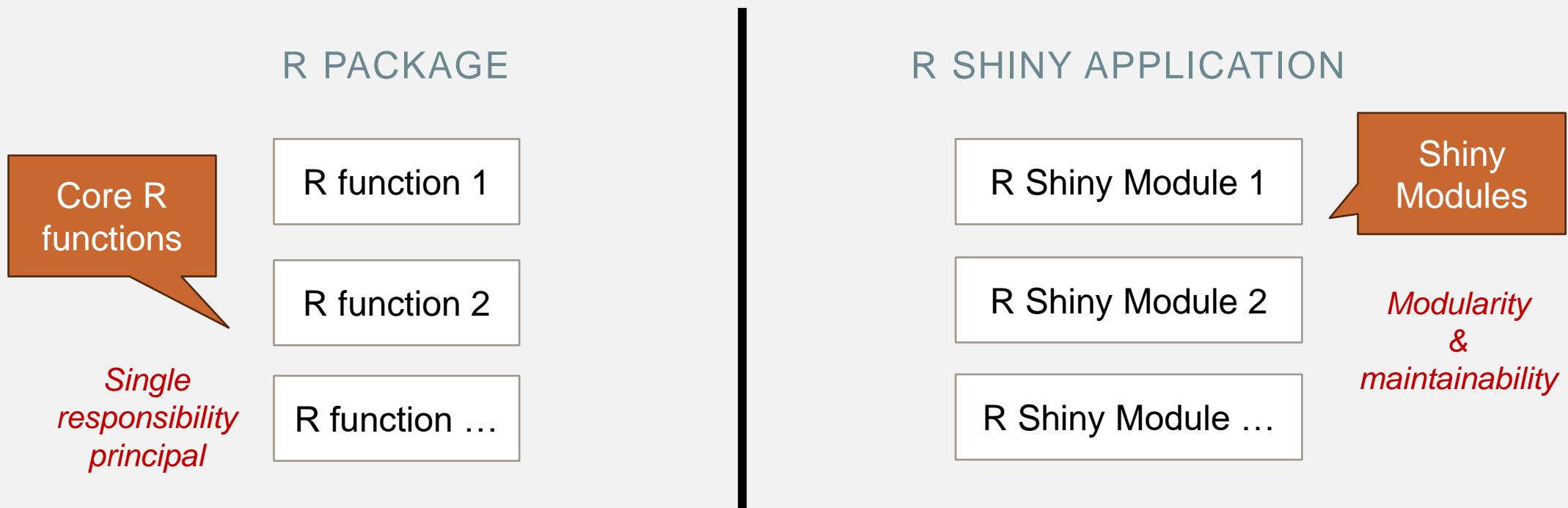
*“All user activity, reactive objects and app templating here”*

- Reactive object setup/management
- ui/server code for modules
- Plots and table creation

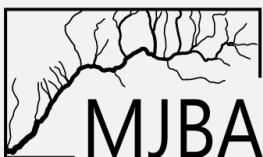
*Separation of Concerns*



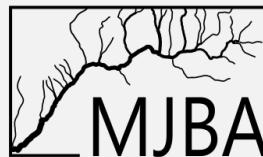
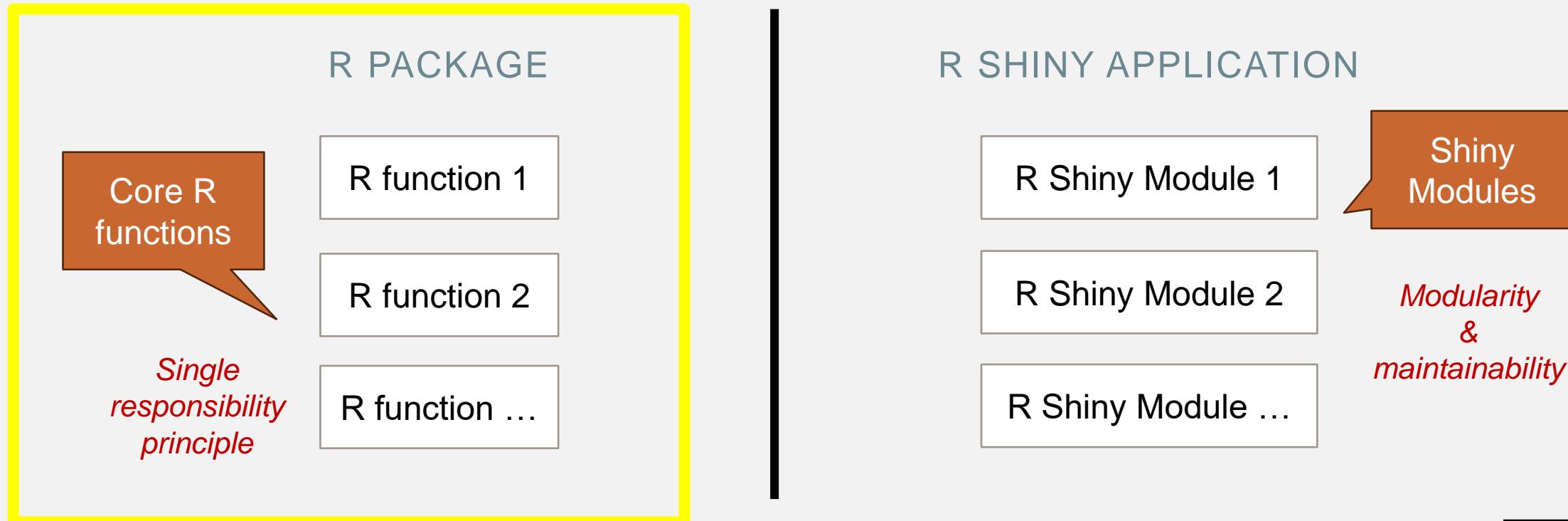
# PROJECT LAYOUT



*Separation of Concerns*



# PROJECT LAYOUT



# Building the R-Package

Natural Resource  
Managers

Project 1



Fisheries  
Biologists

Project 2



Population  
Modeller/Biologist

Project 3



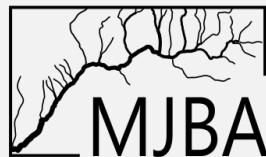
Gather R functions,  
organize and add  
documentation

mean\_Response.R  
pop\_model\_bh\_dd.R  
pop\_model\_ce\_apply.R  
pop\_model\_K\_adj.R  
pop\_model\_matrix\_elements.R  
pop\_model\_setup.R

R Functions  
*[single responsibility  
principal]*

*R package*

inst  
man  
R  
tests  
vignettes  
.gitignore  
.Rbuildignore  
.Rhistory  
 pkgdown.yml  
CEMPRA.Rproj  
DESCRIPTION  
LICENSE  
NAMESPACE



# Building the R-Package

The screenshot shows the RStudio interface with two panes. The left pane displays the 'BuildPackage.R' script, which contains R code with roxygen2 documentation tags. A callout box highlights the roxygen2 tags. The right pane shows the generated R documentation for the 'JoeModel\_Run' function, including sections for Description, Usage, and Arguments, along with detailed explanations for each parameter.

roxygen2 tags for function documentation

```
1 #' Joe Model Run
#
#'
#' @description Runs the Joe Model.
#'
#' @details Runs the Joe Model for cumulative system capacity across stressors and watersheds. Note that only stressors
#'
#' @param dose dataframe. Stressor magnitude file exported from the CEMPRA software
#' @param sr_wb_dat list object. Stressor response workbook returned by the CEMPRA software
#' @param MC_sims numeric. set number of Monte Carlo simulations
#' @param stressors (optional) character vector of stressor names
#' @param adult_sys_cap should the Joe Model be run only with adult systems?
#' @param socioeconomic_inputs (optional) list object. Socioeconomic inputs
#'
#'   set number of Monte Carlo simulations for the Joe model
#' @importFrom rlang .data
#'
#' @examples
#' \dontrun{
#'   library(CEMPRA)
#'
#'   # Load in the sample data from the reference Excel workbook
#'} 1
```

Environment History Connections Build Git Tutorial  
Import Dataset 400 MiB  
R Global Environment  
Files Plots Packages Help Viewer Presentation  
R: Joe Model Run Find in Topic  
JoeModel\_Run (CEMPRA)

### Joe Model Run

**Description**

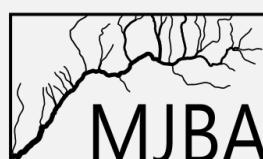
Runs the Joe Model.

**Usage**

```
JoeModel_Run(
  dose = NA,
  sr_wb_dat = NA,
  MC_sims = 100,
  stressors = NA,
  adult_sys_cap = TRUE,
  socioeconomic_inputs = NULL
```

**Arguments**

|                      |   |
|----------------------|---|
| dose                 | dataframe. Stressor magnitude file exported from the CEMPRA software  |
| sr_wb_dat            | list object. Stressor response workbook returned by the CEMPRA software   |
| MC_sims              | numeric. set number of Monte Carlo simulations  |
| stressors            | (optional) character vector of stressor names. Default value is NA if you wish to include all stressors. Provide a character vector of stressors if you only want to include some of the stressors. |
| adult_sys_cap        | Should the Joe Model be run only with variable adult systems?   |
| socioeconomic_inputs | (optional) list object. Socioeconomic inputs  |



# Building the R-Package

<https://r-pkgs.org/>

R Packages (2e)  

Welcome!

Preface

Introduction

Getting started

- 1 The Whole Game
- 2 System setup
- 3 Package structure and state
- 4 Fundamental development workflows
- 5 The package within

Package components

- 6 R code
- 7 Data
- 8 Other components

Package metadata

- 9 DESCRIPTION
- 10 Dependencies: Mindset and Background
- 11 Dependencies: In Practice
- 12 Licensing

Testing

- 13 Testing basics
- 14 Designing your test suite

## R Packages (2e)

Learn how to create a package, the fundamental unit of shareable, reusable, and reproducible R code.

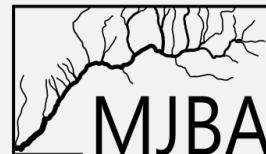
AUTHOR

Hadley Wickham and Jennifer Bryan

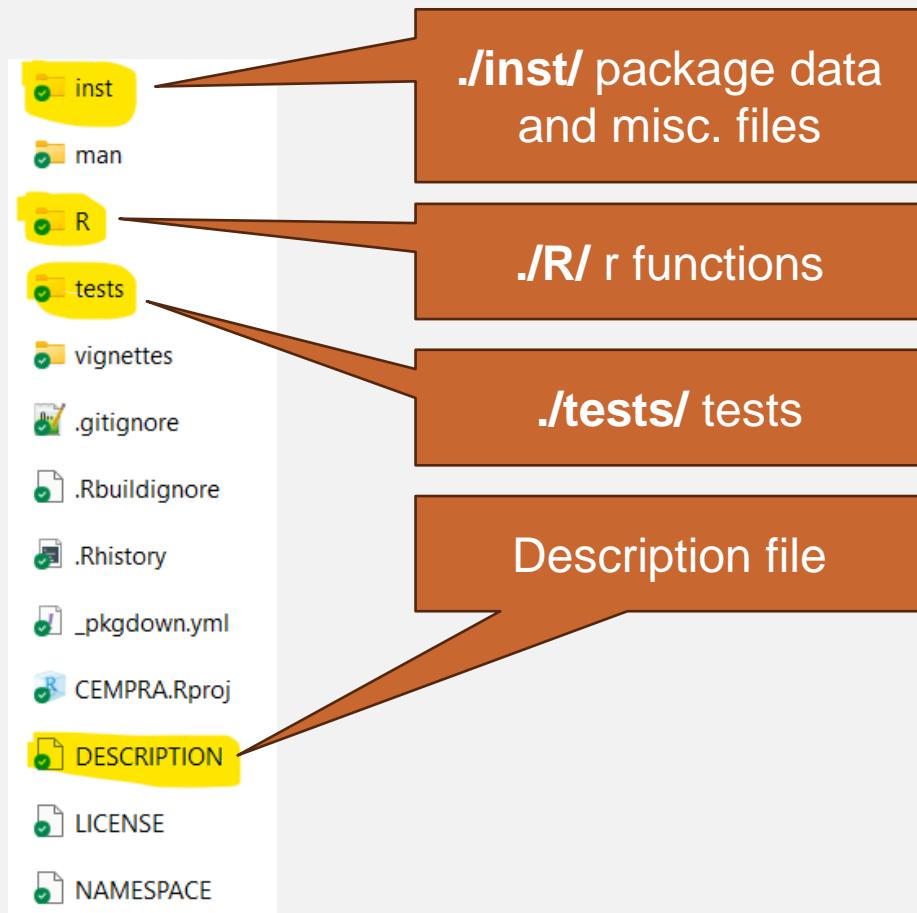
## Welcome!

Welcome to the online version of the 2nd edition of “**R Packages**” by [Hadley Wickham](#) and [Jennifer Bryan](#). Packages are the fundamental units of reproducible R code. They include reusable R functions, the documentation that describes how to use them, and sample data. In this book you’ll learn how to turn your code into packages that others can easily download and use. Writing a package can seem overwhelming at first. So start with the basics and improve it over time. It doesn’t matter if your first version isn’t perfect as long as the next version is better.

This website is and will always be free, licensed under the [CC BY-NC-ND 4.0 License](#). If you’d like a physical copy of the book, you can order it on [Amazon](#).



# Building the R-Package



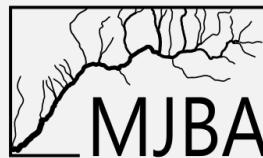
<https://usethis.r-lib.org/>

usethis 2.2.3 Setup Reference Articles ▾ News ▾

usethis

```
library(usethis)

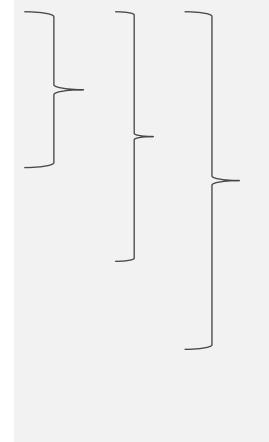
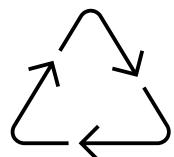
# Create a new package -----
path <- file.path(tempdir(), "mypkg")
create_package(path)
```



# Building the R-Package

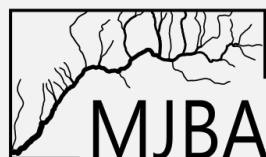
*Developing and updating the package*

```
devtools::load_all()  
devtools::document()  
devtools::test()  
devtools::check()  
devtools::install_github("essatech/CEMPRA")
```



*Updates to R functions (local)  
Rebuild documentation  
Run tests  
Perform checks*

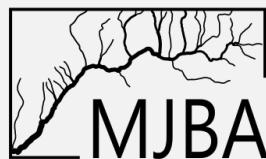
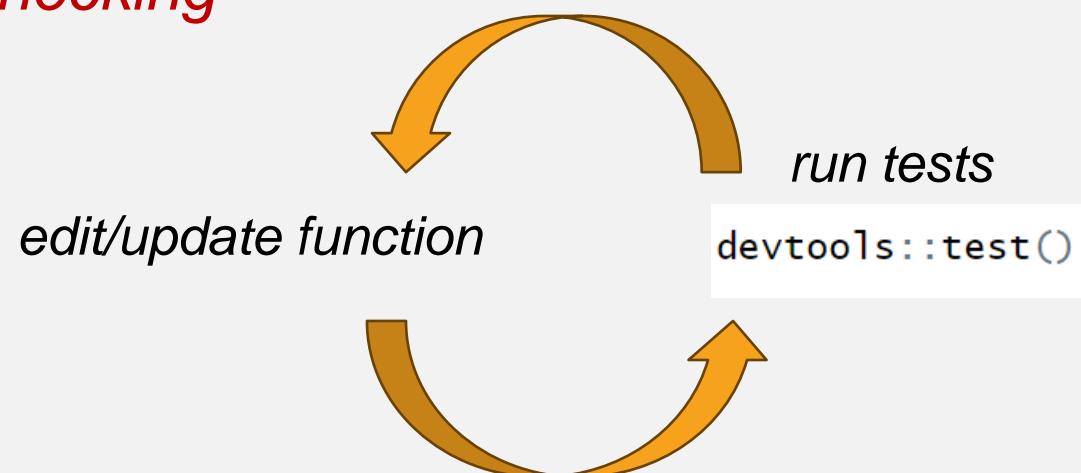
*Publish & install remotely*



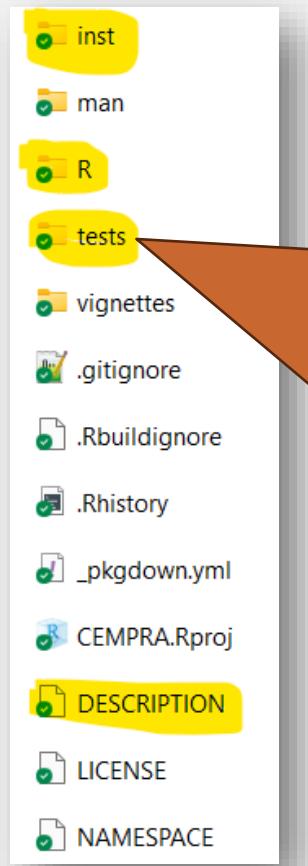
# R-Package Tests

*The major advantage of building and using R packages*

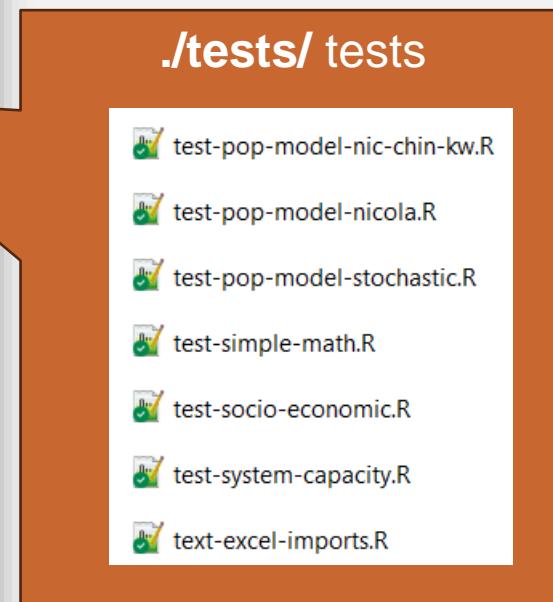
*Debugging and  
Error Checking*



# R-Package Tests



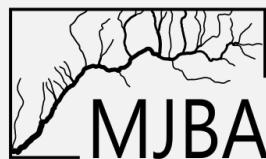
*What do tests look like?*



*Debugging and Error Checking*

```
test_that("simple math works", {  
  # -----  
  c1 <- rtnorm_TruncatedDistributions(n = 5,  
  c2 <- rtnorm_TruncatedDistributions(n = 5,  
  c3 <- rtnorm_TruncatedDistributions(n = 5,  
  
  expect_true(!any(is.na(c1))))  
  expect_true(!any(is.na(c2))))  
  expect_true(!any(is.na(c3))))  
  expect_true(length(c1) == 5)  
  expect_true(length(c2) == 5)
```

```
devtools:::test()  
[ FAIL 1 | WARN 0 | SKIP 0 | PASS 995 ]  
>
```



# BUILDING THE R SHINY APPLICATION

## R PACKAGE

*“Biology and core data processing here”*

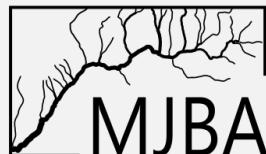
- Population ecology code
- Matrix math
- Complex data manipulations
- Import/export functionality

## R SHINY APPLICATION

*“All user activity, reactive objects and app templating here”*

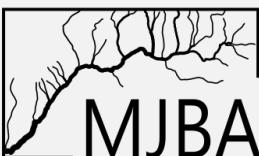
- Reactive object setup/management
- ui/server code for modules
- Plots and table creation

*Separation of Concerns*



# Building the R Shiny Application

- Create as a separate R project
- ui.R, server.R, & global.R configuration
- Heavy use of R Shiny modules for **modularization**
- Can be create as a separate R project



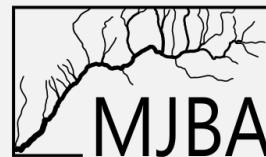
# Building the R Shiny Application

## R Project Directory

```
data  
R  
rsconnect  
tests  
VideoDecodeStats  
www  
.gitignore  
.lintr  
CEMPRAShiny.Rproj  
global.R  
README.md  
server.R  
ui.R
```

```
module_about.R  
module_all_sr_curves.R  
module_ce_model.R  
module_dose_response.R  
module_export.R  
module_huc_results.R  
module_huc_stressor_magnitude.R  
module_import.R  
module_import_se_workbook.R  
module_joe_model_csc_plots.R  
module_joe_model_csc_plots_selected.R  
module_joe_model_run.R  
module_joe_vs_population.R  
module_main_map.R
```

- Individual R Shiny modules act as ‘components’ or miniature apps providing modularization.
- Using Shiny modules prevents the creation of large bloated scripts that are difficult to interpret and maintain.
- Shiny modules are the key to scaling app functionality without overwhelming app complexity.



# Building the R Shiny Application

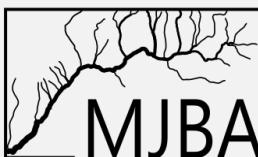
What is an R Shiny module? [./R/MYMODULE.R](#)

```
module_MYMODULE_ui <- function(id) {  
  ns <- NS(id)  
  
  # UI code goes here...  
  
}
```

```
module_MYMODULE_server <- function(id) {  
  moduleServer(id,  
    function(input, output, session) {  
      ns <- session$ns  
  
      # Server code goes here...  
  
    })  
}
```

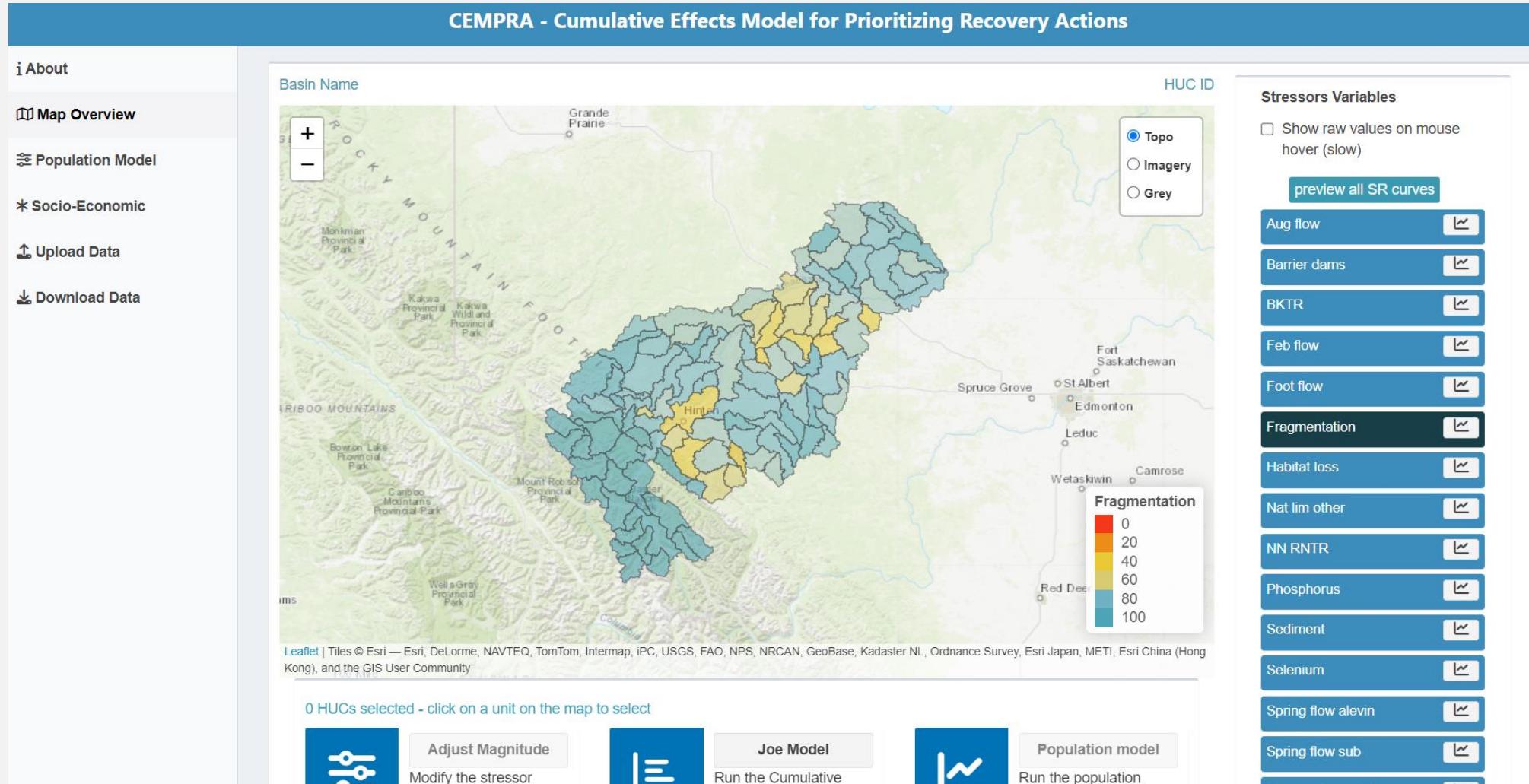
ui.R

server.R



# Building the R Shiny Application

What do R Shiny modules look like on the page?



# Building the R Shiny Application

What do R Shiny modules look like on the page?

**CEMPRA - Cumulative Effects Model for Prioritizing Recovery Actions**

- [About](#)
- [Map Overview](#)
- [Population Model](#)
- [Socio-Economic](#)
- [Upload Data](#)
- [Download Data](#)

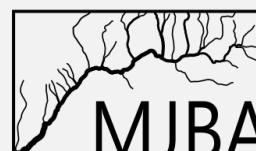
*Each colored block is its own module & functions as its own mini Shiny app*

Basin Name: [Input field]

HUC ID: [Input field]

Stressors Variables:

- Show raw values on mouse hover (slow)
- [preview all SR curves](#)
- [Aug flow](#)
- [Barrier dams](#)
- [BKTR](#)
- [Feb flow](#)
- [Foot flow](#)
- [Fragmentation](#)
- [Habitat loss](#)
- [Nat lim other](#)
- [NN RNTR](#)
- [Phosphorus](#)
- [Sediment](#)
- [Selenium](#)
- [Spring flow alivn](#)
- [Spring flow sub](#)



0 HUCs selected - click on a unit on the map to select

 [Adjust Magnitude](#)  
Modify the stressor

 [Joe Model](#)  
Run the Cumulative

 [Population model](#)  
Run the population

# Building the R Shiny Application

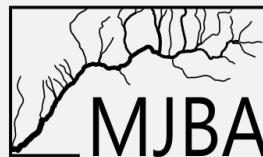
Some utility modules: might not have a UI component

```
print("Setting up reactive values for user session...")

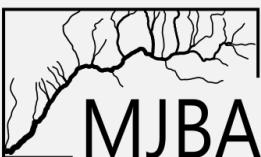
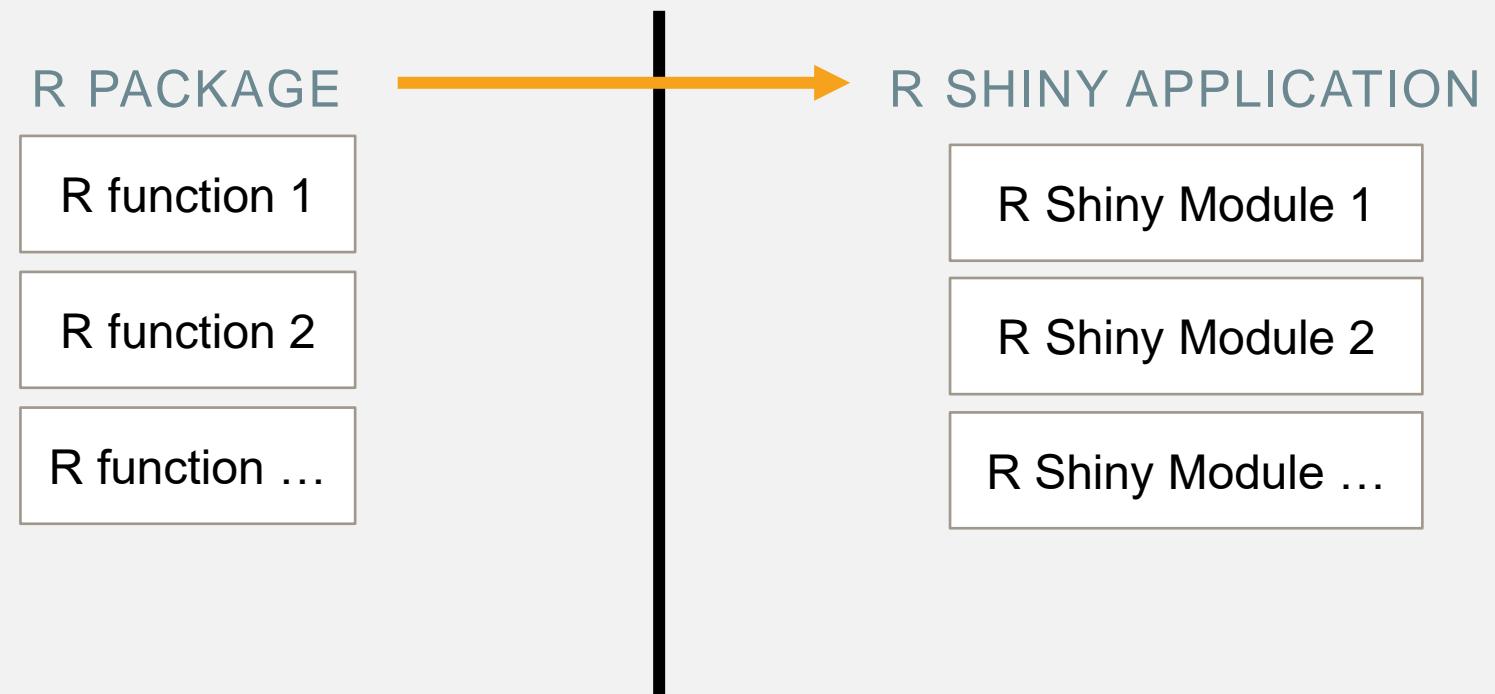
# Determine if we are using polygons or lines
session$userData$geom_type <- "polygons"

# Designate stressor magnitude as reactive values
rv_stressor_magnitude <- reactiveValues(sm_dat = sm_wb_dat)
# Add to userData object for session
session$userData$rv_stressor_magnitude <- rv_stressor_magnitude

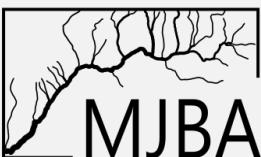
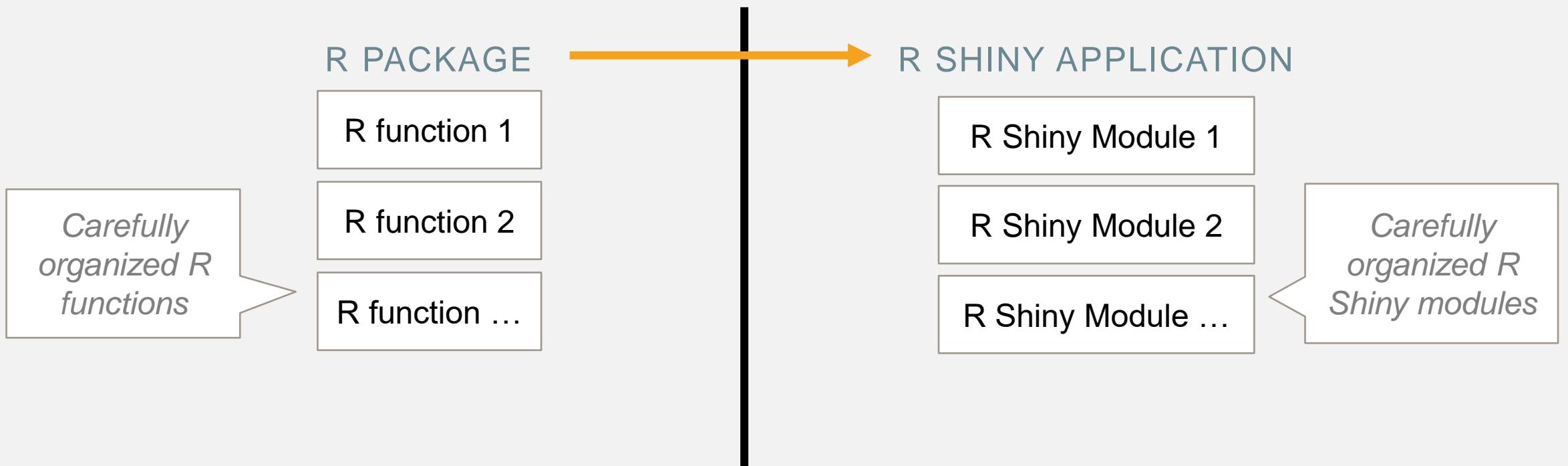
# Designate the stressor response object as a reactive value
rv_stressor_response <- reactiveValues(
  main_sheet           = sr_wb_dat$main_sheet,
  stressor_names       = sr_wb_dat$stressor_names,
  pretty_names         = sr_wb_dat$pretty_names,
  sr_dat               = sr_wb_dat$sr_dat,
  active_layer         = sr_wb_dat$stressor_names[1],
  active_values_raw    = NULL,
  active_values_nochange = NULL)
```



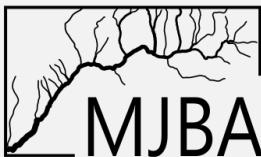
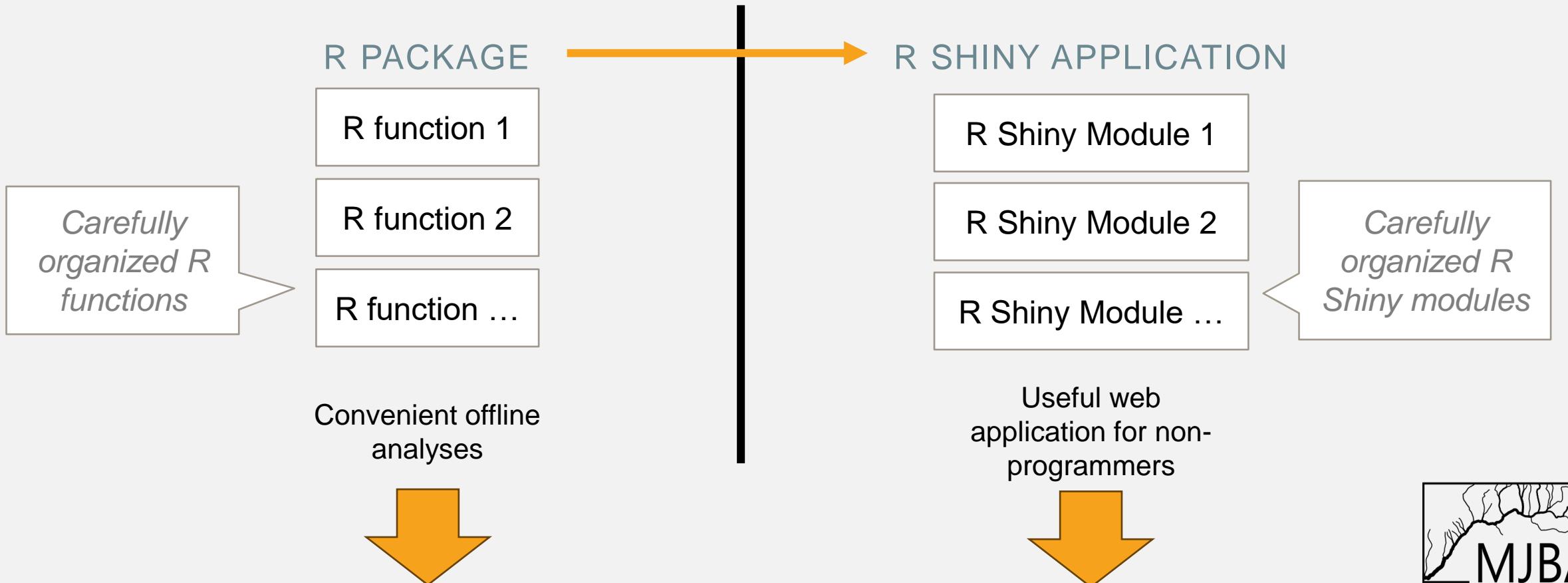
# R project layout in consideration of core software development principals



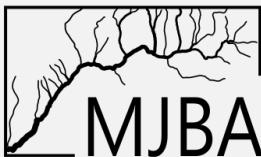
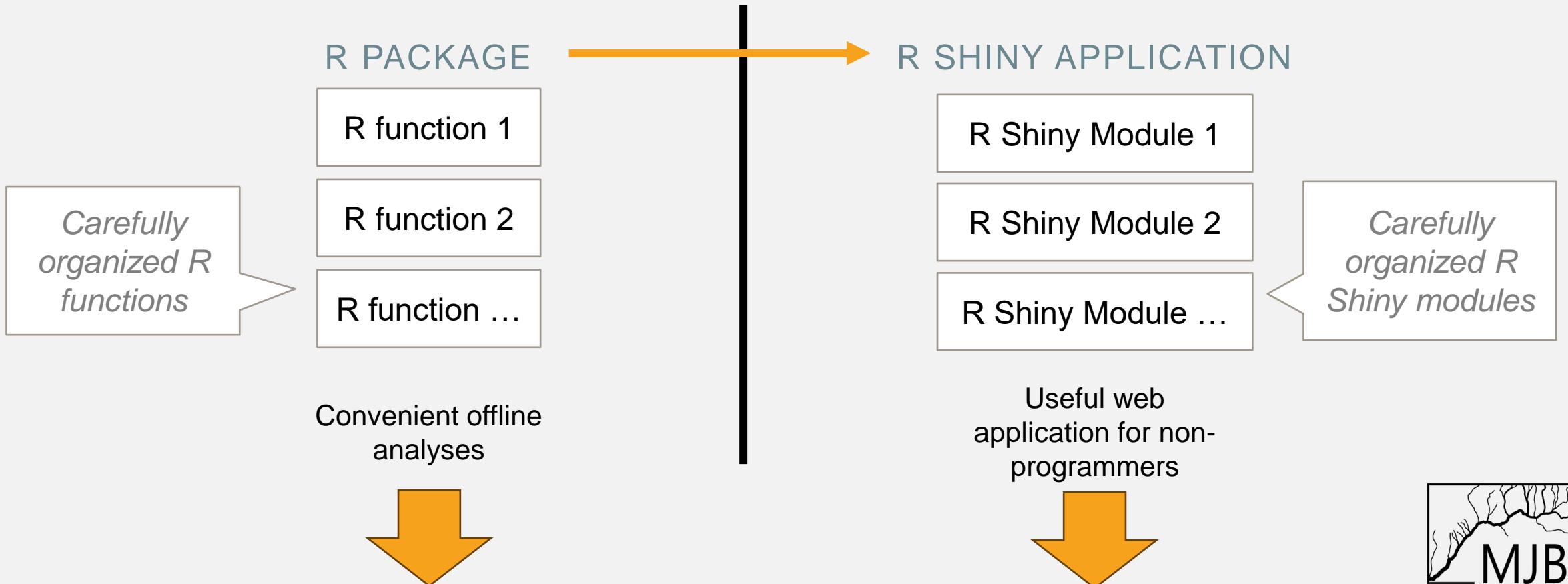
# R project layout in consideration of core software development principals



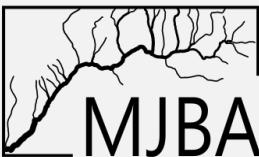
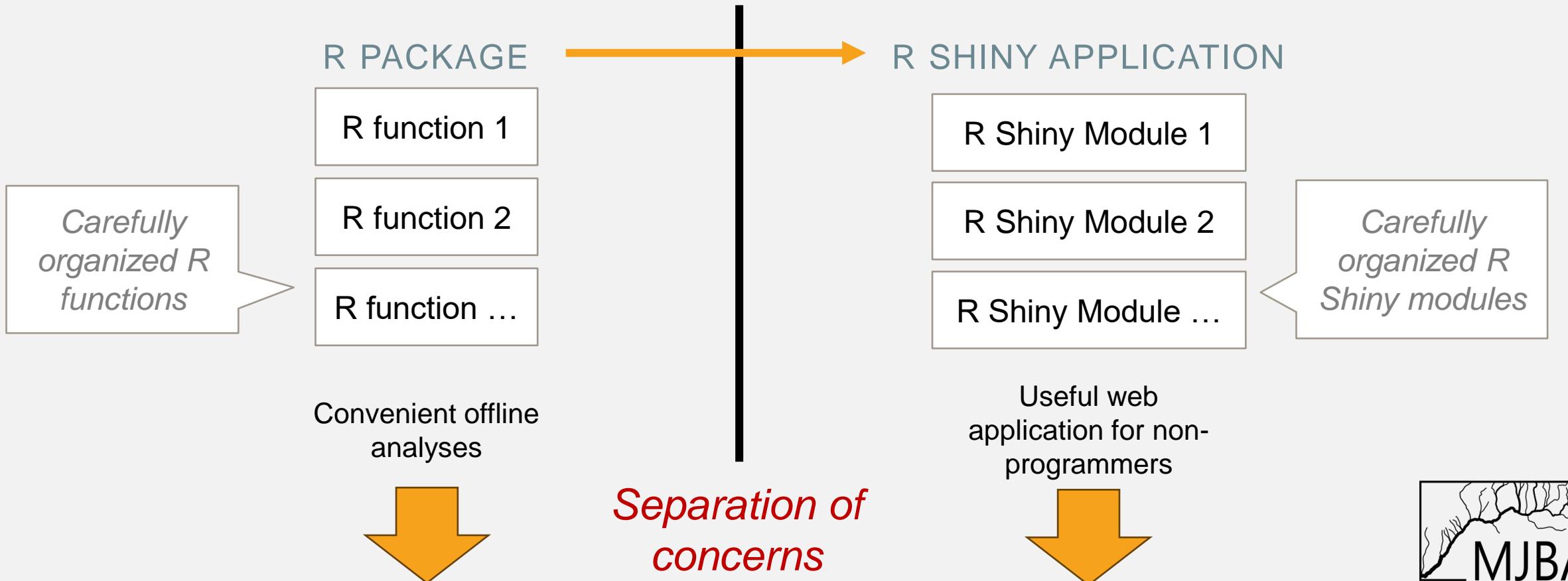
# R project layout in consideration of core software development principals



# R project layout in consideration of core **software development principals**



# R project layout in consideration of core **software development principals**



# R project layout in consideration of core **software development principals**

*Single responsibility principle*

*Carefully organized R functions*

R PACKAGE

R function 1

R function 2

R function ...

Convenient offline analyses



R SHINY APPLICATION

R Shiny Module 1

R Shiny Module 2

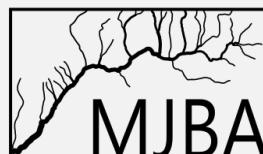
R Shiny Module ...

*Carefully organized R Shiny modules*

Useful web application for non-programmers



*Separation of Concerns*



## R project layout in consideration of core **software development principals**

*Single responsibility principal*

*Carefully organized R functions*

R PACKAGE

R function 1

R function 2

R function ...



R SHINY APPLICATION

R Shiny Module 1

R Shiny Module 2

R Shiny Module ...

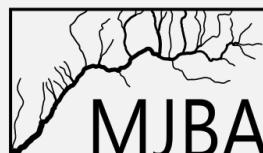
*Carefully organized R Shiny modules*

Convenient offline analyses



*Separation of concerns*

Useful web application for non-programmers



*Modularity*

*Maintainability*

## R project layout in consideration of core **software development principals**

*Single responsibility principle*

*Carefully organized R functions*

R PACKAGE

R function 1

R function 2

R function ...



R SHINY APPLICATION

R Shiny Module 1

R Shiny Module 2

R Shiny Module ...

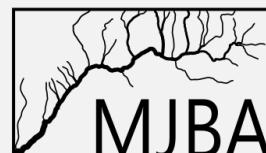
*Carefully organized R Shiny modules*

Convenient offline analyses



*Separation of concerns*

Useful web application for non-programmers



*Modularity*

*Maintainability*

*Scalability*

## R project layout in consideration of core **software development principals**

*Single responsibility principle*

*Carefully organized R functions*

R PACKAGE

R function 1

R function 2

R function ...



R SHINY APPLICATION

R Shiny Module 1

R Shiny Module 2

R Shiny Module ...

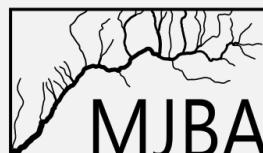
*Carefully organized R Shiny modules*

Convenient offline analyses



*Separation of concerns*

Useful web application for non-programmers



*Modularity*

*Maintainability*

*Scalability*

*Reusability*

## R project layout in consideration of core **software development principals**

*Single responsibility principle*

*Carefully organized R functions*

R PACKAGE

R function 1

R function 2

R function ...



R SHINY APPLICATION

R Shiny Module 1

R Shiny Module 2

R Shiny Module ...

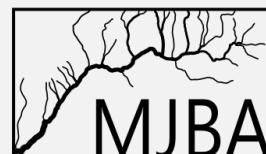
*Carefully organized R Shiny modules*

Convenient offline analyses



*Separation of concerns*

Useful web application for non-programmers



*Modularity*

*Maintainability*

*Scalability*

*Reusability*

*Parallel  
development*

*Testing*

## R project layout in consideration of core **software development principals**

*Single  
responsibility  
principle*

*Carefully  
organized R  
functions*

R PACKAGE

- R function 1
- R function 2
- R function ...

Convenient offline  
analyses



R SHINY APPLICATION

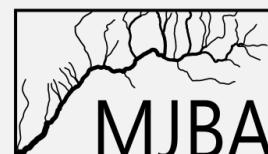
- R Shiny Module 1
- R Shiny Module 2
- R Shiny Module ...

*Carefully  
organized R  
Shiny modules*

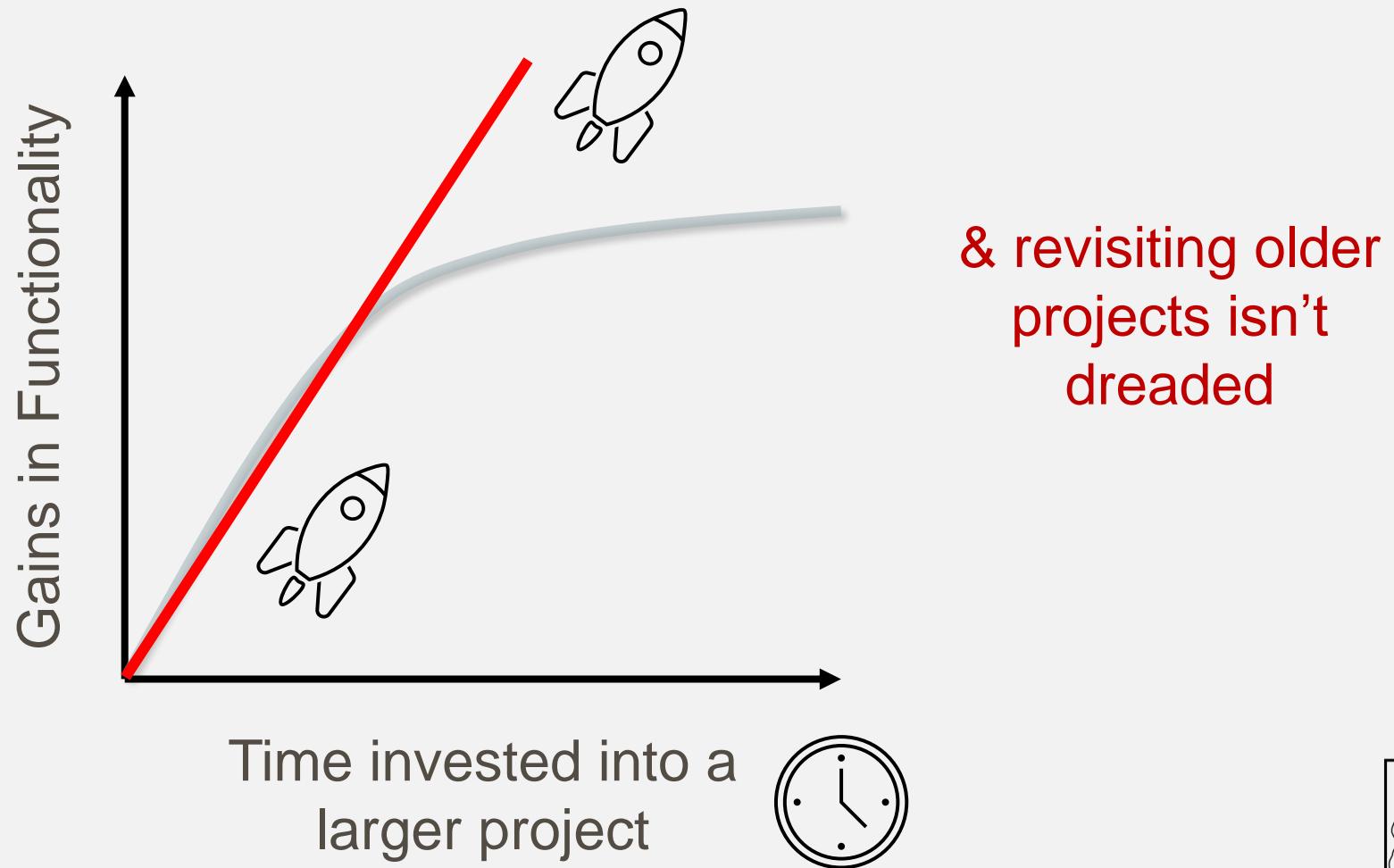
Useful web  
application for non-  
programmers



*Separation of  
concerns*



# Why even worry about organizational structures and systems in R...?



# Quarto Book

## CEMPRA Guidance Document



### CEMPRA

- 1 Introduction
  - 2 Stressor-Response Functions
  - 3 Modelling Pathways and Assessment Endpoints
  - 4 Setup and Installation
  - 5 Data Inputs
  - 6 R-Shiny Application
  - 7 Life Cycle Model
  - 8 Stressor-Response Library
  - 9 Example Datasets
  - 10 R Package Tutorials
  - 11 Concluding Remarks
- References
- Appendices
- A Multi-Stressor Interaction Matrix

## CEMPRA Guidance Document

Cumulative Effects Model for Prioritizing Recovery Actions (CEMPRA)

### PUBLISHED

November 10, 2023

## CEMPRA

### Editors

- Matthew Bayly, M.J. Bayly Analytics Ltd.
- Alexandra Tekatch, ESSA Technologies Ltd.
- Dr. Jordan Rosenfeld, the University of British Columbia, BC WLRS
- Dr. Eva Enders, INRS
- Lauren Jarvis, Department of Fisheries and Oceans

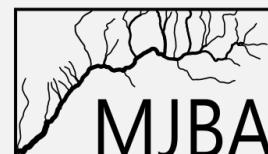
### Contributors

- Matthew Bayly, MJBA
- Alexandra Tekatch, ESSA
- Dr. Jordan Rosenfeld, UBC/BC-WLRS
- Dr. Eva Enders, INRS
- Lauren Jarvis, DFO
- Julian Heavyside, ESSA
- Andrew Paul, AEP
- Kyle Wilson, CCIRA
- Pedro Gonzalez, UBC
- Laura MacPherson, AEP
- Isuru Dharmasena
- Marc Porter, ESSA

### Table of contents

- CEMPRA
- Editors
- Contributors
- Suggested Citation
- Project Components
- Purpose
- Acknowledgements
- 'Joe Model' Testimonial to Joe Nelson
- Executive Summary

*Project funded (in part) through the British Columbia Salmon Restoration and Innovation Fund (BCSRIIF).*



# Quarto Book

CEMPRA Guidance  
Document 



|   |
|---|
| CEMPRA  |
| 1 Introduction                                |
| 2 Stressor-Response Functions                 |
| 3 Modelling Pathways and Assessment Endpoints |
| 4 Setup and Installation                      |
| 5 Data Inputs                                 |
| 6 R-Shiny Application                         |
| 7 Life Cycle Model                            |
| 8 Stressor-Response Library                   |
| 9 Example Datasets                            |
| 10 R Package Tutorials                        |
| 11 Concluding Remarks                         |
| References                                    |
| Appendices                                    |
| A Multi-Stressor Interaction Matrix           |

## 9 Example Datasets

### 9.1 Athabasca Rainbow Trout

(MacPherson et al., 2020) leveraged the Joe Modelling framework to support recovery action planning and threat analysis of Athabasca Rainbow Trout. The Joe Model was a valuable resource for synthesizing stressors due to its ease of and utility as a design and communication tool. Stressors were developed in a near real-time workshop-like setting to game out alternative management scenarios. The flexibility of the stressor-response input data allows for the inclusion of synthetic proxies and hypothetical impact pathways, weaving together academic knowledge, anecdotal descriptions and expert opinion. The Joe Model was ultimately used as a prioritization tool to help design actions, programs, and priorities across a large geographic and complex region.

Default sample dataset when tool loads:

- [Stressor Response Workbook](#)
- [Stressor Magnitude Workbook](#)
- [Watershed Locations.gpkg](#)
- [Life Cycle Profile \(optional\)](#)

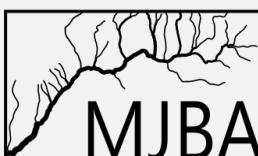
The default study area, stressor list and species profile in the Shiny application are from the (MacPherson et al., 2020) Athabasca Rainbow Trout project.

### 9.2 Simple Working Example (hypothetical)

This straightforward example serves as an easy-to-use template for your own input files, offering minimal

#### Table of contents

- 9.1 Athabasca Rainbow Trout
- 9.2 Simple Working Example (hypothetical)
- 9.3 WSEP (Watershed Status Evaluation Protocol) Fisheries Sensitive Watersheds (FSWs)
- 9.4 Meso-Habitat Units (hypothetical)
- 9.5 Matrix Interaction (Example 1: Template)
- 9.6 Matrix Interaction (Example 2: Application)
- 9.7 Nicola Basin Chinook Salmon, Coho Salmon, and Steelhead



# Quarto Book

## CEMPRA Guidance Document

- 
- CEMPRA
- 1 Introduction
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## 7 Life Cycle Model

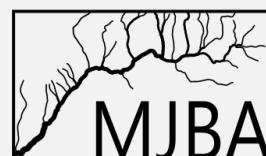
The screenshot shows a YouTube video player. At the top, it says 'CEMPRA 04: Life Cycle Model' and 'Life Cycle Model Development'. Below that, it says '(Major contributions from Dr. Kyle Wilson)'. To the right are 'Watch later' and 'Share' buttons. On the left, there's a small profile picture of a person. In the center, there's a large green 'X' icon. Below the title, it says 'Density-Dependent Constraints on Growth' and '(OPTION 1) Location and stage-specific carrying capacities:'. It shows a table with columns for HUC\_ID, NAME, k\_stage\_0\_mean, k\_stage\_1\_mean, k\_stage\_2\_mean, k\_stage\_3\_mean, and k\_stage\_4\_mean. The first row has values: 1, 1, 1200, 300, 7850, 0, 0. A red box highlights this row. Below the table, it says '(e.g., Location 1 can produce up to 1,200 parr.)'. At the bottom of the video player, it says 'Watch on YouTube' with a play button icon.

### 7.1 Overview

The integrated life cycle model is a core component of the CEMPRA tool. The life cycle modeling component is a valuable endpoint to evaluate and understand cumulative effects through the lens of demographic rates and population ecology. Some user groups may be satisfied with the simplified Joe Modelling (stressor roll-up) component of the CEMPRA tool and, therefore, not wish to interact with the

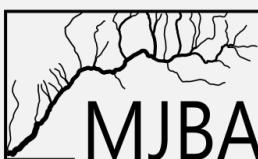
### Table of contents

- 7.1 Overview
- 7.2 Data Input: Life Cycle Profiles
- 7.3 Matrix Life Cycle Model
- 7.4 Density-Dependent Constraints on Growth
- 7.5 Stochastic Simulations
- 7.6 Building a Life Cycle Profile
- 7.7 Benefits and Limitations



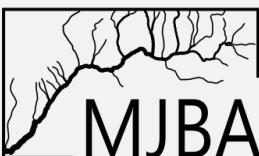
# Quarto Book

| Page title and screen class |   | Views                | Users               | Views per user | Average engagement time | Event count          | Key events |
|-----------------------------|---|----------------------|---------------------|----------------|-------------------------|----------------------|------------|
|                             |   | 142<br>100% of total | 28<br>100% of total | 5.07<br>Avg 0% | 3m 30s<br>Avg 0%        | 404<br>100% of total | 0.00       |
| 1                           | CEMPRA Guidance Document                                    | 42                   | 26                  | 1.62           | 24s                     | 132                  | 0.00       |
| 2                           | CEMPRA Guidance Document - 4<br>Setup and Installation      | 17                   | 3                   | 5.67           | 11m 01s                 | 53                   | 0.00       |
| 3                           | CEMPRA Guidance Document - 1<br>Introduction                | 11                   | 5                   | 2.20           | 4m 21s                  | 24                   | 0.00       |
| 4                           | CEMPRA Guidance Document - 7<br>Life Cycle Model            | 11                   | 6                   | 1.83           | 49s                     | 31                   | 0.00       |
| 5                           | CEMPRA Guidance Document - 9<br>Example Datasets            | 11                   | 5                   | 2.20           | 21s                     | 39                   | 0.00       |
| 6                           | CEMPRA Guidance Document - 2<br>Stressor-Response Functions | 9                    | 3                   | 3.00           | 1m 51s                  | 17                   | 0.00       |
| 7                           | CEMPRA Guidance Document - 5<br>Data Inputs                 | 9                    | 3                   | 3.00           | 32s                     | 21                   | 0.00       |
|                             | CEMPRA Guidance Document - 8                                |                      |                     |                |                         |                      |            |



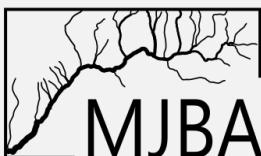
# **Quarto Book**

- Started as a MS Word document
- Convert Word to html & then html to mark down (using ChatGPT)
- Conversion a little awkward & time-intensive... need a better method.



## **Take home messages**

- Large R projects don't have to become overly complex
- Leveraging the R package structure & Shiny app modules can create a clean organizational framework.
- This helps us adhere to key principles that guide the design and implementation of robust, maintainable, and scalable software.





# BUILDING AN R PACKAGE, R SHINY APPLICATION, AND QUARTO BOOK FOR CUMULATIVE EFFECT ASSESSMENTS IN BC (CEMPRA)

**Matthew Bayly**

M.J. Bayly Analytics Ltd.

Whistler – British Columbia

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[mjbayly.com](http://mjbayly.com)