



Ecopath  
International  
Initiative

# Spatial ecosystem modelling using Ecopath with Ecosim

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Webinar, 29 August 2016



# Outline

Ecopath with Ecosim – brief overview

Recent developments in Ecospace

Work in progress

Other ways to use EwE

The EwE ecosystem

# Ecopath with Ecosim



# Ecopath with Ecosim

Ecological model that tracks the paths of energy through a food web

Functional groups

Requires relatively few input parameters

Data often readily available  
(stock assessment, FishBase, literature, ...)

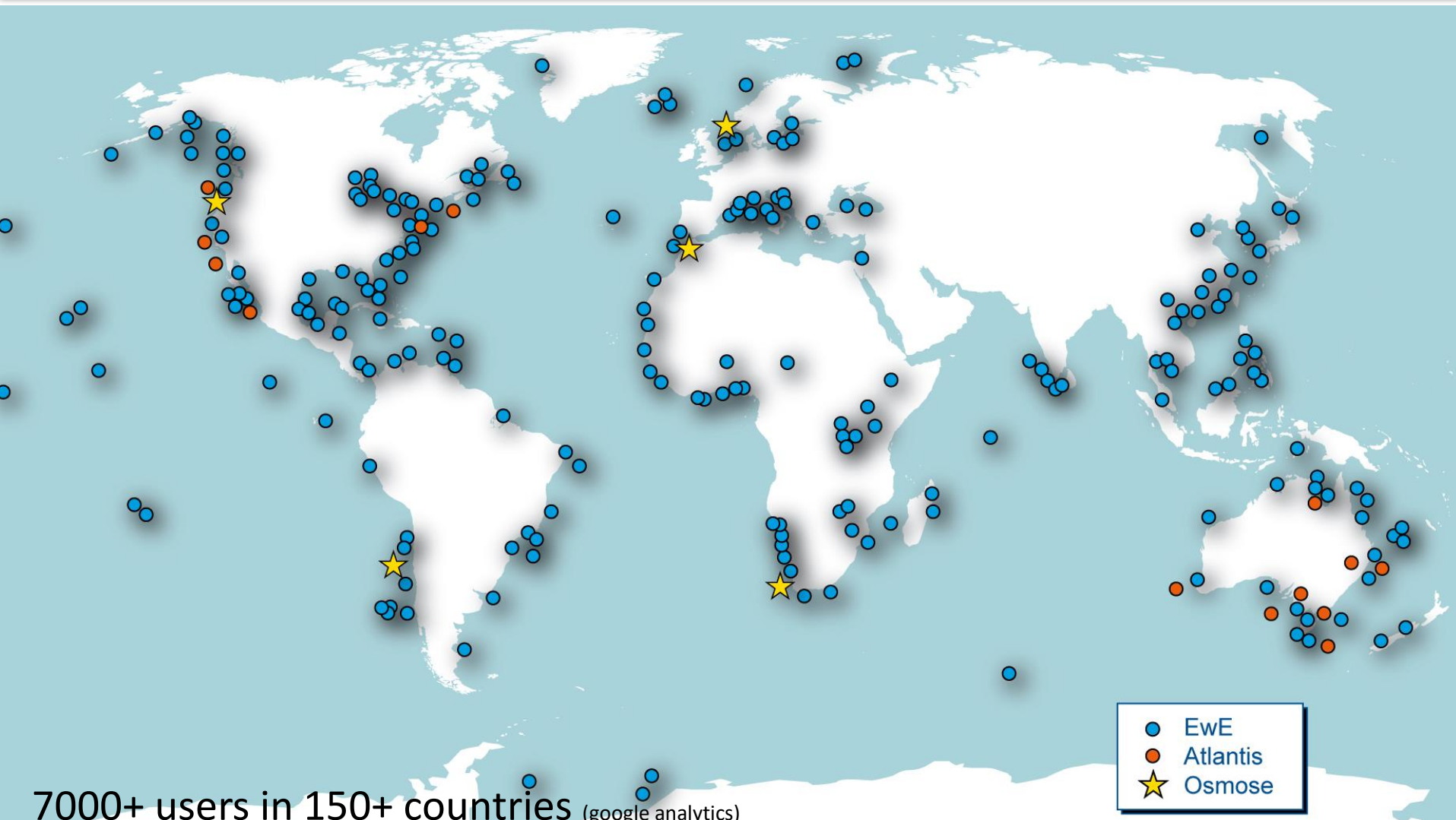
Includes environment and human activities

# Ecopath with Ecosim

|      |                                           |
|------|-------------------------------------------|
| 1984 | Ecopath conceived (Polovina 1984)         |
| 1990 | First desktop version released            |
| 1995 | Ecosim introduced                         |
| 1998 | Ecospace introduced                       |
| 2006 | Re-engineered                             |
| 2011 | Supported by Ecopath R&D Consortium       |
| 2012 | Open source, user support, co-development |
| 2014 | Thirty years anniversary                  |

Freely available from <http://www.ecopath.org>

# Ecopath with Ecosim



# Ecopath with Ecosim

## Three major components

|          |                            |
|----------|----------------------------|
| Ecopath  | static mass-balanced model |
| Ecosim   | temporal dynamics          |
| Ecospace | spatial-temporal dynamics  |

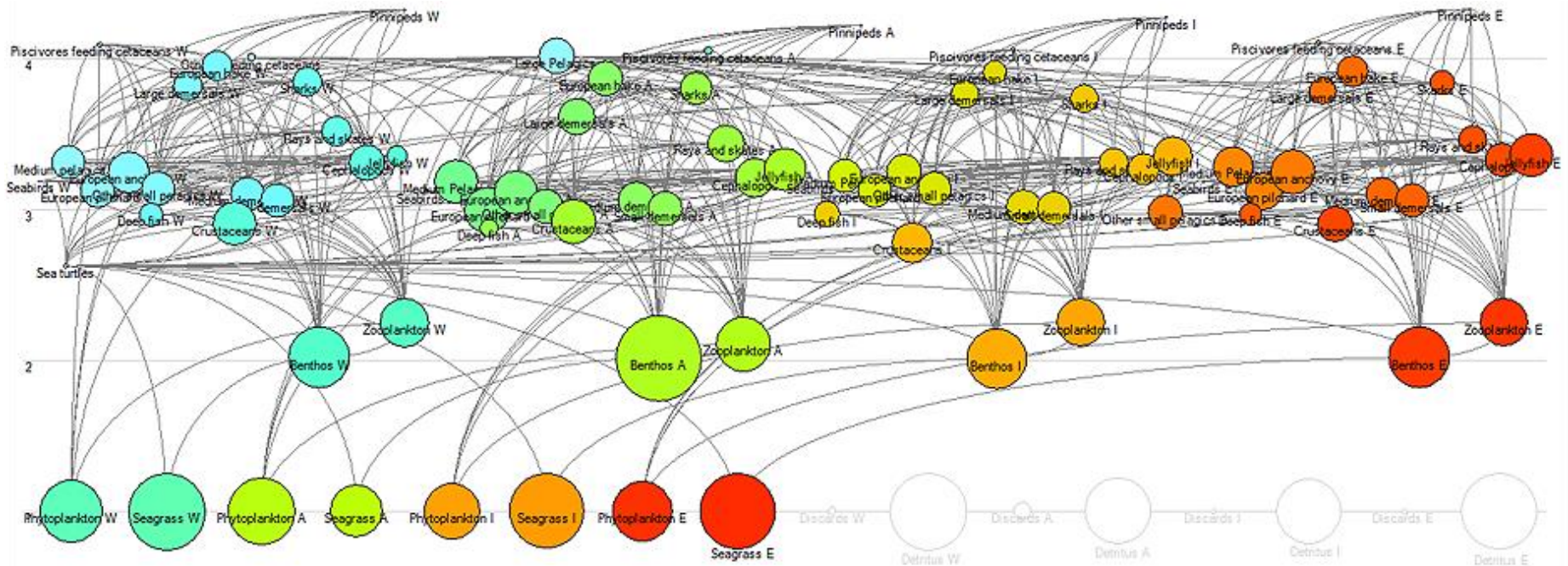
## Additional modules

|            |                                       |
|------------|---------------------------------------|
| Ecotracer  | contaminant tracing                   |
| 'Searches' | Fishing Policy, MPA, Monte Carlo, MSE |
| Plug-ins   |                                       |



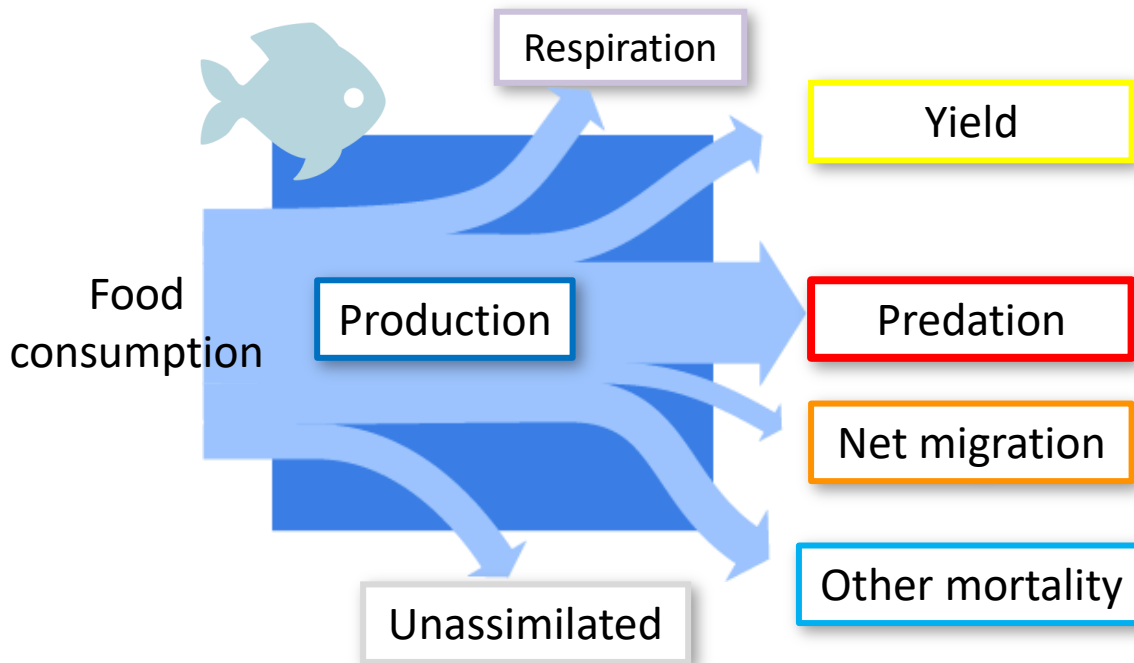
# Ecopath

A snapshot of the state of an ecosystem,  
its interactions, and exploitation





# Ecopath



|           |                                              |
|-----------|----------------------------------------------|
| $B_i$     | Biomass                                      |
| $P_i/B_i$ | Production                                   |
| $Q_i/B_i$ | Specific consumption                         |
| $DC_{ij}$ | Fraction of prey $i$ in diet of predator $j$ |
| $B_i A_i$ | Biomass accumulation                         |
| $EE_i$    | Production used in the system                |
| $1-EE_i$  | Unexplained mortality                        |

$$1. \quad \left( \frac{Q}{B} \right)_i \cdot B_i = \left( \frac{P}{B} \right)_i \cdot B_i + R_i + UN_i$$

$$2. \quad \left( \frac{P}{B} \right)_i \cdot B_i = \sum_{Pred\_j=1}^n \left( \frac{Q}{B} \right)_j \cdot B_j \cdot DC_{ij} + E_i + Y_i + BA_i + \left( \frac{P}{B} \right)_i \cdot B_i \cdot (1 - EE_i)$$



# Ecosim

Temporal-dynamic module of EwE, initialized from Ecopath

Includes biomass and size structure dynamics

Requires only a few extra parameters

## **Used, among others, to assess**

Quantify combined effect of species dynamics, fishing impacts, and environmental impacts on a food web over time

Replicate past scenarios (time series fitting)

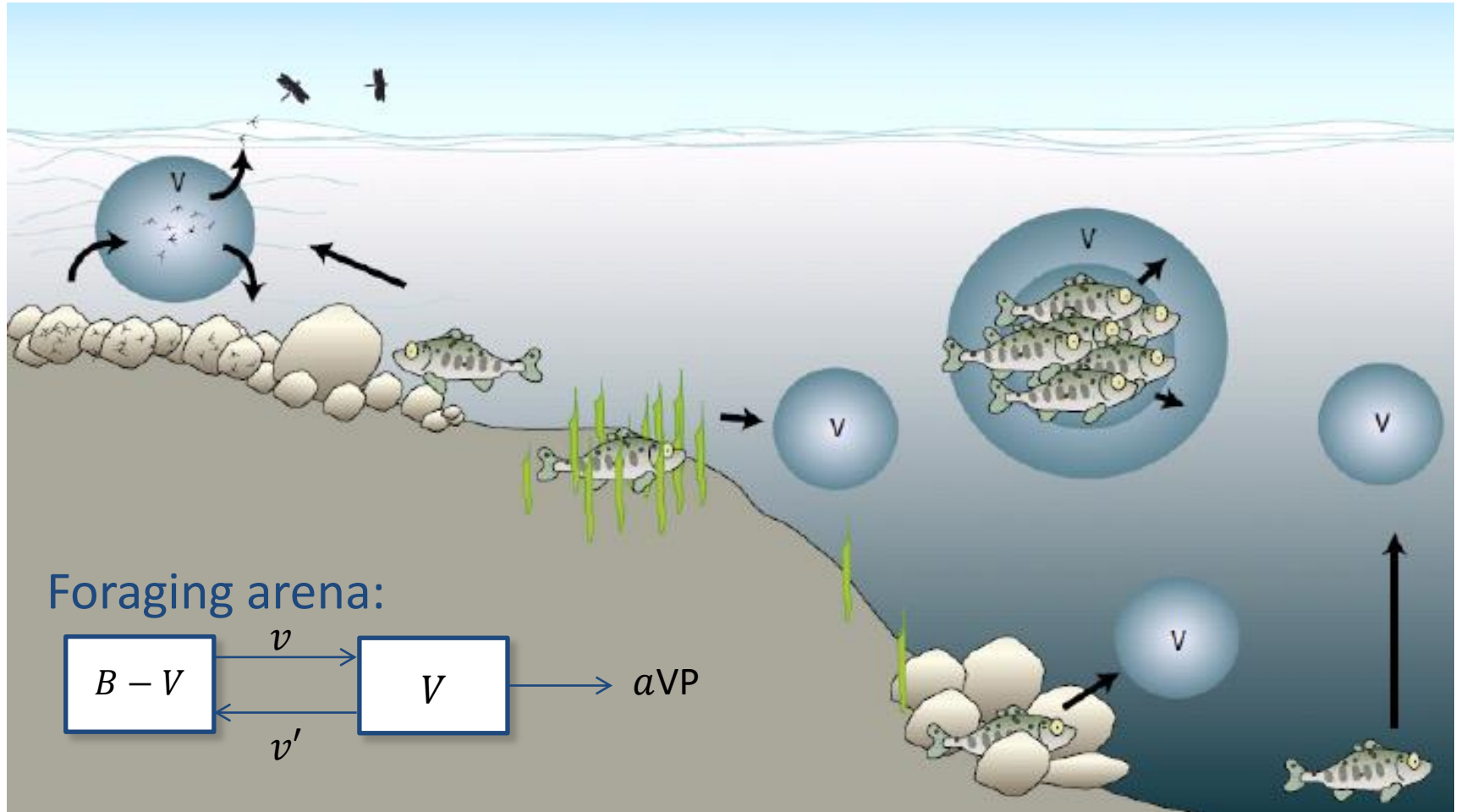
Explore future scenarios

Explore fishing policy alternatives

Test model robustness



# Ecosim



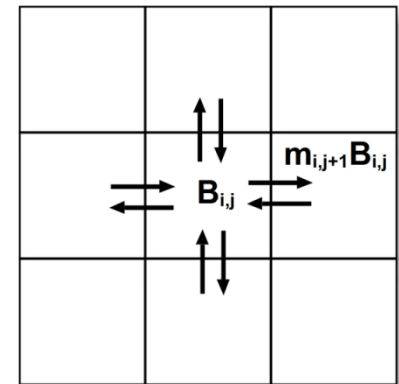


# Ecospace

Spatial temporal component of EwE, executes Ecosim for every 'water' cell in a grid

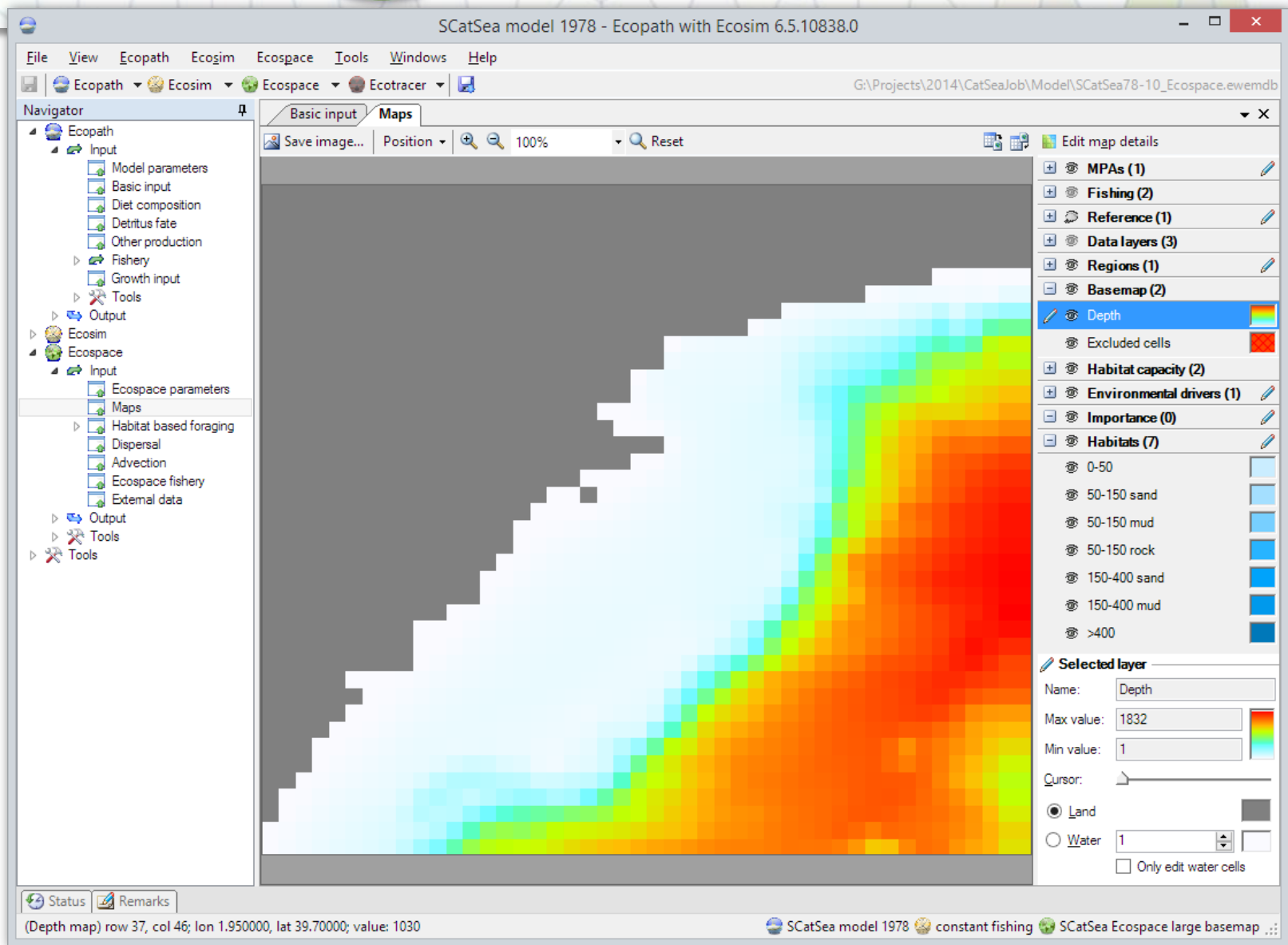
Requires extra inputs, related to movement, habitat, fishing, environment

Groups and fleets try to move to nearby optimal conditions





# Ecospace





# Ecospace

SCatSea model 1978 - Ecopath with Ecosim 6.5.10838.0

File View Ecopath Ecosim Ecospace Tools Windows Help

G:\Projects\2014\CatSeaJob\Model\SCatSea78-10\_Ecospace.ewemdb

Navigator

Ecospace fishery

Set: 1 Apply

| Fleet \ habitat use:  | All                                 | 0-50                     | 50-150 sand                         | 50-150 mud                          | 50-150 rock                         | 150-400 sand                        | 150-400 mud                         | >400                     | MPA1                                |
|-----------------------|-------------------------------------|--------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------|-------------------------------------|
| 1 Trawling fishery    | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |
| 2 Purse seine fishery | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 3 Longline fishery    | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 4 Troll bait fishery  | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |

Habitat based foraging  
Dispersal  
Advection  
Ecospace fishery  
External data

Output  
Tools

Edit map details

MPAs (1)  
MPA1  
Fishing (2)  
Reference (1)  
Reference  
Data layers (3)  
Regions (1)  
Basemap (2)  
Habitat capacity (2)  
Environm...drivers (1)  
Importance (0)  
Habitats (7)

Selected layer  
Name: MPA1  
Max value: 1  
Min value: 0  
Cursor: —>

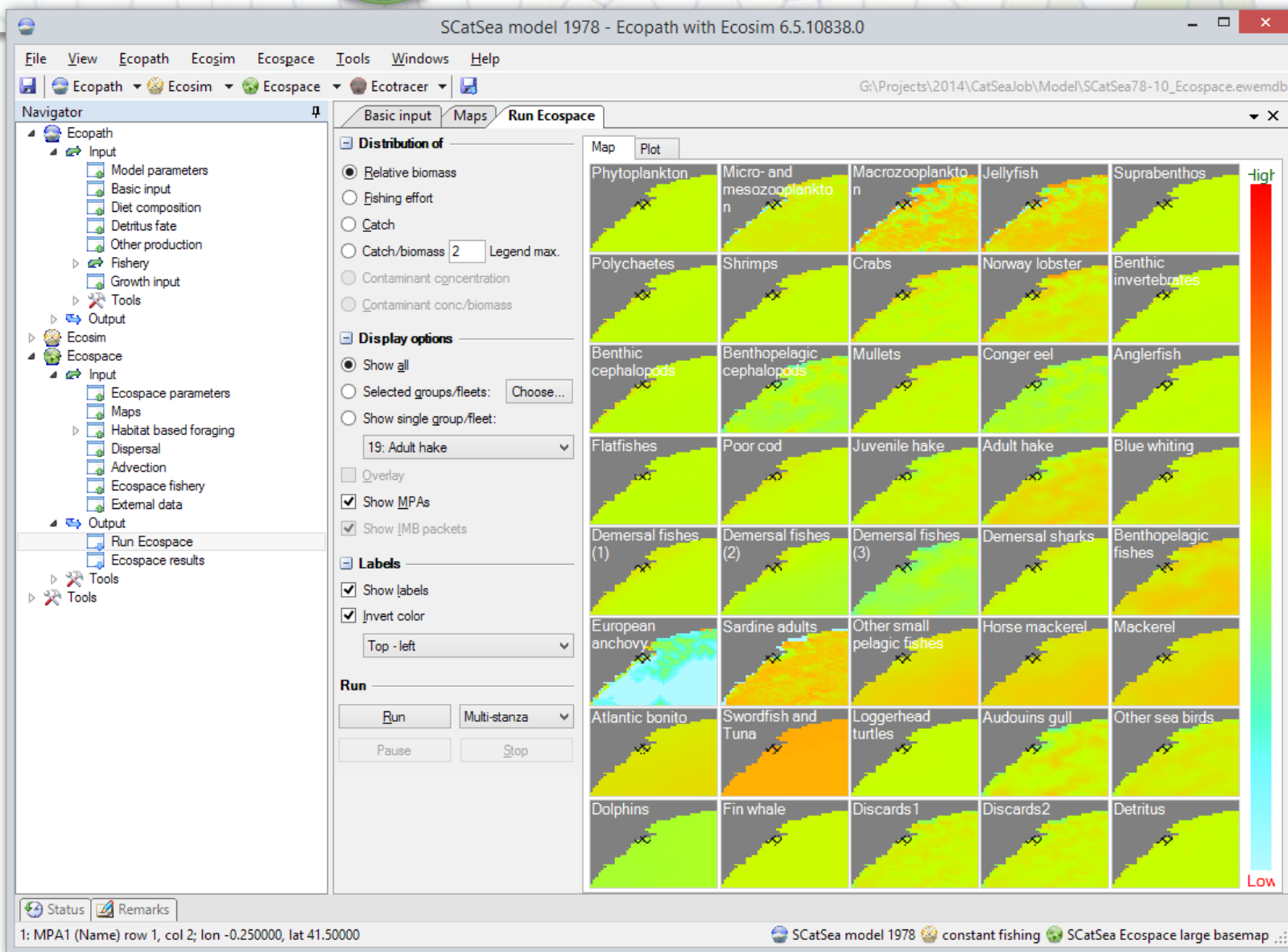
Status Remarks

1: MPA1 (Name) row 1, col 16; lon 0.450000, lat 41.50000

SCatSea model 1978 constant fishing SCatSea Ecospace large basemap



# Ecospace





# Ecospace

## **Used, among others, to assess**

Distribution of marine species and fishing effort

Spatial impact of fishing

Management options, e.g. impact of MPAs

Impact of environmental change (EwE version 6.3+)

Running model has been linked to Marxan & Atlantis

Includes an IBM approach

# Recent developments in Ecospace

## **2011 Ecospace had three major limitations**

1. Unable to represent sub-cell features
2. Unable to explicitly incorporate environmental effects on species: “why are the species where they are?”
3. Limited facilities to exchange data with the outside world, thus unable to include environmental variability

# 1. Representing sub-cell features



# Problem

Cells may contain small but important features that cannot be represented well, such as coral reefs

Old Ecospace accepted only one habitat type per cell, and yes/no habitat usage

Using ever smaller cells is no option: computationally demanding and wasteful, with risk of over-representing features and dynamics

Example: small but ecologically important coral reef

# Solution

Ecospace (EwE version 6.3+) allows habitats to overlap, and habitats can occupy a fraction  $[0,1]$  of a cell

Species can utilize a fraction  $[0, 1]$  of each habitat type

Old Ecospace models are directly translated to this structure, and work as expected

# Habitats in fractions of a cell

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Edit layer 'Coastal'

Navigator

Ecopath

Import Export Set: Apply

|    | 2   | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    | 16    |
|----|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1  | 000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2  | 000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 | 0.000 | 0.000 | 1.000 |
| 3  | 000 | 0.000 | 0.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 4  | 000 | 0.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 5  | 000 | 0.000 | 1.000 | 1.000 | 0.889 | 0.778 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.667 | 0.778 |
| 6  | 000 | 1.000 | 1.000 | 0.889 | 0.667 | 0.444 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.556 |
| 7  | 000 | 1.000 | 0.889 | 0.667 | 0.333 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.222 |
| 8  | 000 | 0.857 | 0.667 | 0.333 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.111 |
| 9  | 000 | 0.750 | 0.444 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 11 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 13 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 15 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 000 | 0.667 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 17 | 000 | 0.625 | 0.333 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18 | 000 | 0.714 | 0.444 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | 000 | 0.800 | 0.500 | 0.222 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

OK Cancel Apply

1: Coastal (Name)

Anchovy Bay New Ecosim scenario BayOfAnchovies

# Groups using fractions of habitats

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

Navigator

- Ecopath
  - Input
    - Model parameters
    - Basic input
    - Diet composition
    - Detritus fate
    - Other production
  - Fishery
  - Tools
  - Output
- Ecosim
- Ecospace
  - Input
    - Ecospace parameters
    - Maps
    - Habitat based foraging
      - Apply foraging responses
      - Group capacity model
      - Habitat foraging usage
      - Functional responses grid
    - Dispersal
    - Advection
    - Ecospace fishery
    - Marine Protected Areas

Maps Habitat based foraging Habitat foraging usage Group capacity model

Set: 0.000 Apply

| Group \ habitat # | All   | Coastal | Sand  | Rocky | Deep  |
|-------------------|-------|---------|-------|-------|-------|
| 1 Whales          |       | 0.200   | 1.000 | 1.000 | 1.000 |
| 2 Seals           |       | 1.000   | 0.700 | 1.000 | 0.200 |
| 3 Cod             | 1.000 |         |       |       |       |
| 4 Whiting         | 1.000 |         |       |       |       |
| 5 Mackerel        | 1.000 |         |       |       |       |
| 6 Anchovy         | 1.000 |         |       |       |       |
| 7 Shrimp          | 1.000 |         |       |       |       |
| 8 Benthos         | 1.000 |         |       |       |       |
| 9 Zooplankton     | 1.000 |         |       |       |       |
| 10 Phytoplankton  | 1.000 |         |       |       |       |
| 11 Detritus       | 1.000 |         |       |       |       |

Status Remarks

3: Cod (PreferredHabitat of 1: Coastal) Anchovy Bay New Ecosim scenario BayOfAnchovies

## 2. Why are species where they are?



# Habitat capacity model

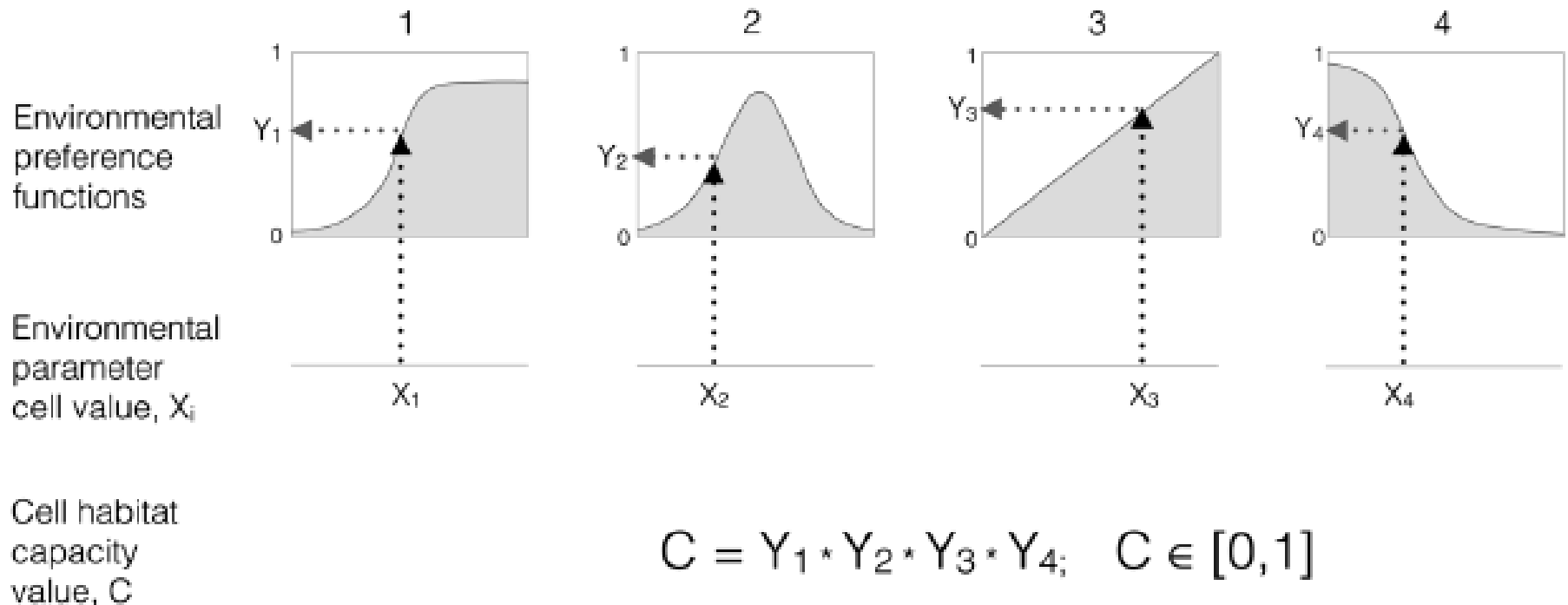
Original Ecospace could not explain species distributions. Habitat usage was an aggregated assumption implying environmental preferences

Ecospace (EwE version 6.3+) defines spatial foraging arena size from species' response to environmental conditions

Ecospace has become an integrated food-web / species envelope model

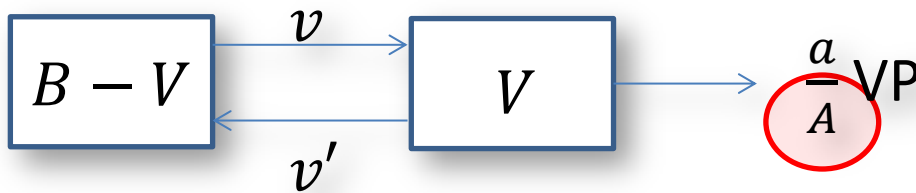
# Habitat capacity model

Dynamic habitat model predicts how productive individual cells are for each species, based on multiplicative effect of environmental responses



# Habitat capacity model

Foraging capacity in a cell depends on the area to predate:



|         |                                                |
|---------|------------------------------------------------|
| $V$     | vulnerable prey density                        |
| $B$     | prey biomass                                   |
| $P$     | predator abundance                             |
| $v, v'$ | vulnerability exchange rates to and from arena |
| $a$     | Search rate                                    |
| $A$     | Foraging arena size                            |

Predation calculation is altered:

$$V = \frac{v B}{v + v' + a P / A}$$

The term  $a P / A$  in the denominator is circled in red.

# Habitat capacity model

## Backward compatibility

For old Ecospace models, capacity is determined from existing habitat maps and habitat preferences

New Ecospace models (EwE version 6.5+) can derive capacity from habitat assumptions, from functional responses to environmental conditions, or from both habitats and functional responses

This is a *per-group* setting (!)

# Setting up the habitat foraging capacity model



# 1. Select group capacity model

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

Navigator

- Ecopath
  - Input
  - Output
- Ecosim
- Ecospace
  - Input
    - Ecospace parameters
    - Maps
    - Habitat based foraging
      - Apply foraging responses
      - Group capacity model**
      - Habitat foraging usage
      - Functional responses grid
    - Dispersal
    - Advection
    - Ecospace fishery
    - Marine Protected Areas
    - External data
  - Output
  - Tools

Basic input Group capacity model

Habitats Environmental responses Both Set: Apply

|    | Group name    | Use habitat                         | Use environmental responses         | Both                     |
|----|---------------|-------------------------------------|-------------------------------------|--------------------------|
| 1  | Whales        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 2  | Seals         | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 3  | Cod           | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 4  | Whiting       | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 5  | Mackerel      | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 6  | Anchovy       | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 7  | Shrimp        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 8  | Benthos       | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 9  | Zooplankton   | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 10 | Phytoplankton | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 11 | Detritus      | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |

Status Remarks

1: Temperature (Name) Anchovy Bay New Ecosim scenario BayOfAnchovies

## 2. Define environmental drivers

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

Navigator

- Ecopath
  - Input
    - Mod
    - Bas
    - Diet
    - Det
    - Oth
  - Fish
  - Too
  - Output
- Ecosim
- Ecospace
  - Input
    - Eco
    - Map
    - Hab
    - Disp
    - Adv
    - Eco
    - Mar
    - Ext
  - Output
  - Tools

Define environmental input maps

|   | Name                | Drive capacity                      | Description            | Status |
|---|---------------------|-------------------------------------|------------------------|--------|
| 1 | Depth               | <input checked="" type="checkbox"/> | Depth map (bathymetry) |        |
| 2 | Temperature         | <input checked="" type="checkbox"/> |                        |        |
| 3 | Distance from coast | <input checked="" type="checkbox"/> |                        |        |

**Edit**

Add Remove Keep

**Order**

Move up Move down

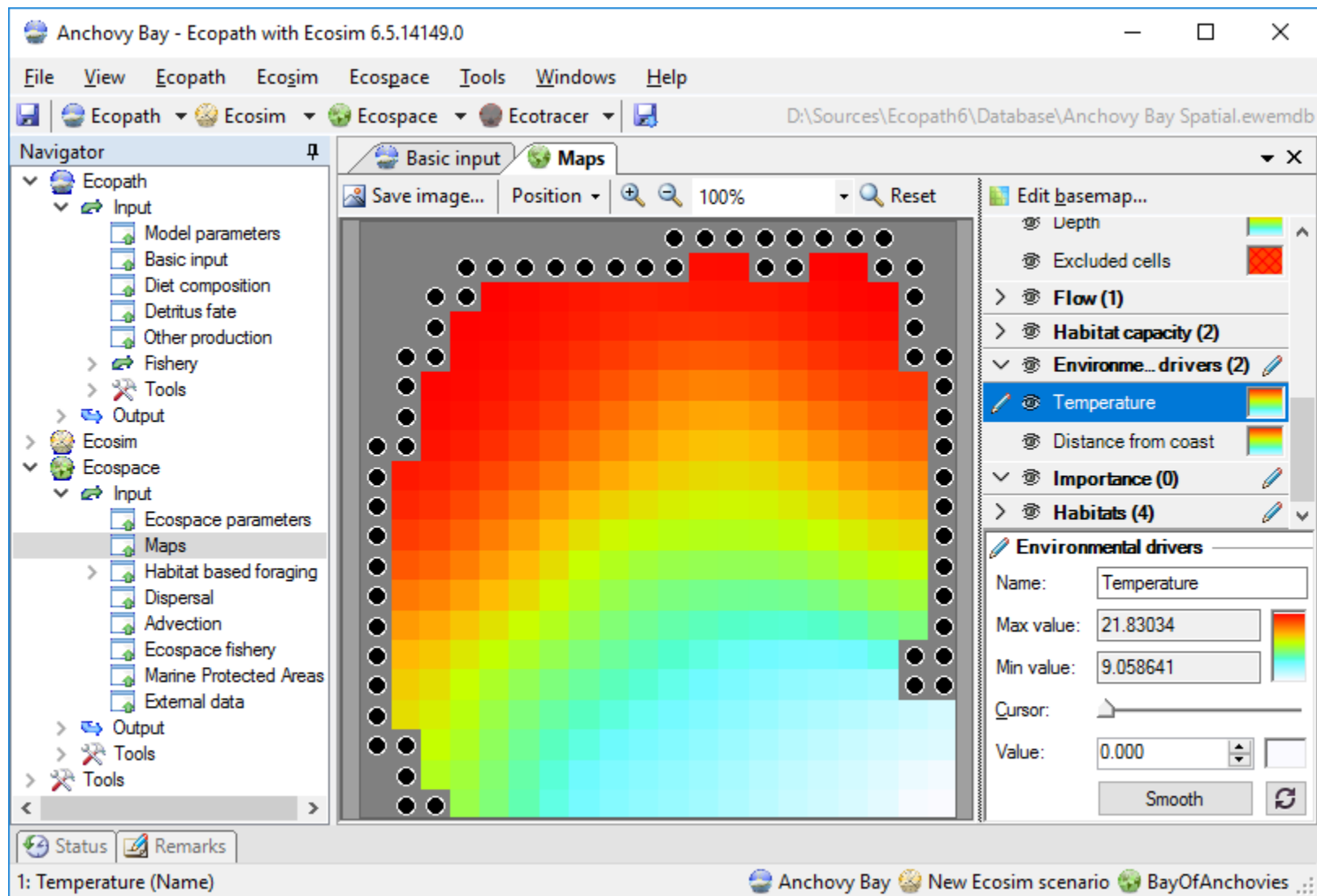
OK Cancel

Status Remarks

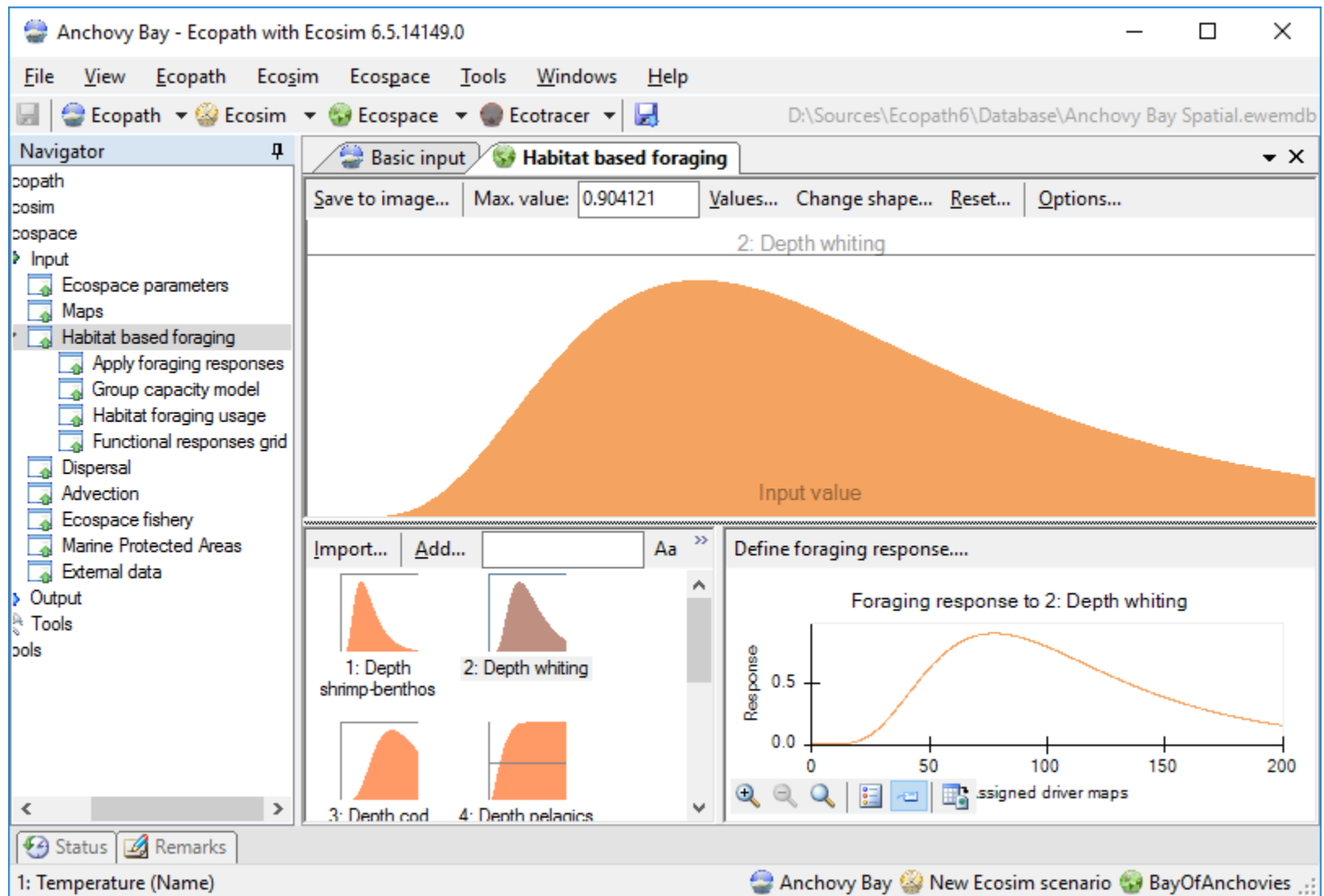
1: Temperature (Name)

Anchovy Bay New Ecosim scenario BayOfAnchovies

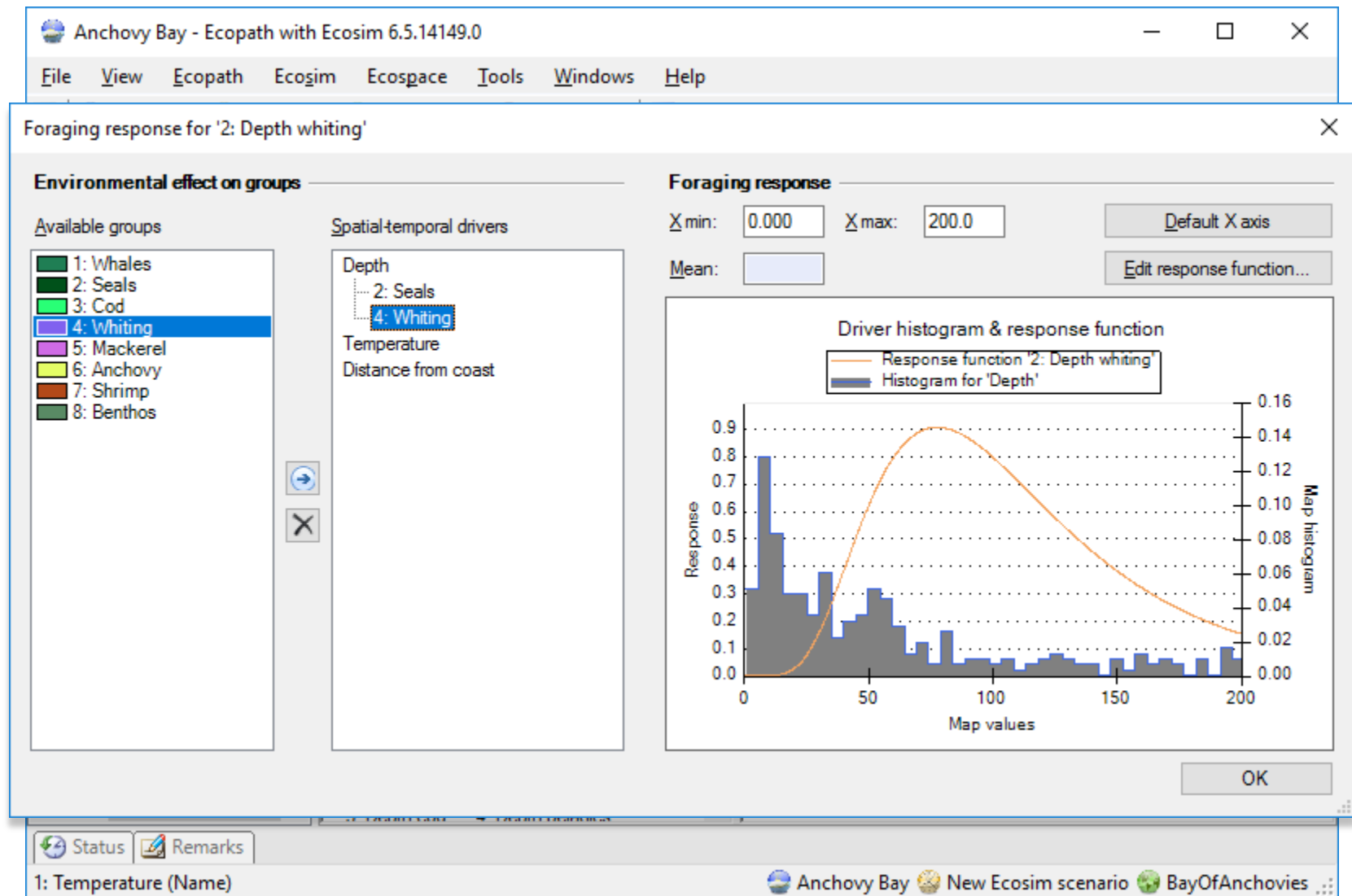
# 3. Populate env. driver maps



# 4. Define env. response curves



# 5. Connect groups, drivers and responses



# 6. Check set-up and run

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

Apply foraging responses Group capacity model

Define environmental driver maps... Habitats Environmental responses Both

| Group name       | Depth                   | Temperature  | Distance from coast |
|------------------|-------------------------|--------------|---------------------|
| 1 Whales         | 3: Depth cod            |              | 7: Distance whales  |
| 2 Seals          | 2: Depth whiting        |              | 8: Distance seals   |
| 3 Cod            | 3: Depth cod            | 5: Temp cold |                     |
| 4 Whiting        | 2: Depth whiting        | 6: Temp warm |                     |
| 5 Mackerel       | 4: Depth pelagics       | 5: Temp cold |                     |
| 6 Anchovy        | 4: Depth pelagics       | 6: Temp warm |                     |
| 7 Shrimp         | 1: Depth shrimp-benthos |              |                     |
| 8 Benthos        | 1: Depth shrimp-benthos |              |                     |
| 9 Zooplankton    |                         |              |                     |
| 10 Phytoplankton |                         |              |                     |

| Group name       | Use habitat                         | Use environmental res               |
|------------------|-------------------------------------|-------------------------------------|
| 1 Whales         | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 2 Seals          | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 3 Cod            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 4 Whiting        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 5 Mackerel       | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 6 Anchovy        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 7 Shrimp         | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 8 Benthos        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 9 Zooplankton    | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 10 Phytoplankton | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 11 Detritus      | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |

Habitat foraging usage

Set: Apply

| Group \ habitat # | All   | Coastal | Sand | Rocky | Deep |
|-------------------|-------|---------|------|-------|------|
| 6 Anchovy         |       |         |      |       |      |
| 7 Shrimp          |       |         |      |       |      |
| 8 Benthos         |       |         |      |       |      |
| 9 Zooplankton     | 1.000 |         |      |       |      |
| 10 Phytoplankton  | 1.000 |         |      |       |      |
| 11 Detritus       | 1.000 |         |      |       |      |

Status Remarks

1: Temperature (Name)

Anchovy Bay New Ecosim scenario BayOfAnchovies

# Hab. Cap. case study

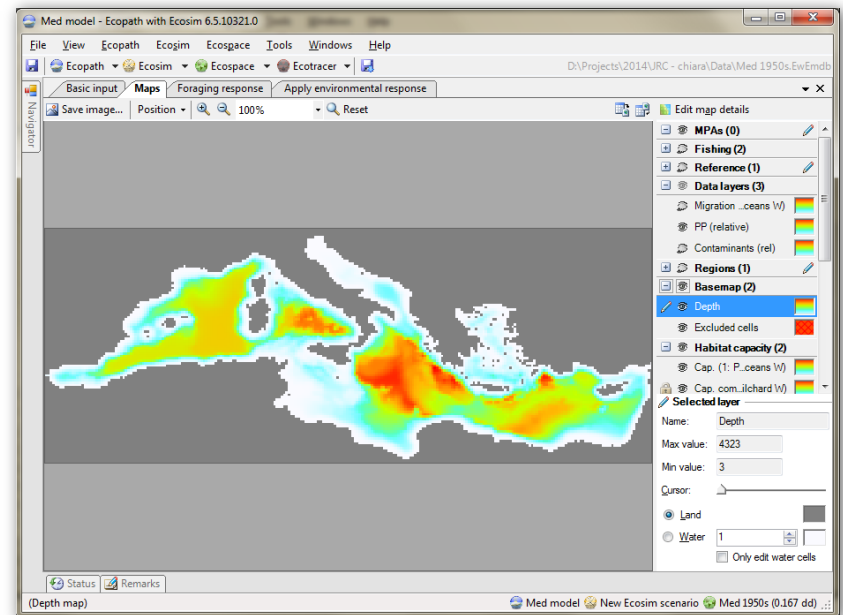
## Foraging habitat capacity model case study

Full Mediterranean EwE model

90+ functional groups, assigned to 4 MSFD zones

Time frame 1950 – 2010

Entire basin at 0.167 dd grid



# Hab. Cap. case study

## 1. Define environmental drivers

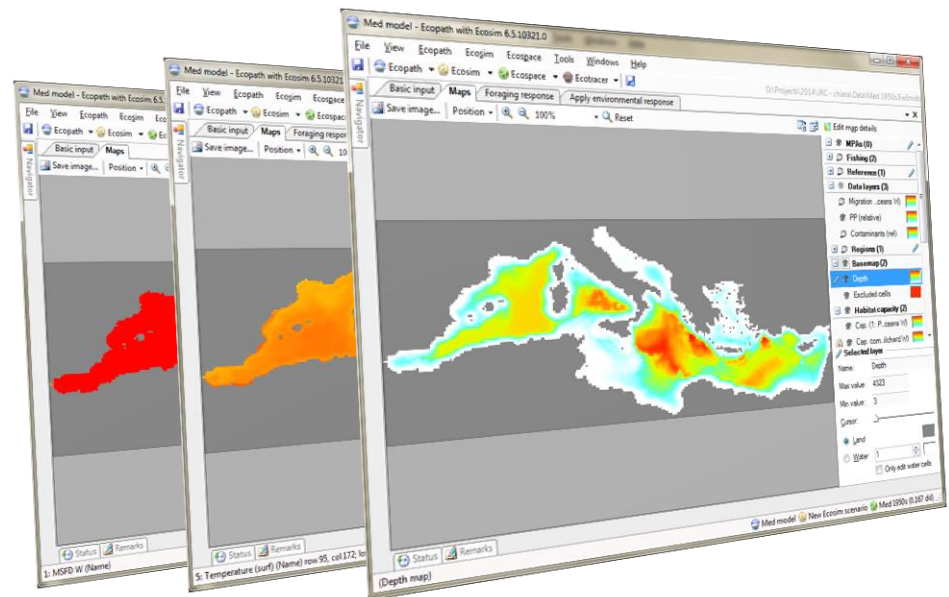
Primary production

Salinity (surface and bottom)

Temperature (surface and bottom)

Depth

MSFD area restrictions



# Hab. Cap. case study

## 2. Define environmental responses

Here we are using a plug-in to import environmental responses from AquaMaps species envelopes

The image shows a workflow for importing environmental response data from AquaMaps into Ecopath with Ecosim. On the left, the AquaMaps website is displayed, featuring a world map and search options for marine species. A large blue arrow points from the AquaMaps website to the Ecopath with Ecosim software interface on the right. The software interface shows the 'Import Aquamaps HSPEN' dialog box, which allows users to select species and environmental envelopes to import. The 'Species' list includes 'Sardina pilchardus (European pilchard)'. The 'Envelopes' list includes 'Depth (m)', 'Temperature (A°C)', 'Salinity (psu)', 'Primary Production', and 'Sea Ice Concentration'. The 'Import' button is visible. The background shows the Ecopath with Ecosim interface with various toolbars and a sidebar.

**AquaMaps** (08/2013 - CURRENTLY OPTIMIZED FOR MOZILLA FIREFOX):  
Standardized distribution maps for over 17,300 species of fishes, marine mammals and invertebrates  
AquaMaps is a joint project of FishBase and SeaLifeBase  
Home | About AquaMaps | More Info | Environmental Data | Tools | Services | Hints | Feedback  
AquaMaps | High Resolution Maps | Reviewed Maps

Marine Biodiversity Map: click on the map to obtain local species list for that area.  
All | Sharks & rays | Bony fish | Invertebrates | Deep-sea | Marine mammals | High Seas

Data sources: GBIF OBIS

Search Marine Species by Common Name  
contains [ ] Search (e.g. blue whale)

To search for freshwater species, click here

Search Marine Species by Scientific Name  
Genus is [ ] Search (e.g. Balaenoptera)  
Species contains [ ] Search (e.g. musculus)

| Species No. | Species No. |
|-------------|-------------|
| 2513 - 5996 | 1054 - 2512 |
| 442 - 1053  | 186 - 441   |
| 78 - 185    | 33 - 77     |
| 15 - 32     |             |

**Import Aquamaps HSPEN**

Drop AquaMaps HSPEN file(s) here

**Species**

- ☒ Sardina pilchardus (European pilchard)

**Envelopes**

- ☒ Depth (m)
- ☒ Temperature (A°C)
- ☒ Salinity (psu)
- ☒ Primary Production
- ☒ Sea Ice Concentration

View example file... Import

**Acknowledgements**

**AquaMaps**

**JRC**  
EUROPEAN COMMISSION

**Ecopath with Ecosim**

File View Ecopath Ecosim Tools Output Ecosim Ecospace Input Maps Habitat based foraging Apply foraging response Group capacity model Habitat foraging usage Functional responses Dispersal Advection Ecospace fishery Marine Protected Areas External data Output Tools Tools

Status Remarks

1: Temperature (Name)

Anchovy Bay - Ecopath with Ecosim 6.5.1

Anchovy Bay Spatial.ewemdb

Options...

Depth shrimp-benthos

1: Depth shrimp-benthos

150 200 250

river maps

Anchovy Bay New Ecosim scenario BayOfAnchovies

# Hab. Cap. case study

## 3. Apply drivers and responses

The screenshot displays the 'Med model - Ecopath with Ecosim 6.5.10321.0' software interface. The main window shows a table for defining environmental input maps, with columns for Group name, Depth, and various MSFD parameters. A dialog box titled 'Apply environmental response function' is open, showing a list of response functions and a selected response for '8: Depth (m) Sardina pilchardus (European pilchard)'.

**Med model - Ecopath with Ecosim 6.5.10321.0**

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer

D:\Projects\2014\JRC - chiara\Data\Med 1950s.EwEmdb

Basic input Maps Foraging response **Apply environmental response**

Define environmental input maps...

|    | Group name                     | Depth                     | MSFD W  | MSFD A  | MSFD I | MSFD E | Temperature (surf) | Temperature (bott) | Seagrass |
|----|--------------------------------|---------------------------|---------|---------|--------|--------|--------------------|--------------------|----------|
| 1  | Piscivores feeding cetaceans W |                           | 1: MSFD |         |        |        |                    |                    |          |
| 2  | Others feeding cetaceans       | 26: Depth (m) Other fee   |         |         |        |        |                    |                    |          |
| 3  | Pinnipeds W                    |                           | 1: MSFD |         |        |        |                    |                    |          |
| 4  | Seabirds W                     |                           | 1: MSFD |         |        |        |                    |                    |          |
| 5  | Sea turtles                    |                           |         |         |        |        |                    |                    |          |
| 6  | Large Pelagics                 |                           |         |         |        |        |                    |                    |          |
| 7  | Medium pelagics W              |                           | 1: MSFD |         |        |        |                    |                    |          |
| 8  | European pilchard W            | 8: Depth (m) Sardina pil  | 1: MSFD |         |        |        |                    |                    |          |
| 9  | European anchovy W             |                           | 1: MSFD |         |        |        |                    |                    |          |
| 10 | Other small pelagics W         |                           | 1: MSFD |         |        |        |                    |                    |          |
| 11 | Large demersals W              |                           | 1: MSFD |         |        |        |                    |                    |          |
| 12 | European hake W                |                           | 1: MSFD |         |        |        |                    |                    |          |
| 13 | Medium demersals W             |                           | 1: MSFD |         |        |        |                    |                    |          |
| 14 | Small demersals W              |                           | 1: MSFD |         |        |        |                    |                    |          |
| 15 | Deep fish W                    |                           | 1: MSFD |         |        |        |                    |                    |          |
| 16 | Sharks W                       |                           | 1: MSFD |         |        |        |                    |                    |          |
| 17 | Rays and skates W              |                           | 1: MSFD |         |        |        |                    |                    |          |
| 18 | Cephalopods W                  |                           | 1: MSFD |         |        |        |                    |                    |          |
| 19 | Crustaceans W                  |                           | 1: MSFD |         |        |        |                    |                    |          |
| 20 | Jellyfish W                    | 17: Depth (m) jellyfish ( | 1: MSFD |         |        |        |                    |                    |          |
| 21 | Benthos W                      |                           | 1: MSFD |         |        |        |                    |                    |          |
| 22 | Zooplankton W                  |                           | 1: MSFD |         |        |        |                    |                    |          |
| 23 | Phytoplankton W                |                           | 1: MSFD |         |        |        |                    |                    |          |
| 24 | Seagrass W                     |                           | 1: MSFD |         |        |        |                    |                    |          |
| 25 | Piscivores feeding cetaceans A |                           |         | 1: MSFD |        |        |                    |                    |          |
| 26 | Pinnipeds A                    |                           |         | 1: MSFD |        |        |                    |                    |          |
| 27 | Seabirds A                     |                           |         | 1: MSFD |        |        |                    |                    |          |
| 28 | Medium Pelagics A              |                           |         | 1: MSFD |        |        |                    |                    |          |
| 29 | European pilchard A            |                           |         | 1: MSFD |        |        |                    |                    |          |

**Apply environmental response function**

Filter: depth Aa

**Response functions**

- 2: Depth (m) Large pelagics (Thunr
- 5: Depth (m) Medium pelagics (Sarc
- 8: Depth (m) Sardina pilchardus (Eu
- 11: Depth (m) small pelagics (Micro
- 14: Depth (m) Engraulis encrasicol
- 17: Depth (m) jellyfish (Pelagia noct
- 20: Depth (m) crustaceans (Megan
- 21: Depth (m) deep fish (Cyclothon
- 22: Depth (m) Merluccius merlucciu

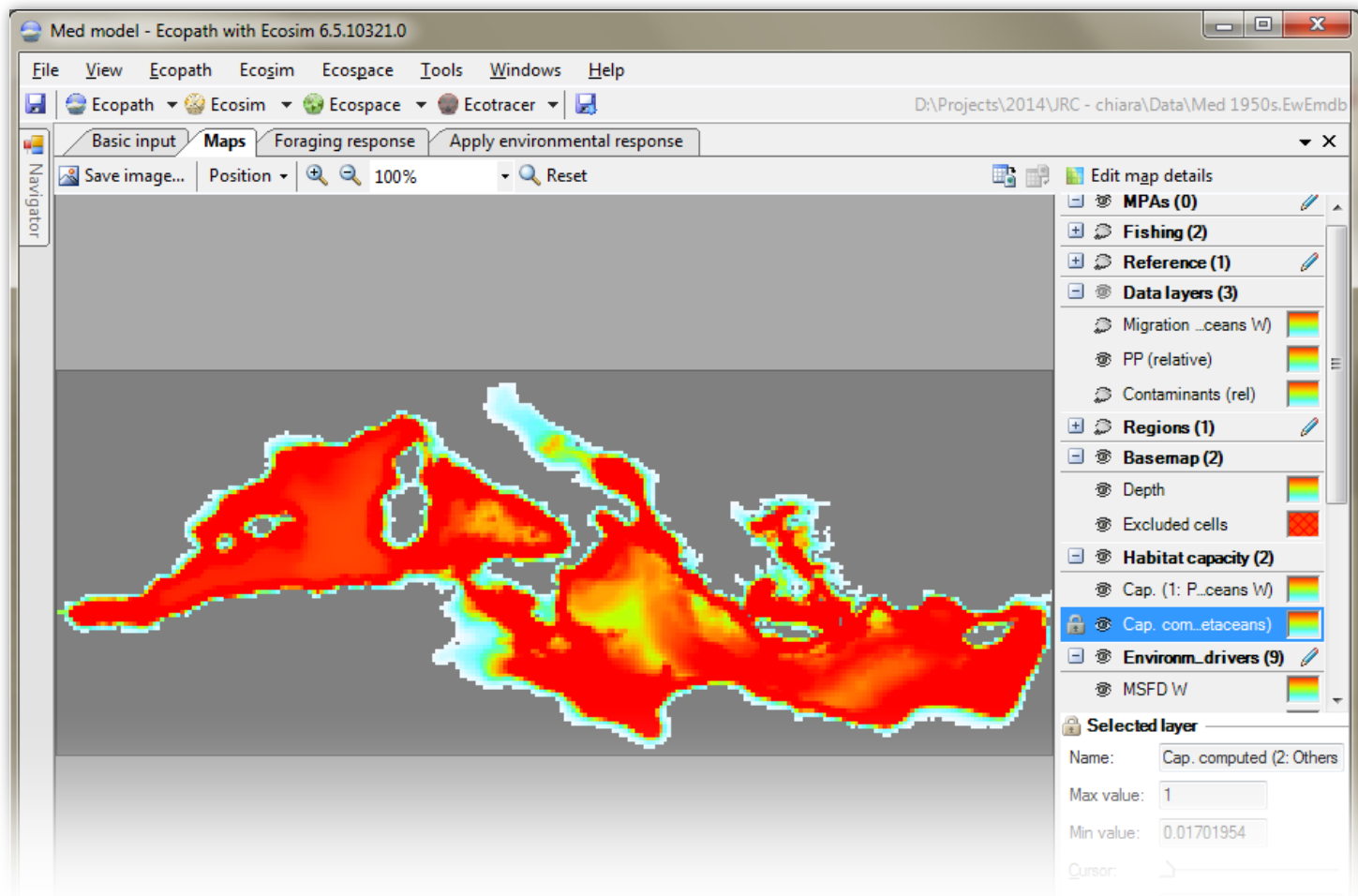
**Applied responses**

- 8: Depth (m) Sardina pilchardus (European pilchard)

OK Cancel

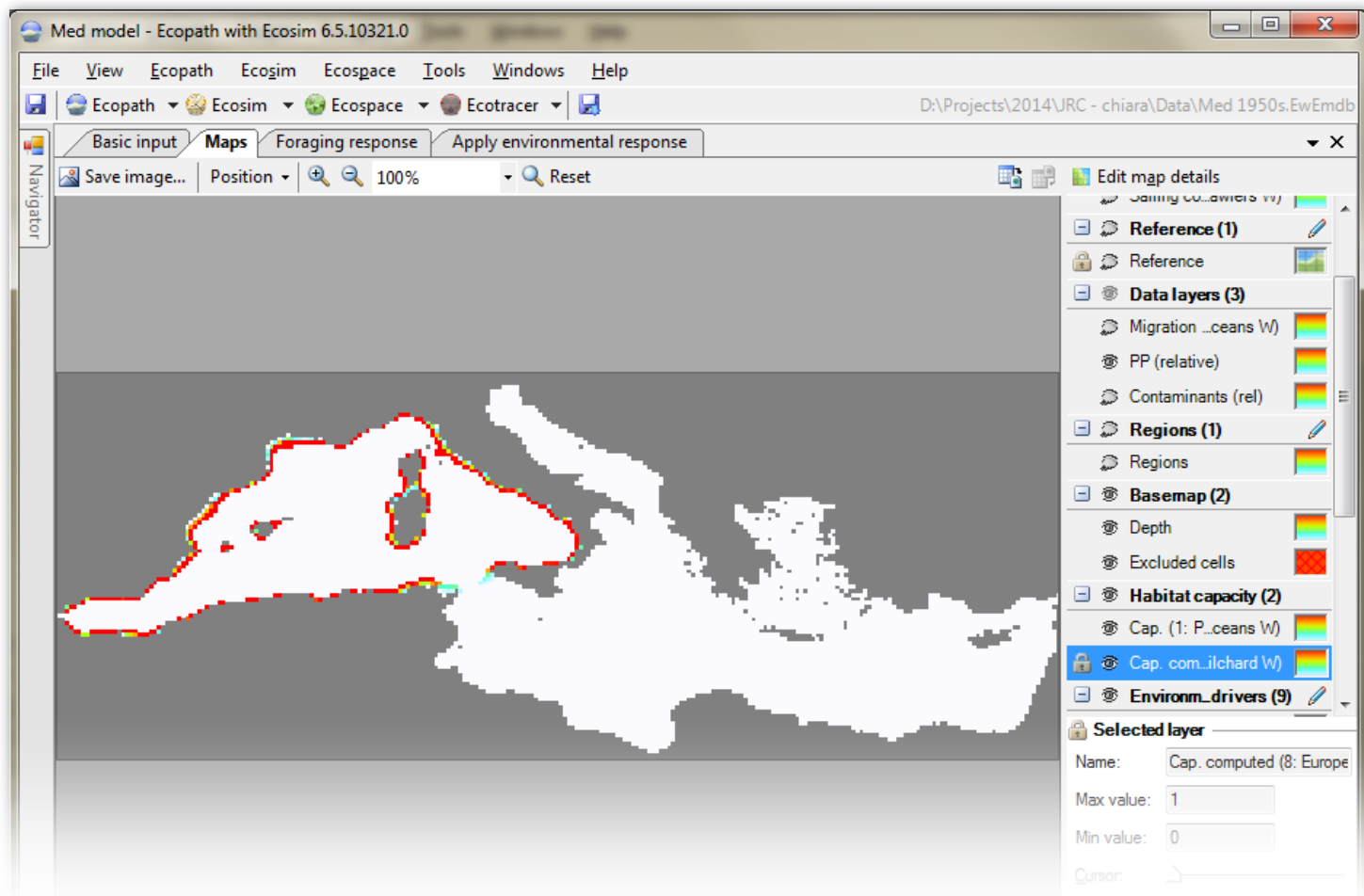
# Hab. Cap. case study

## 4. Ecospace computes capacity (cetaceans - depth)



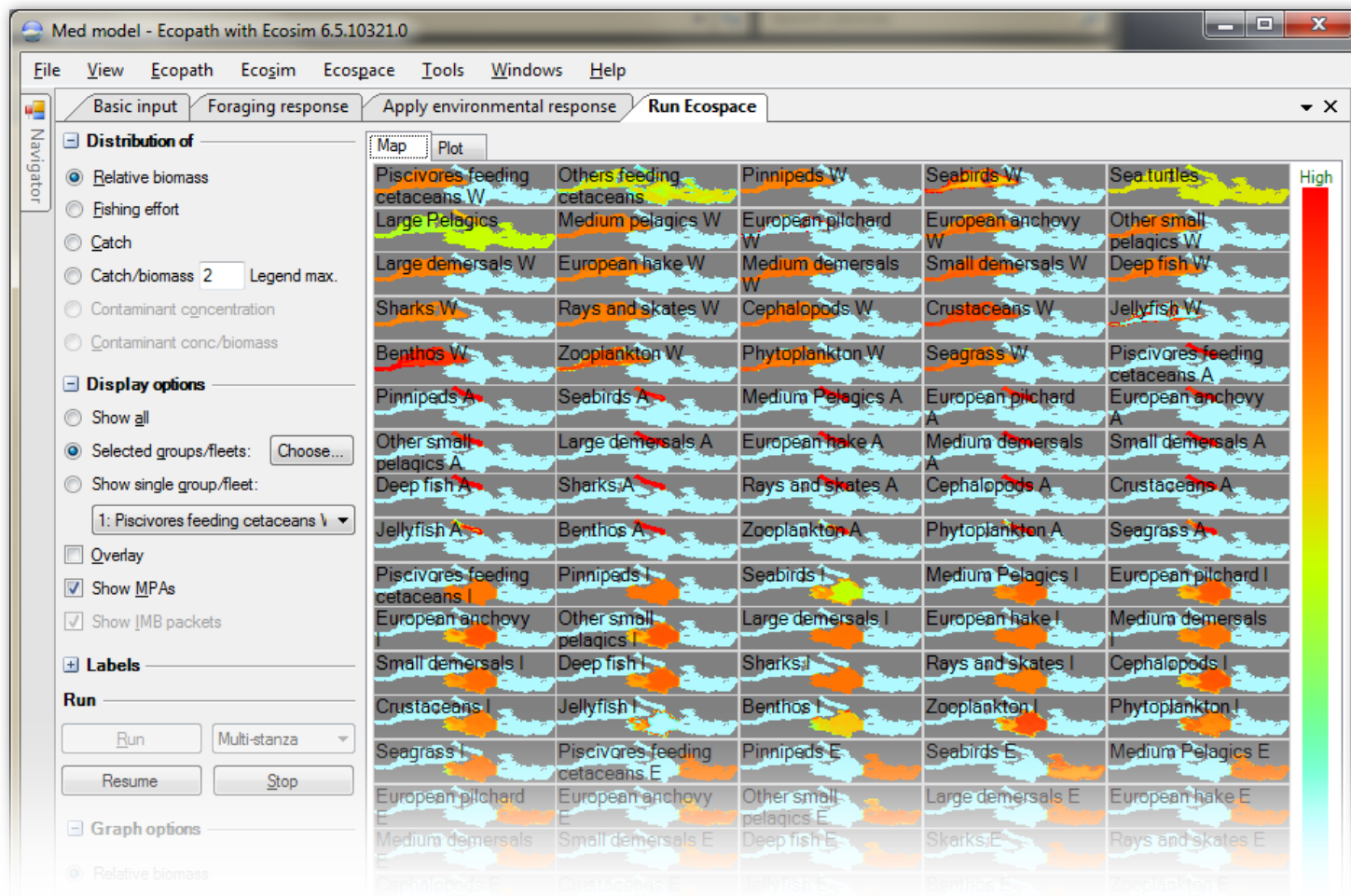
# Hab. Cap. case study

## 4. More capacity (Western sardine - depth, MSFD W)



# Hab. Cap. case study

## 4. Run



# Ecospace spin-off

## **Functional responses are also available to Ecosim**

Previous Ecosim only supported two normal distributed response functions

New Ecosim shares functional response curves with Ecospace

Environmental drivers in Ecosim are functions; not maps

Affects foraging arena size over time

System is backwards compatible with older models

Not published yet, application in progress in PhD thesis

### 3. Exchanging data with the outside world



# Ecospace shortcomings

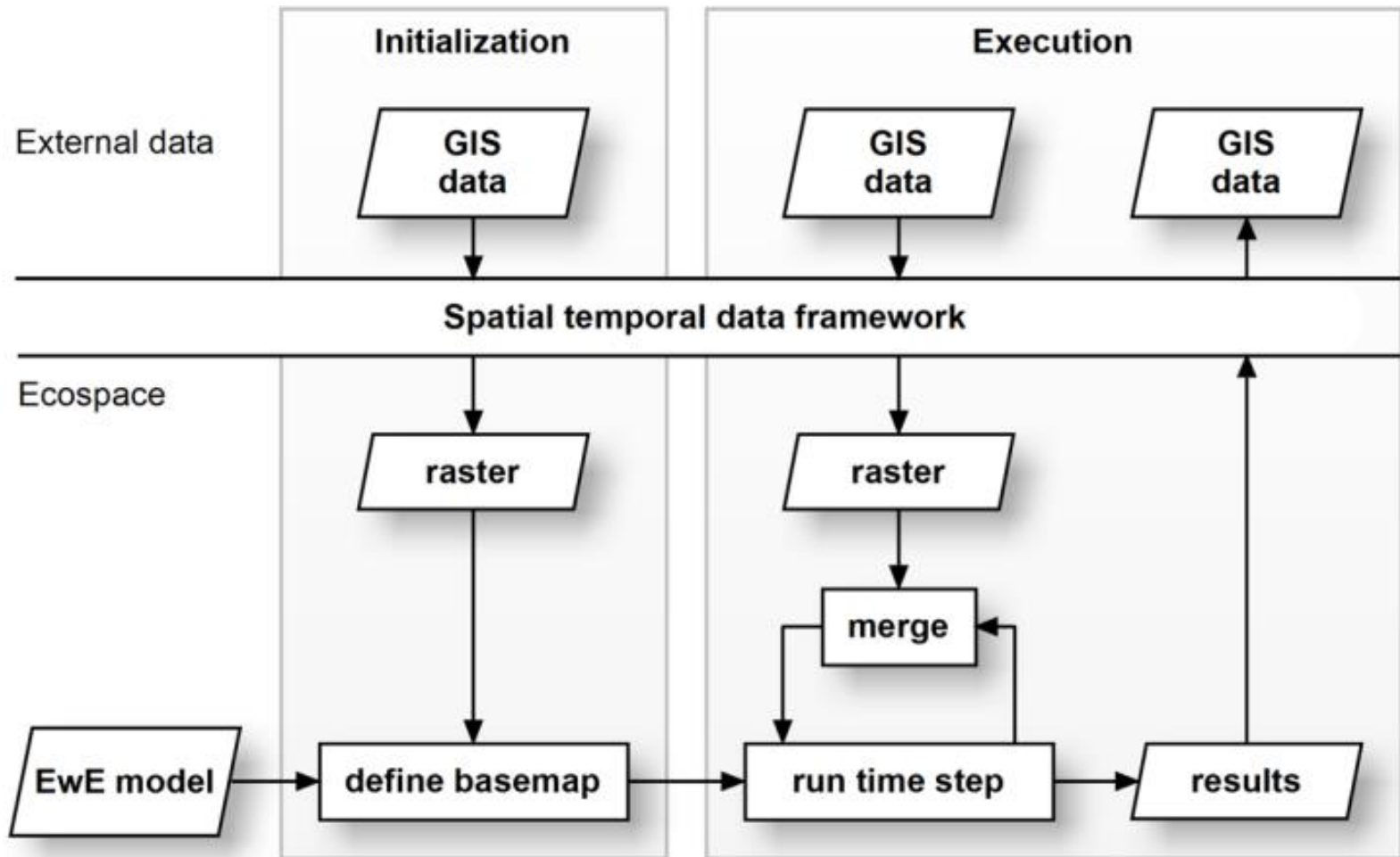
## **Ecospace internal data model was hard to access**

Almost impossible to vary input maps over time

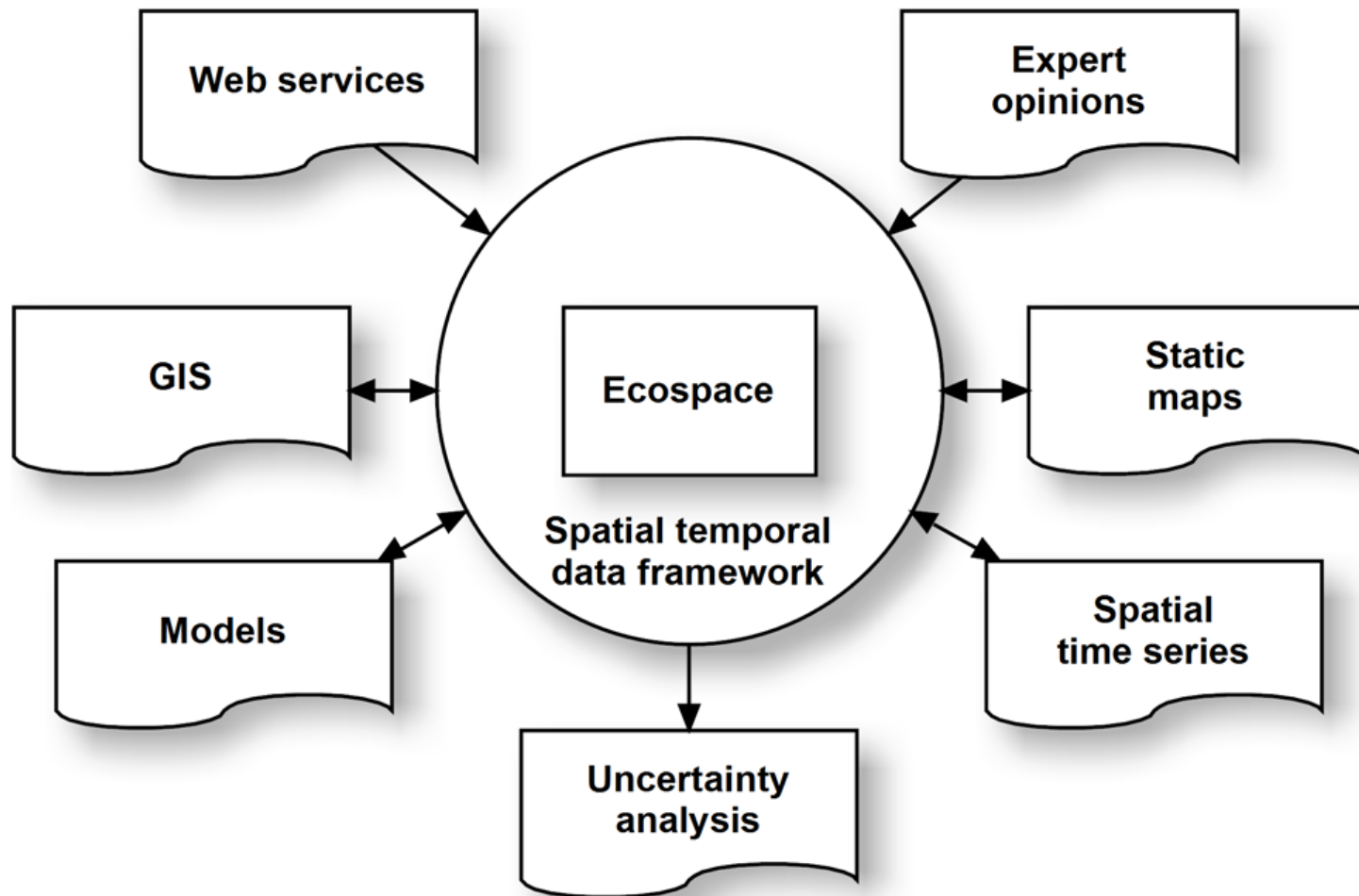
Almost impossible to exchange data with other models

Changing environmental conditions could not be included in spatial temporal analysis

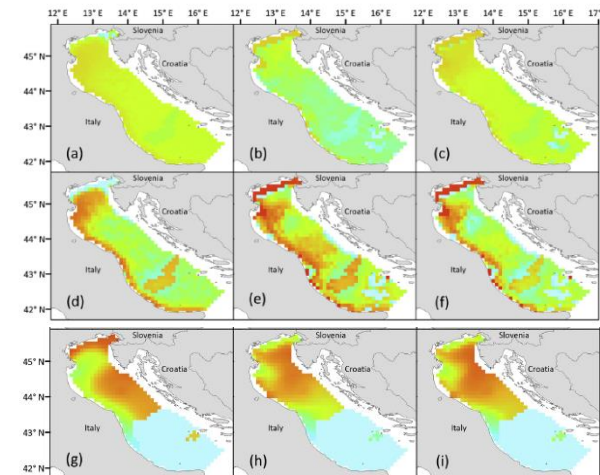
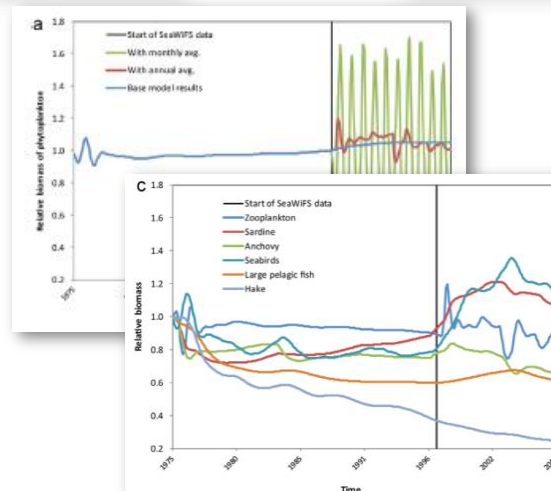
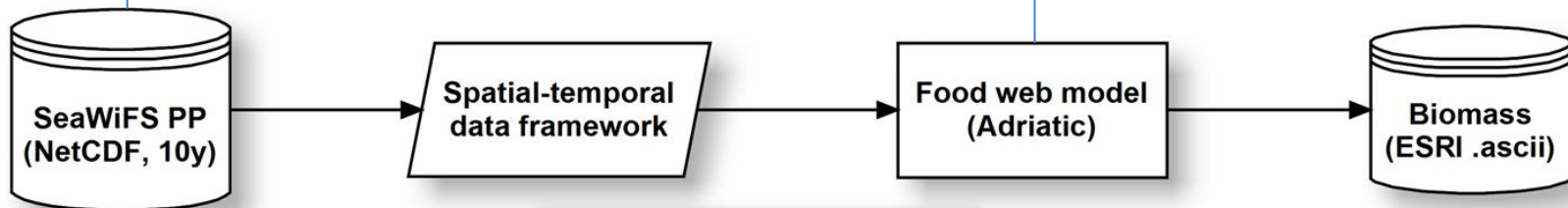
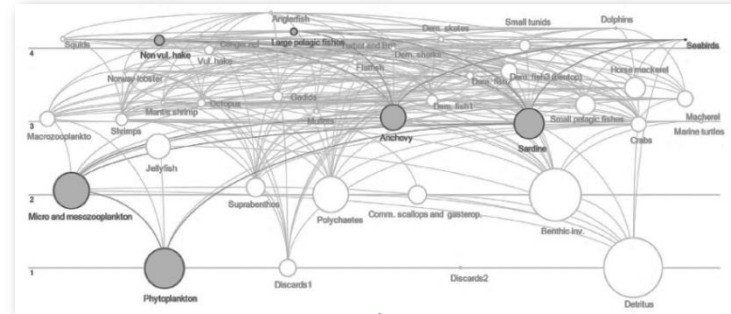
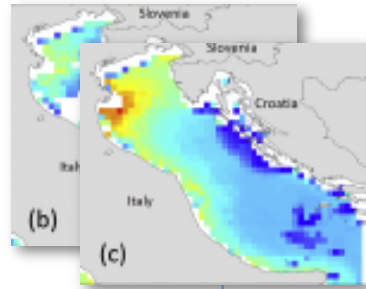
# Spatial temporal data framework



# Spatial temporal data framework



# Spatial Temporal data framework case study



Steenbeek et al (2013) Ecological Modeling

# Current status

Connected to most Ecospace layers

Reads and writes 20+ GIS data formats, both raster and vector

Designed upon EwE plug-in system. Easy to extend with new capabilities

**Not (yet) publicly released: more R&D needed.**

**Can only be applied by directly involving EwE team**

Needs better support for projections

Needs integration of new data types

Needs user testing to streamline workflow

# GIS data for many Ecospace layers

## Connected to existing Ecospace driver layers

Primary production

Environmental drivers

Habitats

Fishing cost

MPA layouts

Contaminants

Migration

Computed foraging capacity

## Coming soon

Advection



# Setting up the spatial temporal data framework



# 1. Define external data

Delta management model - Ecopath with Ecosim 6.5.12689.0

File | View | Tools | Help

Define external spatial temporal connections

**Connect to external spatial temporal data**

Type of connection: A series of spatial files over time ✓ **Create...**

Current configuration: C:\Users\Weroen\AppData\Roaming\Ecopath with Ecosim\ewee\_datasets.xml **manage...**

**Existing connections**

|     | Name                   | Used | Status | From    | To      | Description |
|-----|------------------------|------|--------|---------|---------|-------------|
| [-] | Environmental drivers  |      |        |         |         |             |
| 1   | Chl a_DM as env driver | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 2   | sack-oec1all           | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 3   | SalinityDM             | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 4   | seed-oec1all           | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 5   | spat-oec1all           | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 6   | Temp_DM2               | ✓    | ✓      | 1995/01 | 2020/12 |             |
| 7   | TSS_DM                 | ✓    | ✓      | 1995/01 | 2023/10 |             |
| [-] | Relative PP map        |      |        |         |         |             |
| 8   | Chla DM as rel PP      | ✓    | ✓      | 1995/01 | 2020/12 |             |

**Sharing**

**Export...**

**Configure...**

**Delete**

## 2. Define external data

Configure external data connection

**Description**

Name: Sack PR7

Description:

Variable: Environmental drivers

**Files**

Location: C:\Users\Jeroen\Desktop\Delft3D\Trosim\_Ou...PR7 [Browse...](#)

| File                                                                | Time    |
|---------------------------------------------------------------------|---------|
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m01.asc | 2020/01 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m02.asc | 2020/02 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m03.asc | 2020/03 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m04.asc | 2020/04 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m05.asc | 2020/05 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m06.asc | 2020/06 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m07.asc | 2020/07 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m08.asc | 2020/08 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m09.asc | 2020/09 |
| <input checked="" type="checkbox"/> oeclall_sack_dm_pr7_y01_m10.asc | 2020/10 |

☐ Data is seasonal until 2100/01

**Time utility**

☒ Starting at 2020/01, spaced 1 month(s) [Set file times](#)

[Defaults](#) [OK](#) [Cancel](#)

Name and description to help a user applying this data

Optional filter limits where this data can be applied to

Maps that define the patterns of this data connection over time. Each map represents data at a given moment in time

Utility to time stamp the maps

# 3. Connect external data to maps

Delta management model - Ecosim with Ecosim 6.5.12689.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer C:\Users\Jeroen\Desktop\Delft3D\Model\DM\_30July2015.ewemdb

Navigator

- Ecopath
- Ecosim
- Ecospace
  - Input
    - Ecospace parameters
    - Maps
    - Habitat based foraging
    - Dispersal
    - Advection
    - Ecospace fishery
    - Marine Protected Area
    - External data
  - Output
  - Tools

Basic input External data

Define connections... (all) Only show connected

Apply connections Map

|   | Input map             | Enable external data                | 1              | 2 | 3 | 4 |
|---|-----------------------|-------------------------------------|----------------|---|---|---|
|   | Relative PP map       |                                     |                |   |   |   |
| 1 | PP (relative)         | <input checked="" type="checkbox"/> | Chla DM as rel |   |   |   |
|   | Environmental drivers |                                     |                |   |   |   |
| 1 | Salinity              | <input checked="" type="checkbox"/> | SalinityDM     |   |   |   |
| 2 | Temp                  | <input checked="" type="checkbox"/> | Temp_DM2       |   |   |   |
| 5 | Total Suspended S     | <input checked="" type="checkbox"/> | TSS_DM         |   |   |   |

2005 2010

SalinityDM

Temp\_DM2

TSS\_DM

Chl a\_DM as env driver

sack-oeciall

# Other recently changes to Ecospace

## Automatic saving of outputs

- Various map formats (.asc, .csv, ...)

- Various image formats (.png, .jpg, .bmp, ...)

- Averages by region

## Cell exclusion layer

- Exclude cells from analysis without turning them to land

## Overlapping Marine Protected Areas

- Allow different fisheries regulations in a single cell

## Migration

- Use migration weight maps instead of centroid + spread

# Work in progress



# Advection

Current Advection model in EwE, which computes advection flow fields from wind, mixed layer depth, and upwelling, does not work

## **Work-around (EwE version 6.5+)**

Applying advection flow fields does work: flow layer content can be entered or driven by spatial temporal framework

## **Ongoing developments**

New Advection model only requires depth and wind input to calculate advection and upwelling

# 1. Calculate advection

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

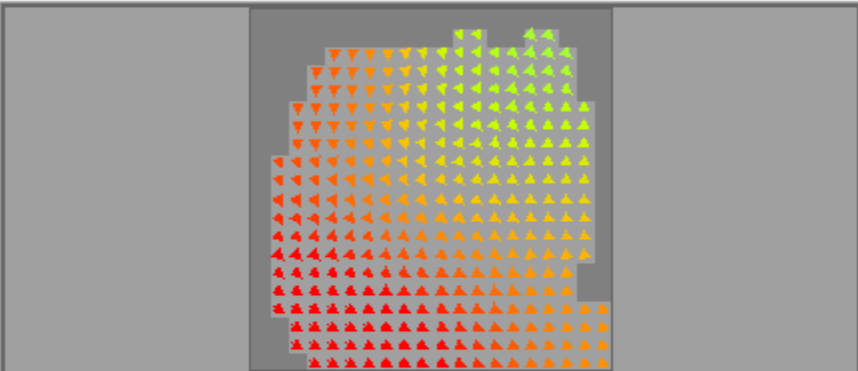
Navigator

- Ecopath
- Ecosim
- Ecospace
  - Input
    - Ecospace parameters
    - Maps
      - Habitat based forcing
        - Apply foraging
        - Group capacity
        - Habitat foraging
        - Functional response
      - Dispersal
      - Advection**
      - Ecospace fishery
      - Marine Protected
      - External data
    - Output
    - Tools

Diet composition Advection

Save image... Position 100% Reset

**Wind map**



Name: Wind map

Max value: 29.34146

Min value: 10.55253

Cursor: [Slider]

Value: 40.000

Smooth [Button]

Month: January

**Model parameters**

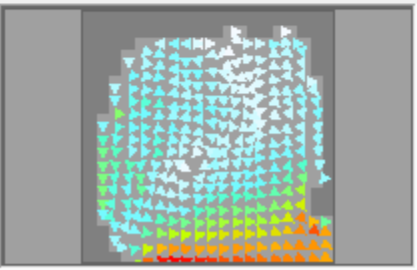
Upwelling: 30.00

PP upwelling: 0.01000

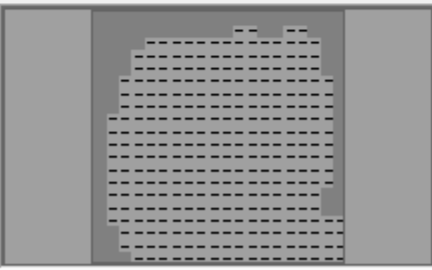
**Compute advection velocities**

Compute [Button] Stop [Button]

**Advection map**



**Upwelling**



Status Remarks

Anchovy Bay New Ecosim scenario BayOfAnchovies

## 2. Choose advected groups

Anchovy Bay - Ecopath with Ecosim 6.5.14149.0

File View Ecopath Ecosim Ecospace Tools Windows Help

Ecopath Ecosim Ecospace Ecotracer D:\Sources\Ecopath6\Database\Anchovy Bay Spatial.ewemdb

Navigator

- Ecopath
- Ecosim
- Ecospace
  - Input
    - Ecospace parameters
    - Maps
    - Habitat based forcing
      - Apply foraging
      - Group capacity
      - Habitat foraging
      - Functional response
    - Dispersal
    - Advection
    - Ecospace fishery
    - Marine Protected Areas
    - External data
  - Output
  - Tools

Diet composition Advection **Dispersal**

Set: False

|    | Group name    | Base dispersal rate | Relative dispersal in bad habitat | Rel. vul to pred. in bad hab. | Rel. feed rate in bad hab. | Is advected                         | Is migratory             | Barrier avoidance weight |
|----|---------------|---------------------|-----------------------------------|-------------------------------|----------------------------|-------------------------------------|--------------------------|--------------------------|
| 1  | Whales        | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 2  | Seals         | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 3  | Cod           | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 4  | Whiting       | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 5  | Mackerel      | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 6  | Anchovy       | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 7  | Shrimp        | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 8  | Benthos       | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 9  | Zooplankton   | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |
| 10 | Phytoplankton | 300.0               | 5.000                             | 2.000                         | 0.500                      | <input checked="" type="checkbox"/> | <input type="checkbox"/> |                          |
| 11 | Detritus      | 10.000              | 5.000                             | 2.000                         | 0.500                      | <input type="checkbox"/>            | <input type="checkbox"/> |                          |

10: Phytoplankton (Is this group affected by advection?)

Anchovy Bay New Ecosim scenario BayOfAnchovies

# Advection

Computed advection, per month, is stored with the EwE model

Advection patterns can be overwritten with external hydrological model output via the spatial temporal data framework

Will be made available in a next EwE version, but development version can be applied by involving the EwE development team

Publication is in progress

# Ecotracer

Modelling the propagation of pollutants through the food web (Ecosim, Ecospace)

Existing Ecotracer module is being debugged, sped up, and made ready for application in large spatial temporal case study

Ecotracer model is driven by a contaminants forcing function (Ecosim) or contaminants map (Ecospace)

Publication is in progress

# Measure Ecospace fit

Use spatial-temporal reference time series to report how well Ecospace reproduces observations

Prototype version uses point (x,y,z) time series

Future version should use the spatial-temporal data framework

Needs further R&D, funding

# Ecosim forcing in Ecospace

Allow non-spatial forcing (Ecosim) to be applied to Ecospace

Prototype only applies biomass forcing time series

Can be extended to include any type of forcing

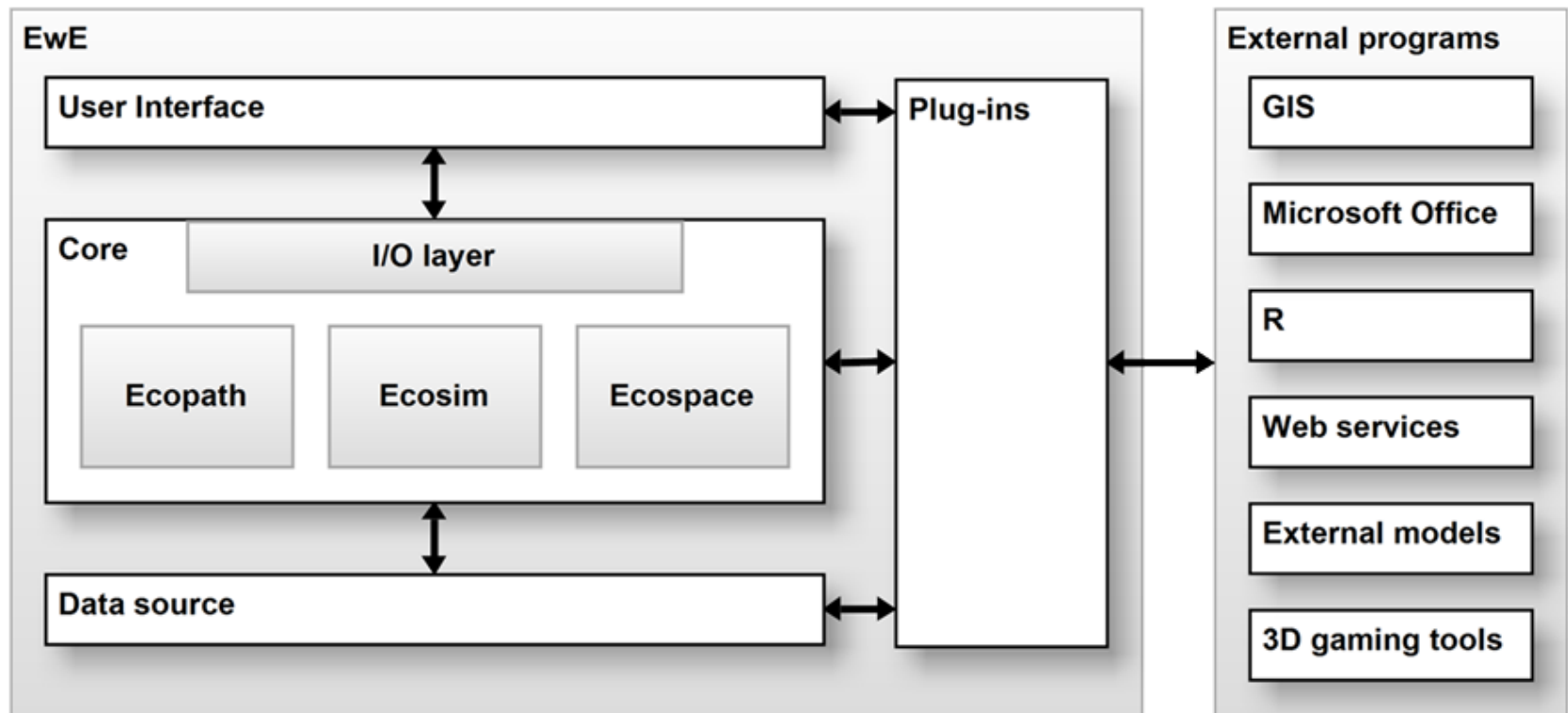
Needs further R&D, funding

# Other ways to use EwE



# Other ways to use EwE

## Modular structure of EwE



# Other ways to use EwE

## Plug-ins

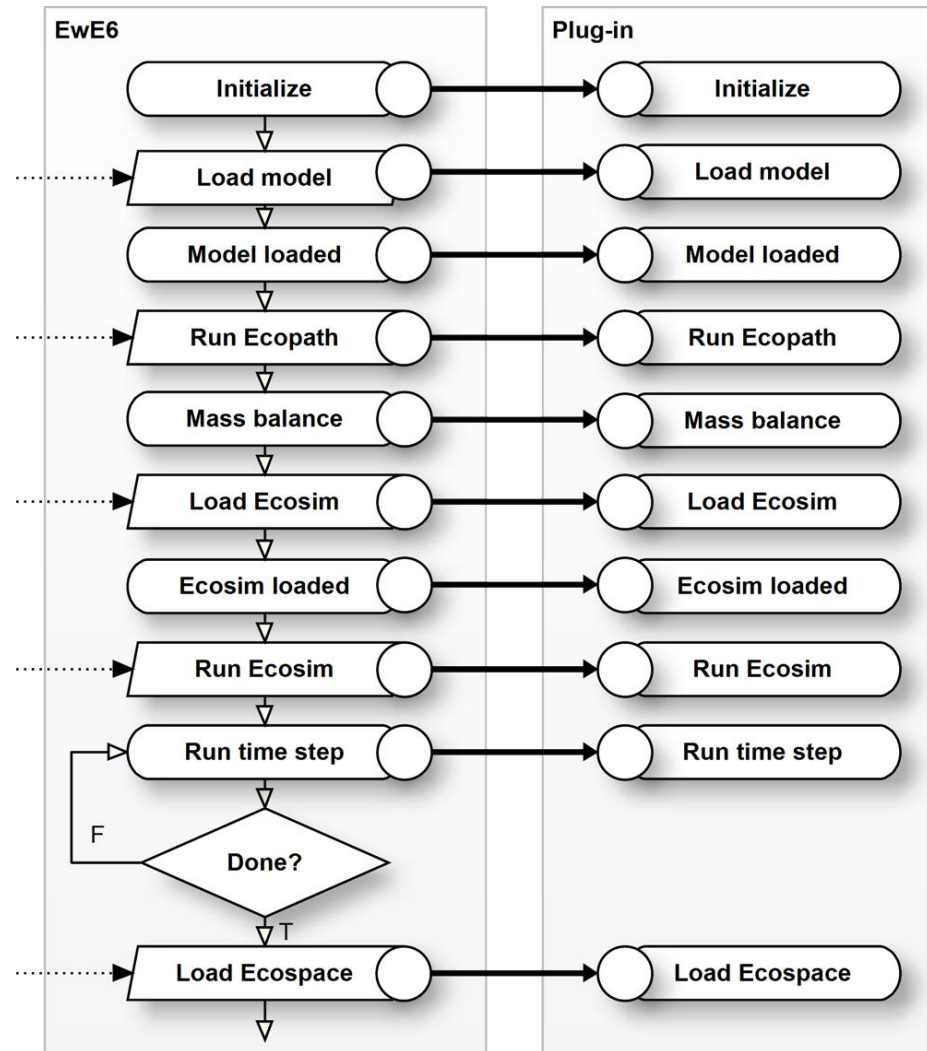
Independently of EwE

Auto-loaded on start-up

Included in program flow

Replace or extend  
computations and user  
interface

Perform external analysis  
and do other really neat  
things!



# Other ways to use EwE

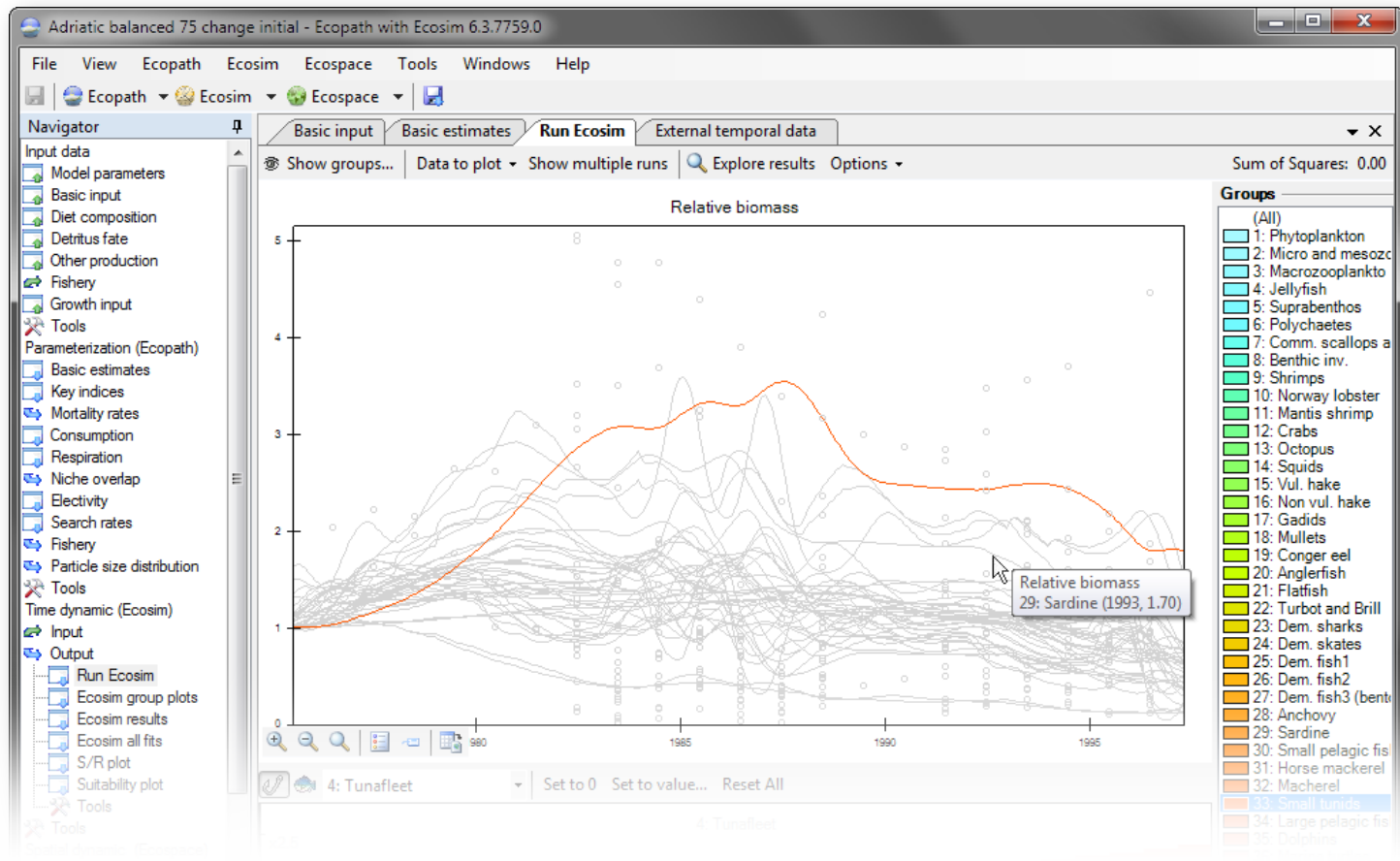
## A few plug-ins

|                         |                  |
|-------------------------|------------------|
| Aquamaps importer       | EII              |
| Biodiversity indicators | IRD, in progress |
| Ecotroph analysis       | Agrocampus Ouest |
| WoRMS taxon search      | EII              |
| Multi-Sim               | DFO              |
| Network analysis        | SAMS             |
| Result extractor        | CEFAS            |
| Value Chain             | UBC              |

***Your plug-in?***

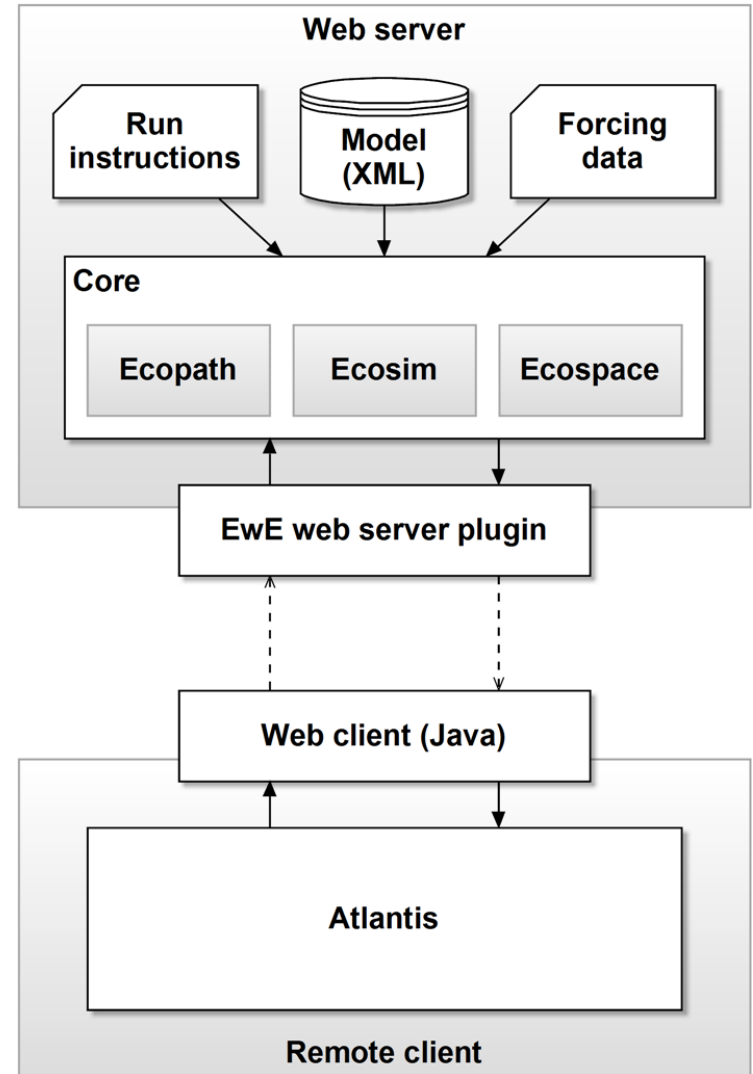
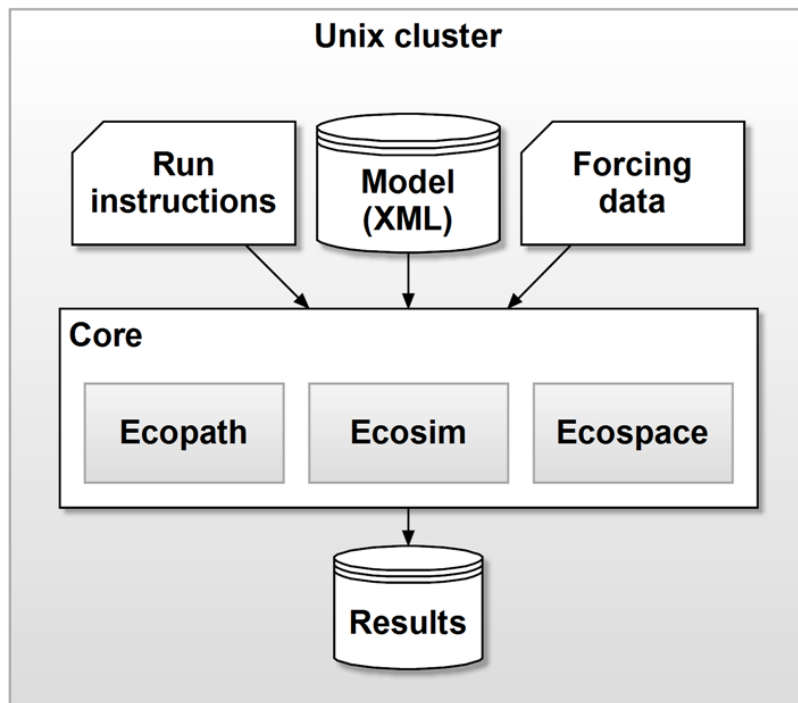
# Other ways to use EwE

## Standard use: EwE6 Scientific Interface



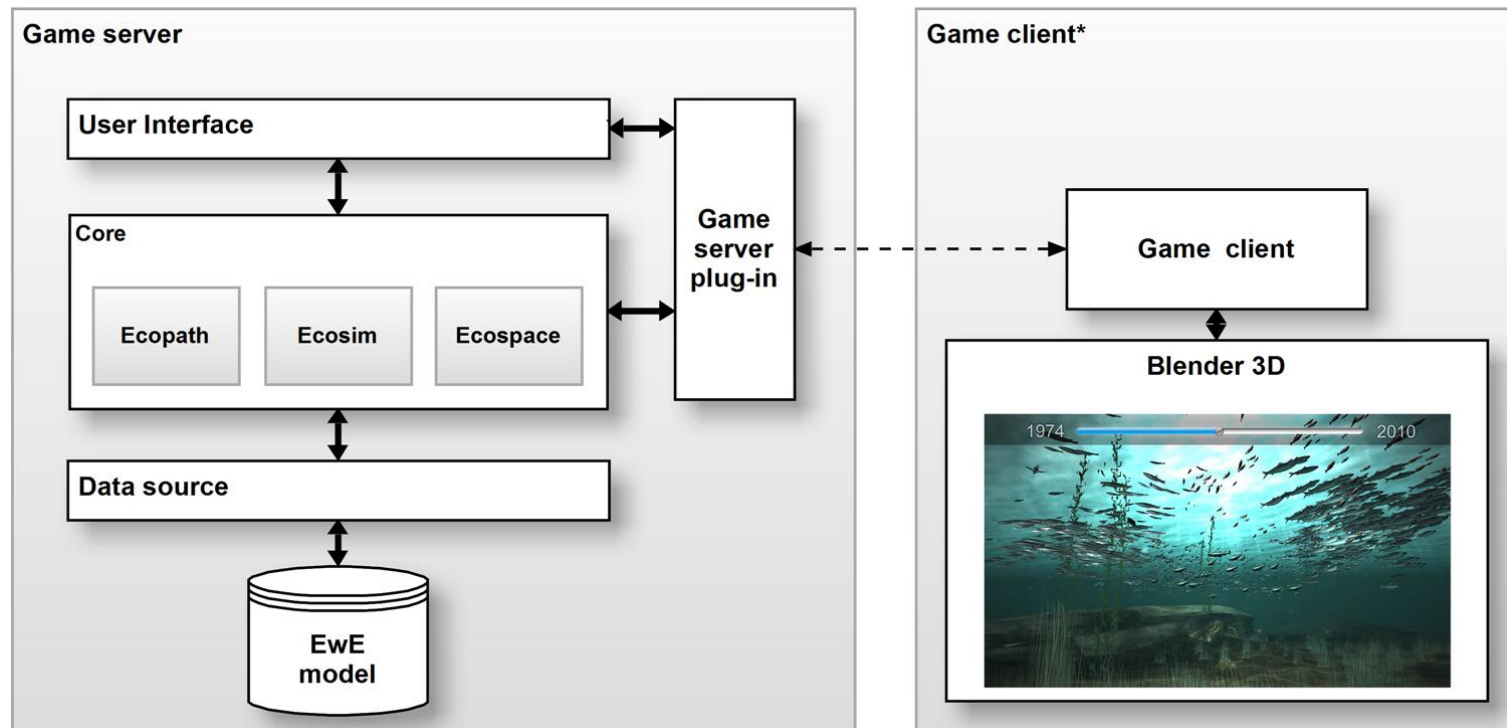
# Other ways to use EwE

## Distributed computing, model interoperability



# Other ways to use EwE

## OceanViz



# The EwE ecosystem



# Ecopath

Research and  
Development  
Consortium

# The EwE ecosystem

**EwE is free and open-source, and has no core funding**

Funding brought by user community via R&D and projects

Overhead used for R&D and maintenance

**Ecopath R&D Consortium: improving and applying EwE**

High quality training courses

Pursuing and executing projects

Release new versions of EwE

Organizing development, user support, co-development

Open for any institute to join, voluntary participation

# The EwE ecosystem

## **EwE needs active users to continue**

Get a support contract for projects that need EwE

Participate in user community (forums, Facebook)

Improve functionality through co-development

Organize training courses with the Consortium

Join the Consortium

<http://ecopath.org/consortium>

<http://facebook.com/eweconsortium>

# Thank you

[jeroen@ecopathinternational.org](mailto:jeroen@ecopathinternational.org)



Ecopath  
International  
Initiative

# Selected references

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