Project: Hydroecology Modelling Tool (HEM) development to inform environmental assessment in water company drought planning

Slide pack contents:

- Context for HEM Tool Development project
- Background to DRIED-UP models and tool
- Screenshots from current DRIED-UP tool

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Context for the HEM Tool Development Project

- To support environmental assessments of Water Company (WCo) supply side drought management activities they are required to collect/collate baseline ecological monitoring data
- This data helps them assess the effect of their supply side drought activities on sensitive ecological receptors
  - Particularly important to understand and provide sufficient assessment in support of any drought permits or drought orders

The development need

- Inconsistency in environmental assessment approaches
- Insufficient detail / rigour in environmental assessments
- Unable to consider / measure levels of uncertainty
  - Needed to help guide future data collection
- Lack of long term, consistent baseline data for many sites and situations makes it difficult to fully understand the impacts of supply side activities on aquatic ecology

EA DRIED-UP tool – current form and development need

- Provides elements of a tool that we want to develop further for WCo use to help improve their environmental assessment which applies:
    - Single-site model (where baseline data for a site is sufficient)
    - Standard model (blends site data with wider DRIED-UP dataset)
- Uses input data (flow, LIFE scores) from a HEV* plot
- But needs further software development work this FY
- This project therefore aims to improve the existing tool to create a new **HEM (hydroecological modelling) tool** for roll-out to WCos

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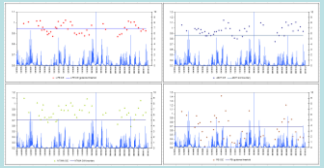
* Hydroecology Validation

We already have parts (but not all) of this process

2 Key project objectives:

1. Existing tool elements need refinement
2. New tool elements and functionality to be added

HE data for site of interest



INPUT

HEM Tool user-friendly wrapper for

HE model or models [DRIED-UP technology]

R code

Large HE dataset already in model

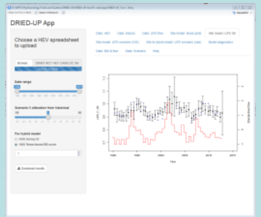
Flow / Drought Scenarios

Input

Interpret what model is telling us in context of drought sensitivity

OUTPUT

1. On-screen
2. Download



HEM tool development project (within scope)

- To further develop our existing DRIED-UP tool into an improved Hydroecology Model (HEM) tool, ready for testing by Water Companies*
- Graphics / visuals improvements
  - Model diagnostics - particularly sensitivity to low flow
  - Model outputs
- Develop assessment of site suitability for applying standard model
- Alternative standard model development
  - DU3, DU5 and NDMN only
- Flow scenario analysis function development
- Documenting model development work and future update/maintenance information

* Please refer to HEM_RFQ Document for full project requirement details

Other HEM development work (out of scope)

The EA will lead on the following work items:

- Collation of HEV data for specific WCo sites
- Training external users on use of the tool
- Post-development testing project (involving WCo & their consultants)
- Review and take stock
  - Not all tested features may make it into final tool
- Roll-out HEM tool for WCo use in 2020

DRIED-UP*

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Background science and current tool

- What it is
- What it does
- Why it does it
- How it does it
- Tools

*** D*istinguishing the *R*elative *I*mportance of *E*nvironmental *D*ata *U*nderpinning flow *P*ressure assessment**

DRIED-UP – What it is

- Sequence of (aquatic) macro-invertebrate hydroecological models developed incrementally between 2005 and 2011
- Mainly funded by EA
- Started with 11 sites in N. Anglian (DU 1)
- Tested on 86 upland sites (DU 2)
- “Current” model based on 146 biology sites across UK (DU 3)
  - Upland and lowland
  - Spring and autumn
- Aim has always been to create a tool to provide an easy to use interface to the models

Where it all started…….

REGULATED RIVERS: RESEARCH & MANAGEMENT
Regul. Rivers: Res. Mgmt. **15**: 543–574 (1999)

RIVER FLOW INDEXING USING BRITISH BENTHIC MACROINVERTEBRATES: A FRAMEWORK FOR SETTING HYDROECOLOGICAL OBJECTIVES

C.A. EXTENCE*, D.M. BALBI AND R.P. CHADD
The Environment Agency of England & Wales, Anglian Region, Northern Area, Waterside North, Lincoln, UK

ABSTRACT

A method linking qualitative and semi-quantitative change in riverine benthic macroinvertebrate communities to prevailing flow regimes is proposed. The Lotic-invertebrate Index for Flow Evaluation (LIFE) technique is based on data derived from established survey methods, that incorporate sampling strategies considered highly appropriate for assessing the impact of variable flows on benthic populations.

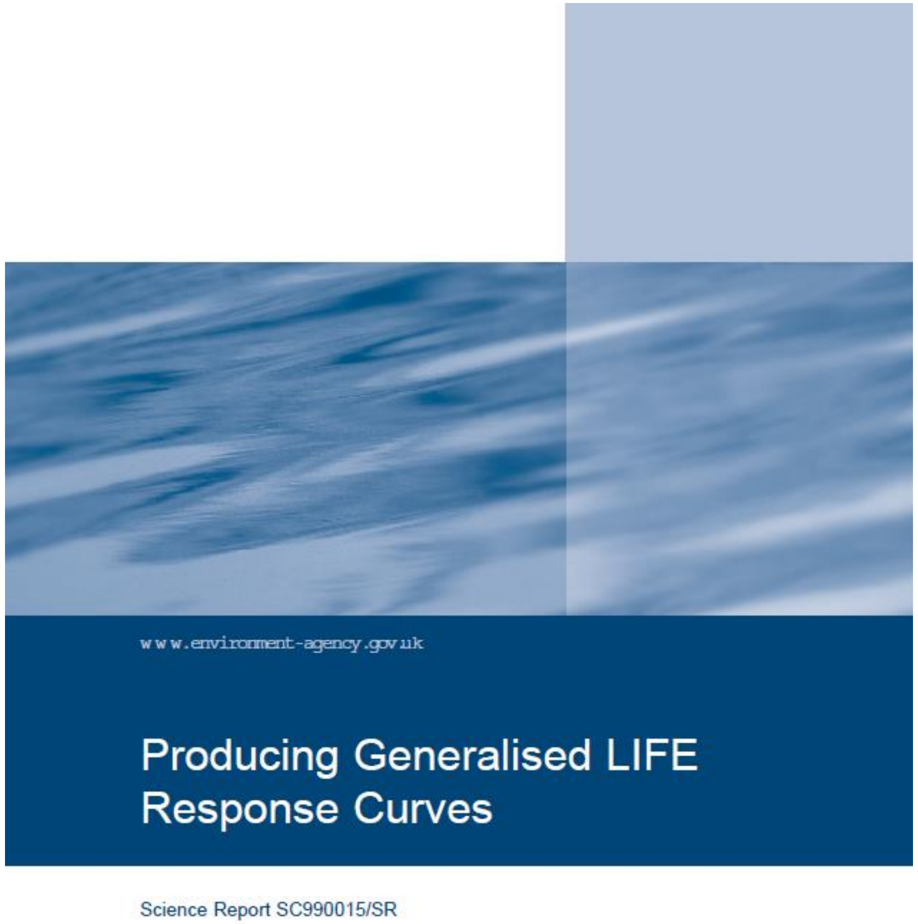
Hydroecological links have been investigated in a number of English rivers, after correlating LIFE scores obtained over a number of years with several hundred different flow variables. This process identifies the most significant relationships between flow and LIFE which, in turn, enables those features of flow that are of critical importance in influencing community structure in different rivers to be defined. Summer flow variables are thus highlighted as being most influential in predicting community structure in most chalk and limestone streams, whereas invertebrate communities colonizing rivers draining impermeable catchments are much more influenced by short-term hydrological events. Biota present in rivers with regulated or augmented flows tend to be most strongly affected by non-seasonal, interannual flow variation.

These responses provide opportunities for analysing and elucidating hydroecological relationships in some detail, and it should ultimately be possible to use these data to set highly relevant, cost-effective hydroecological objectives. An example is presented to show how this might be accomplished.

Key areas of further work include the need to provide robust procedures for setting hydroecological objectives, investigation of habitat quality and LIFE score relationships in natural and degraded river reaches and evaluation of potential links with other biological modelling methods such as RIVPACS.

KEY WORDS: drought; flow; hydroecology; macroinvertebrates

Extence, Balbi and Chadd (1999)



Dunbar and Clarke (2002)

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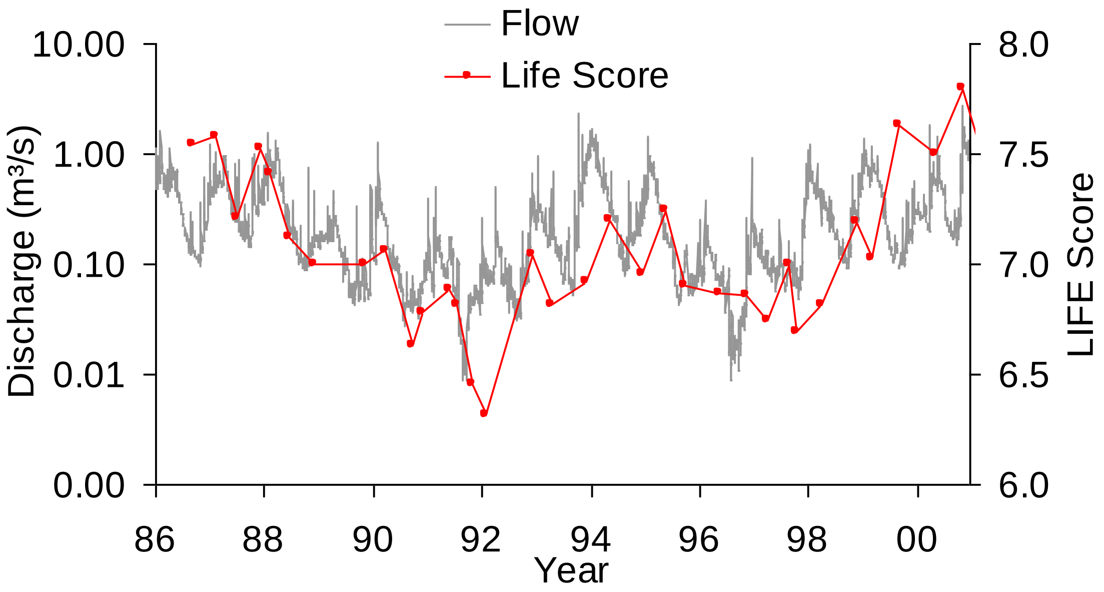
What does DRIED-UP do?

- Describes relationship between observed LIFE and **antecedent** low (Q95) and high (Q10) flow
  - For all sites used to calibrate DU model
  - And for a “new” site of interest



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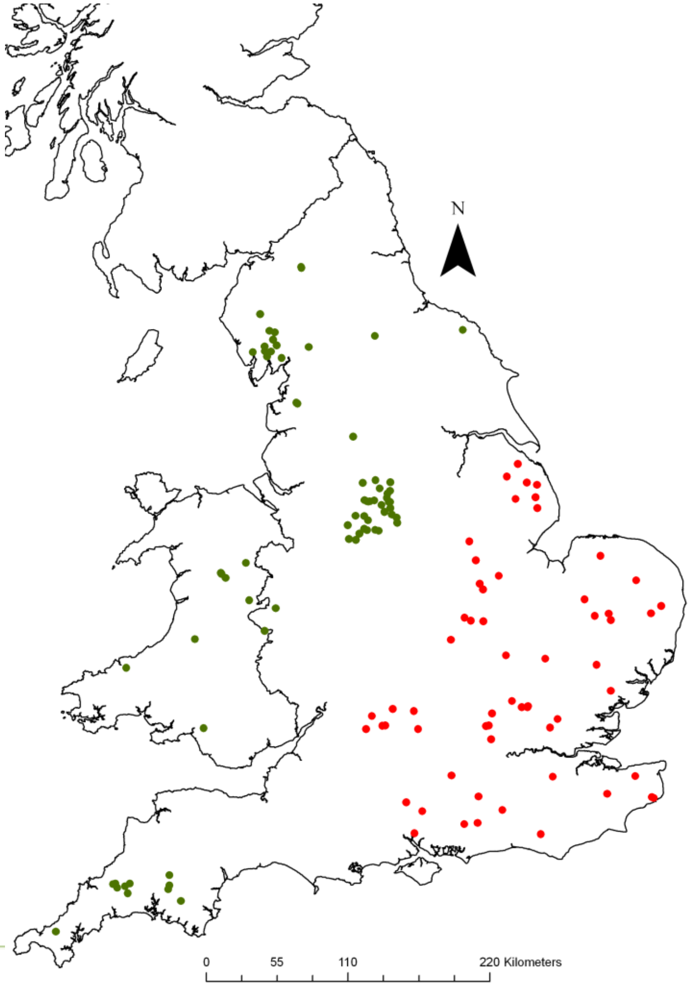
Why does it do what it does?

- You need a **surprisingly large** amount of biological data to model the LIFE-flow relationship for a site
- **Particularly** if you are interested in response to different aspects of the flow regime
- So site-specific LIFE-flow relationships can be **uncertain**
- If multiple flow variables are “tested”, this **uncertainty is even greater than you think**

How DRIED-UP does it

- In DRIED-UP, predictions for any single site (e.g. a new site of interest with some data) **“borrow strength”** from the dataset as a whole
- We sometimes refer to this as a blended (or nudged) response
- **Briefly put: The DU dataset/model can make site-specific relationships more robust**

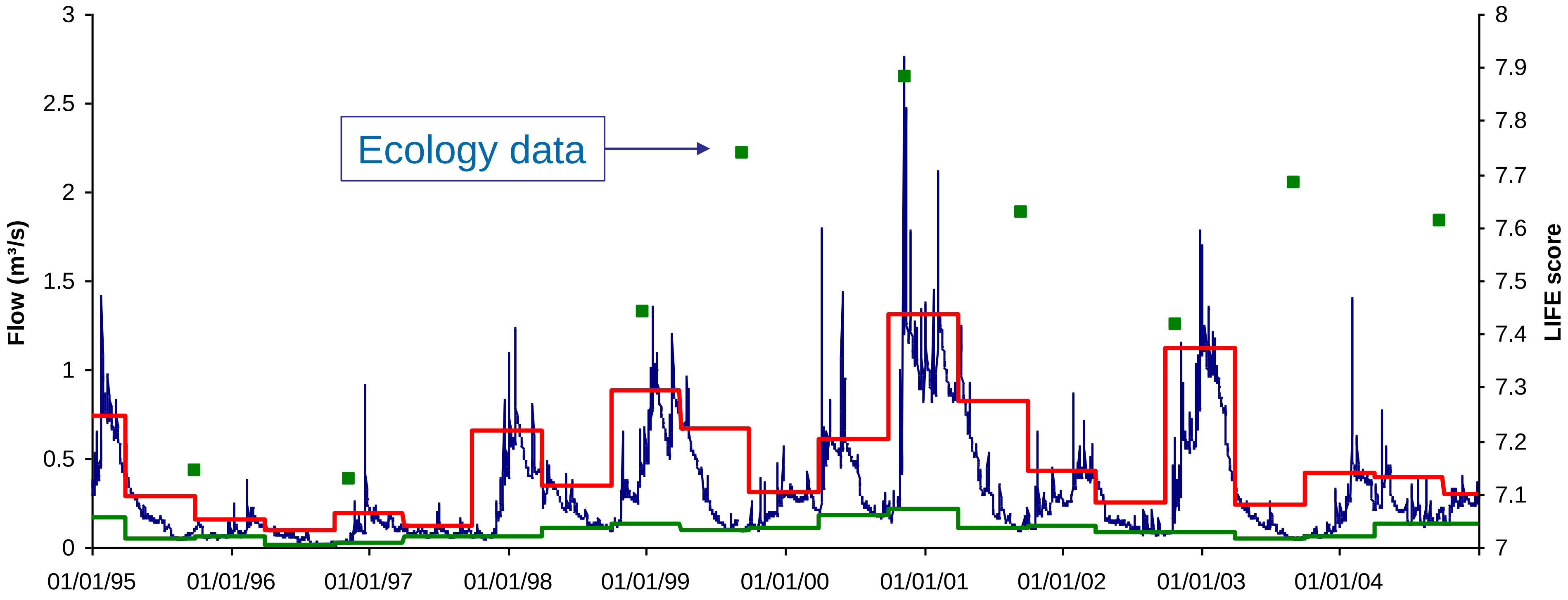
Calibration possible using data from BIOSYS



Model can borrow data from a national baseline dataset

Flow data can be summarised

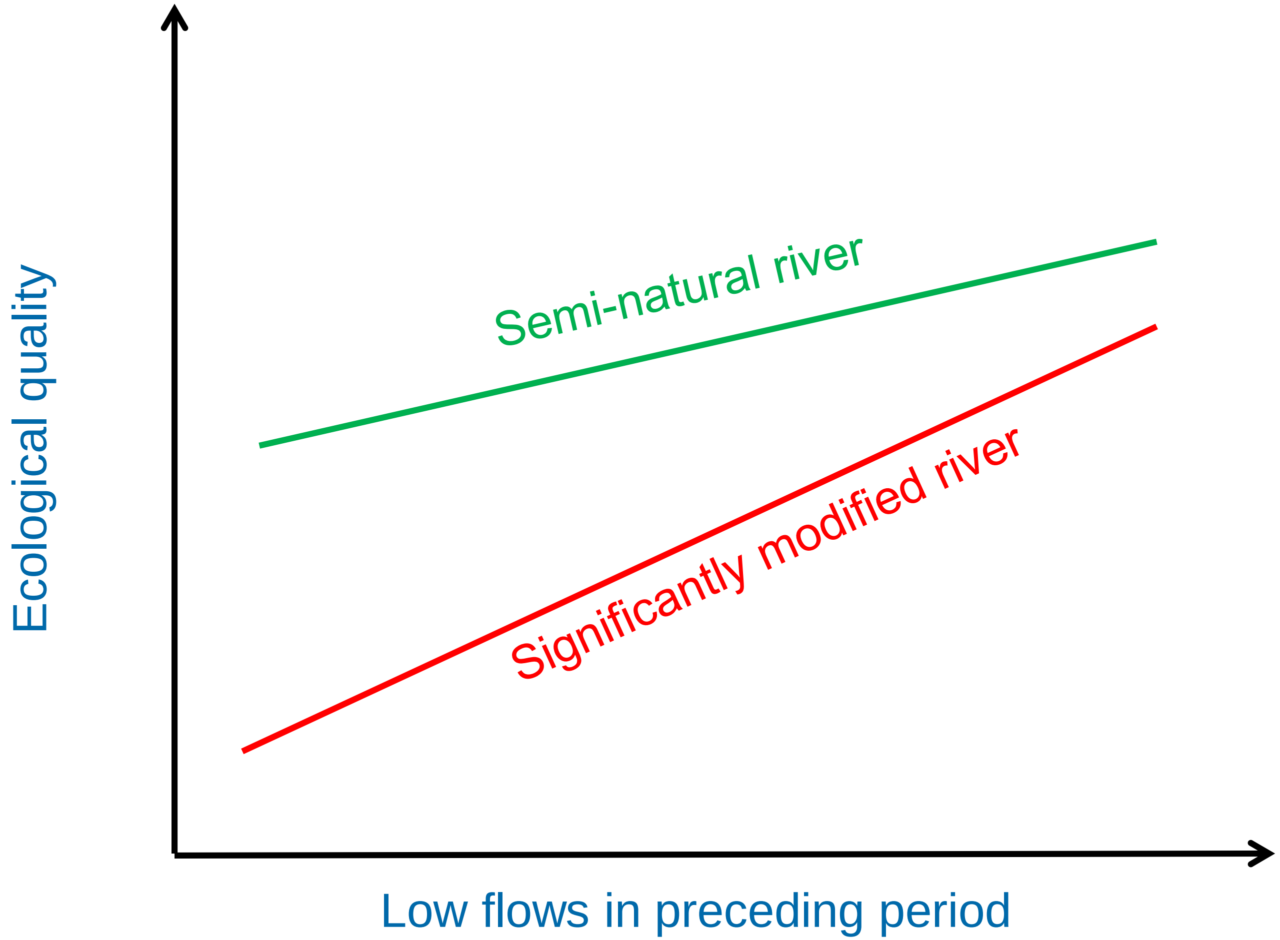
Flow data is processed by the model into time-varying or seasonal statistics



What does DRIED-UP do - revisited

- As flow goes up, LIFE goes up
- As flow goes down, LIFE goes down
- By how much? Depends on two things:
  - Extent of resectioning at the site (from RHS data)
  - Site-specific response: also depends on the pattern of LIFE scores for your site AND their scatter
    - Lots of data + tight fit: response will follow that of the site (you probably did not need DRIED-UP at all)
    - Fewer data + poor fit: response will move towards the DU average

The underlying standard model outputs identify patterns in macro-invertebrate communities relating to flow and also where there has been significant habitat modification



Key DRIED-UP messages

- Physical habitat influences sensitivity to flow change
- Focuses on generic response, while still allowing individual sites to vary

A helpful by-product of how the models work

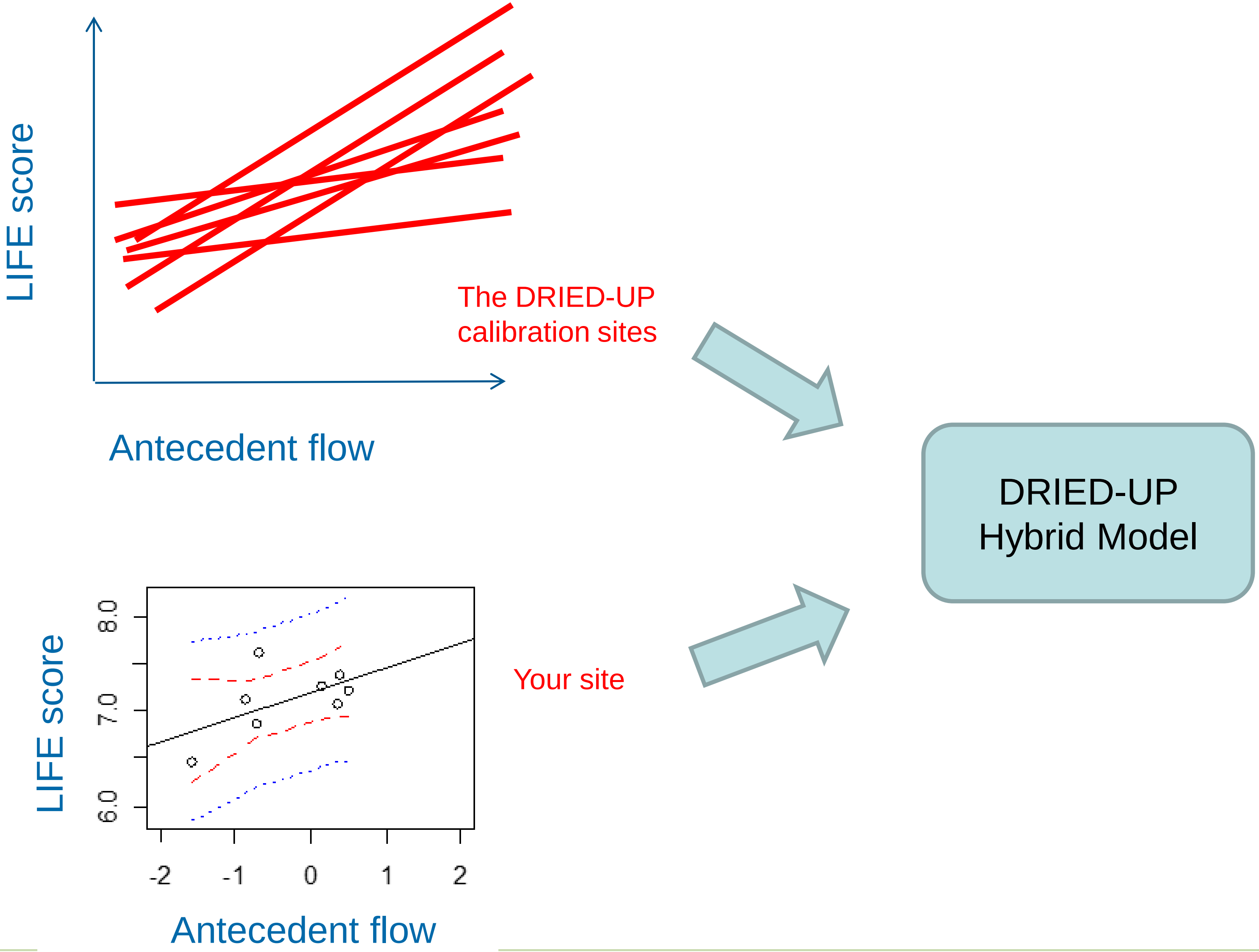
- Models estimate average response
- They estimate variance around that average
- These variances can be used to come up with a predicted response for a site within the model
- If the site fits tightly, this response will be close to that of a site-specific model
- But the site response can also be nudged, this depends on:
  - The variance across all the sites
  - The scatter of the site data (how well it fits)

The models are estimating

- Within-site variance
  - Can be partly explained by sample-level factors (typically antecedent flow)
- Among-site variances
  - Overall LIFE score
  - LIFE score response to antecedent flow
  - Can be partly explained by site-level factors (e.g. level of channel resectioning)
  - Remaining variance is what allows a nudge

Benefits of the blended / nudged response

- It will often be more precise
- You can fit more complex models than would be possible just with site data
- It works with any amount of site data, even just one observation



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Where we are right now

- Web-based tool (R + shiny)
- Data uploaded from HEV spreadsheet
- Puts site into the DU dataset
  - Runs DU model for all the sites (now called the hybrid model)
- ALSO sets up a comparable model just for the site of interest (single-site model)
- Presents results
- Assess a simple hydrological scenario (for illustrative purposes)

DRIED-UP 3 dataset (146 sites)

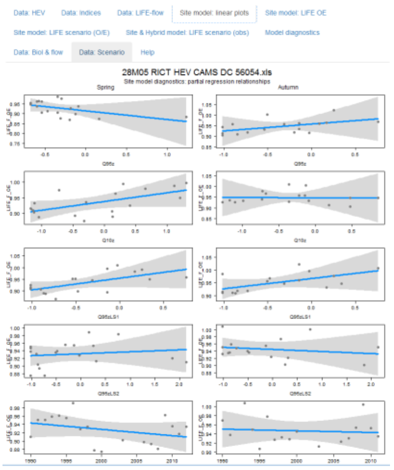
Study site

DRIED-UP 3 dataset (146 sites)

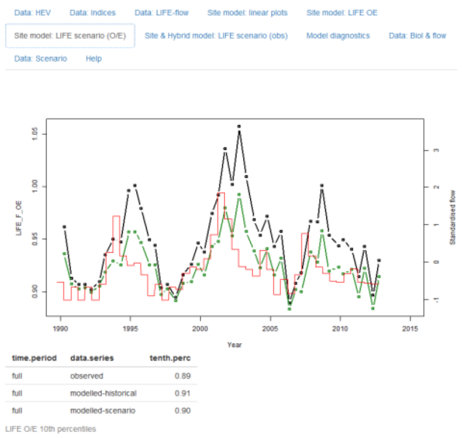
Study site

Refit model

Examine model



Use model to make predictions

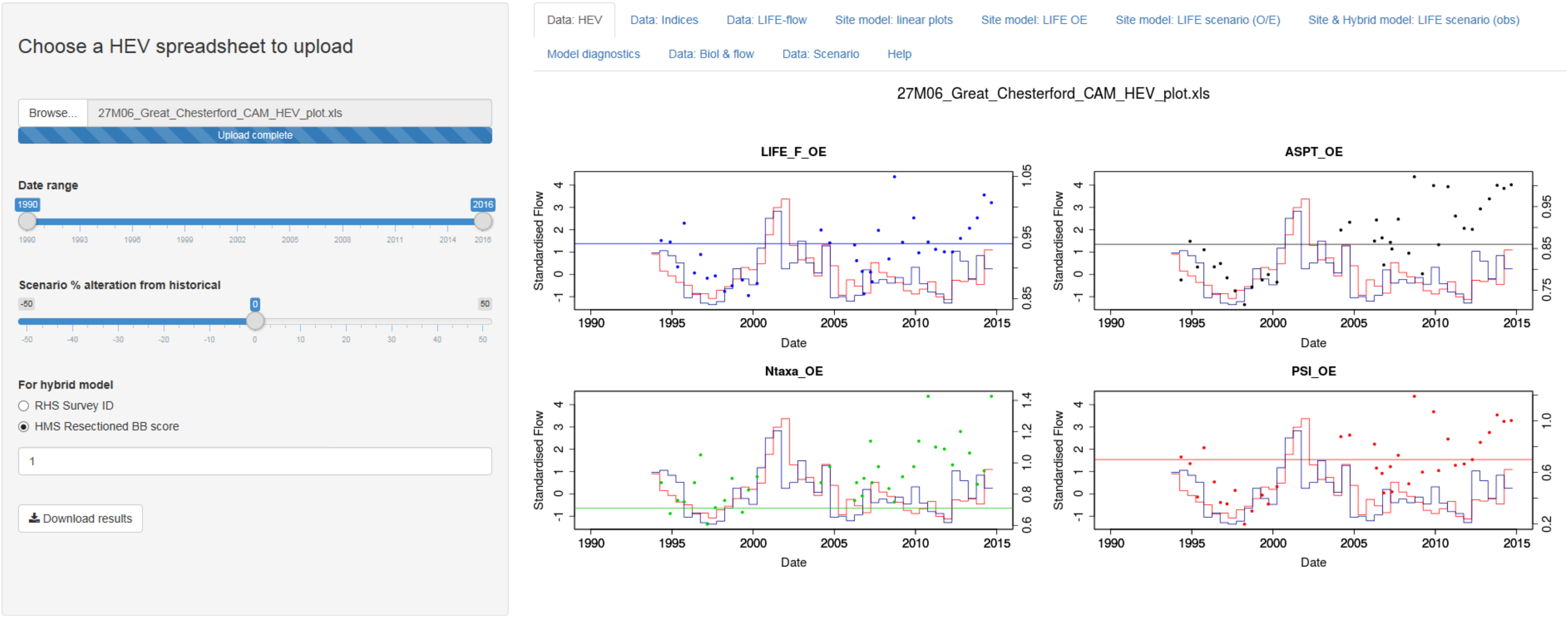


How does it work?

- The underlying tool is written in the R language, including code to:
  - Read in and process the data
  - Fit the DRIED-UP hybrid and site-specific models (these will be developed into HEM standard and HEM stand-alone models within this project)
  - Make predictions using those models
  - Present results, mainly as graphs
  - Export data
- We use an R package called shiny, to put a web front-end onto the existing R code
- Shiny uses lots of tricks to do what it does
- Can run locally, via RStudio
- Can be put into “the cloud”: shinyapps.io (free service for limited use)

Screenshots of existing tool user interface & tab visuals

DRIED-UP App



DRIED-UP App

Choose a HEV spreadsheet to upload

Browse... 27M06_Great_Chesterford_CAM_HEV_plot.xls

Upload complete

Date range

1990 – 2016

1990 1993 1996 1999 2002 2005 2008 2011 2014 2016

Scenario % alteration from historical

-50 0 50

-50 -40 -30 -20 -10 0 10 20 30 40 50

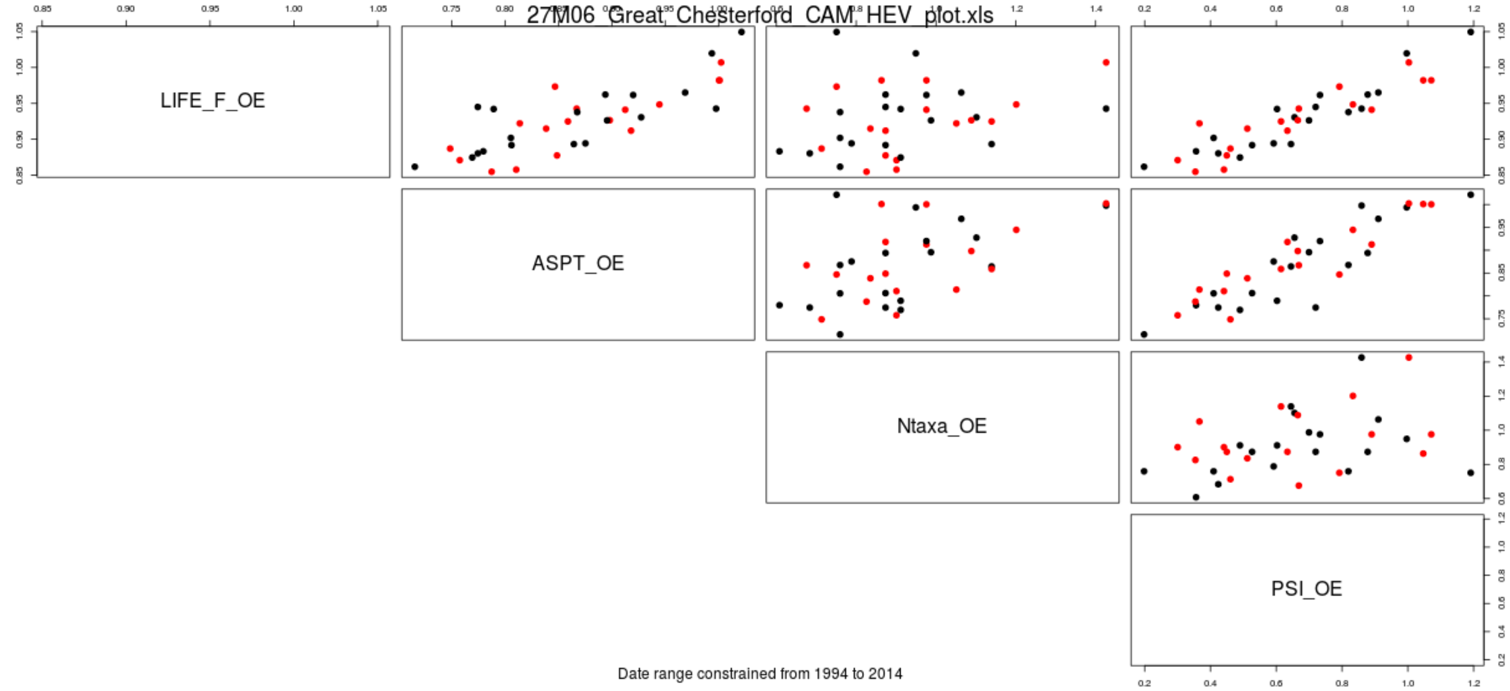
For hybrid model

- RHS Survey ID
- HMS Resectioned BB score

1

Download results

Data: HEV | Data: Indices | Data: LIFE-flow | Site model: linear plots | Site model: LIFE OE | Site model: LIFE scenario (O/E) | Site & Hybrid model: LIFE scenario (obs) | Model diagnostics | Data: Biol & flow | Data: Scenario | Help



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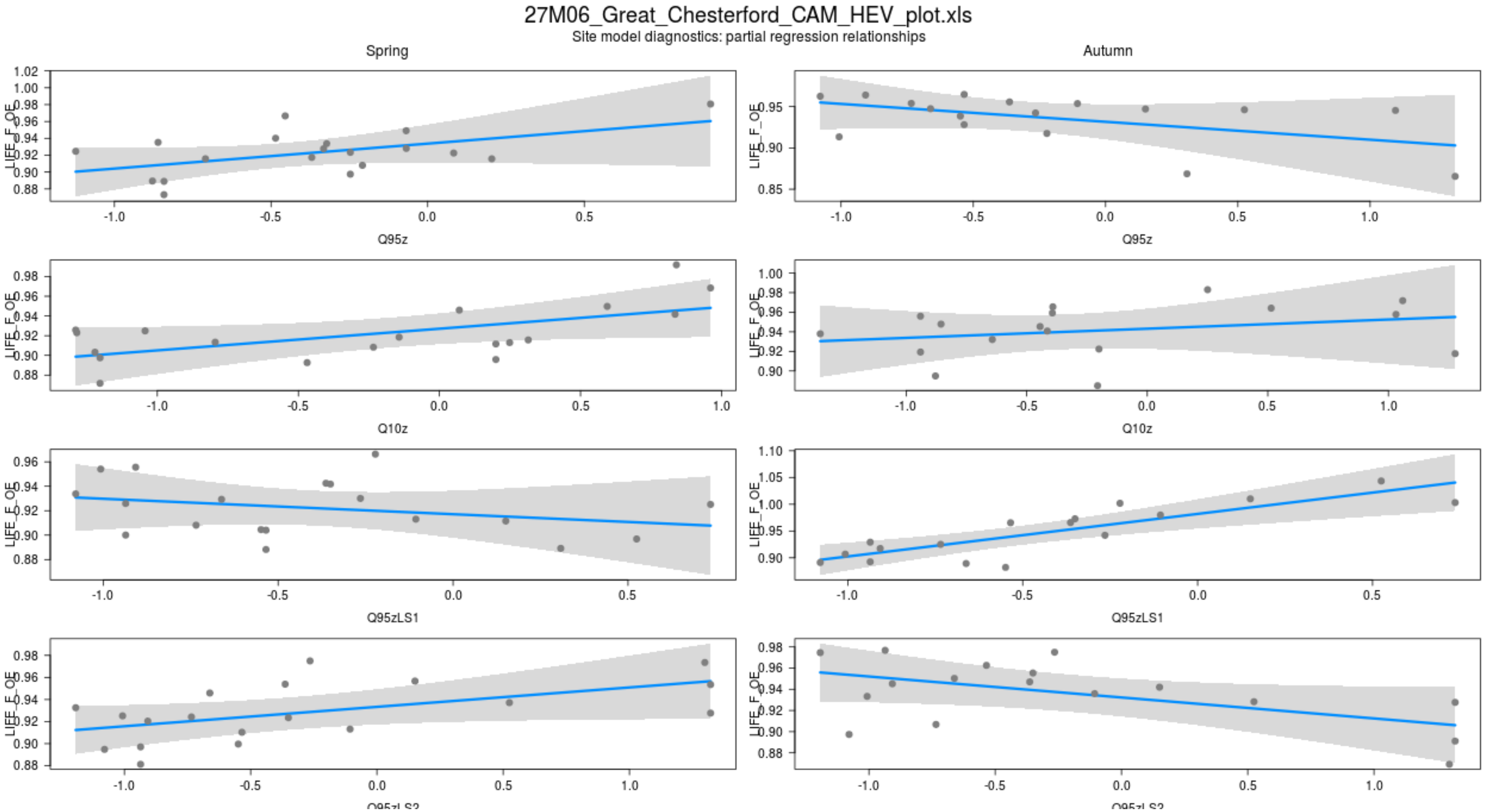

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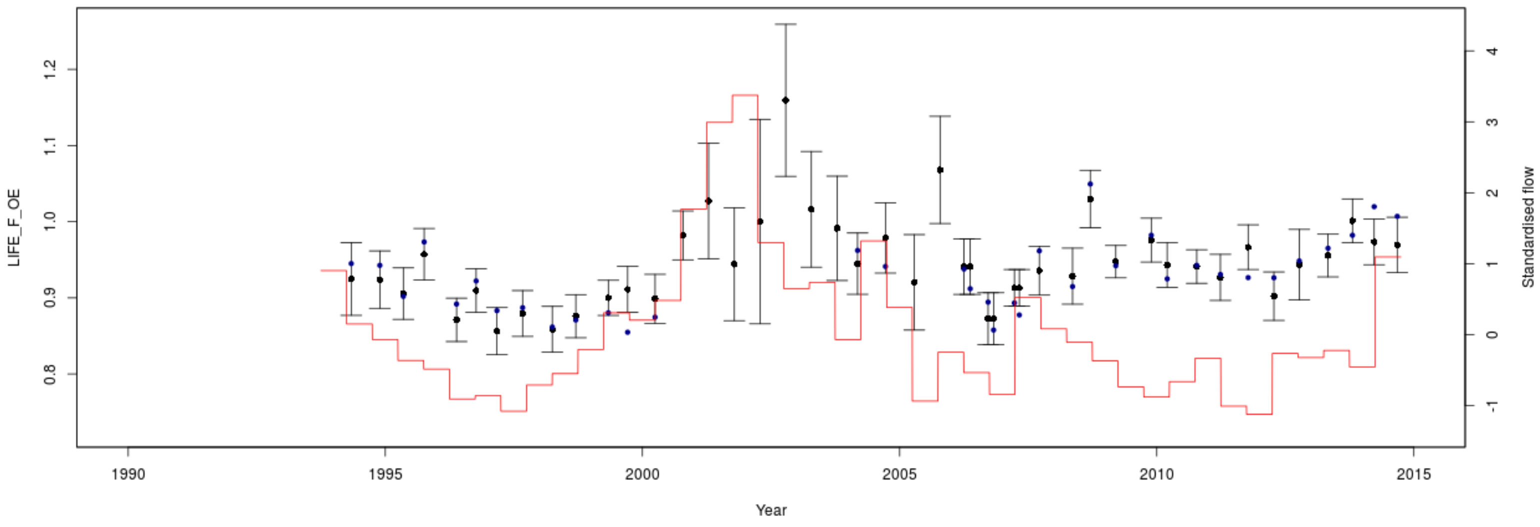

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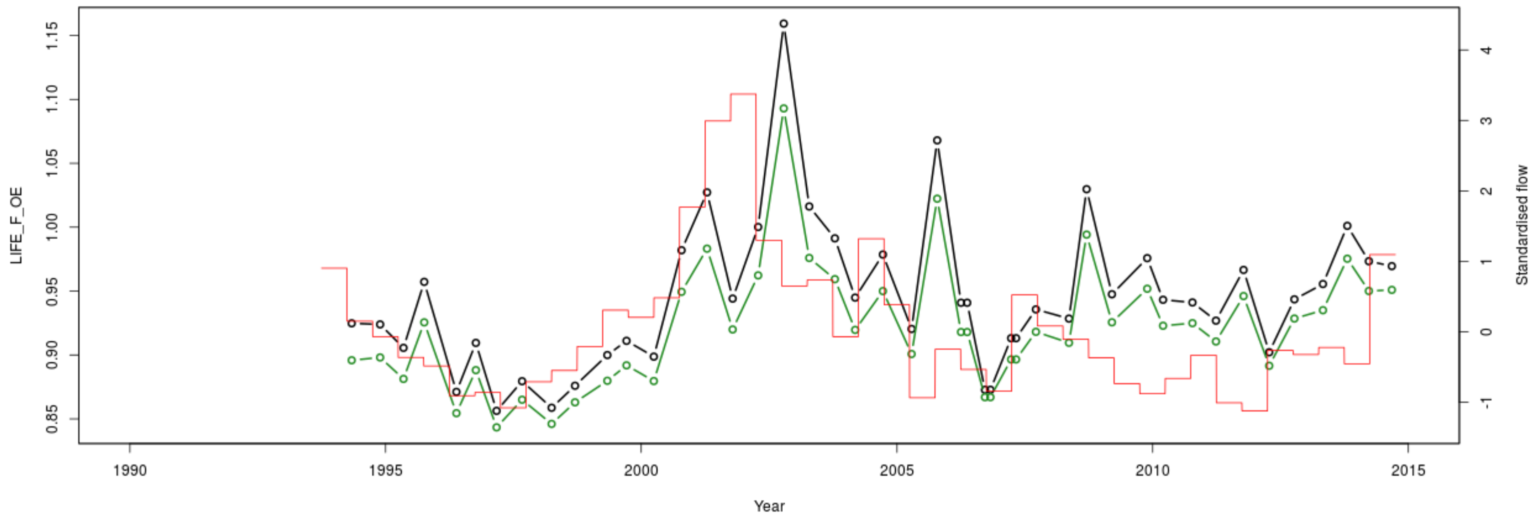

time.period	data.series	tenth.perc
full	observed	0.87
full	modelled-historical	0.87
full	modelled-scenario	0.87

LIFE O/E 10th percentiles

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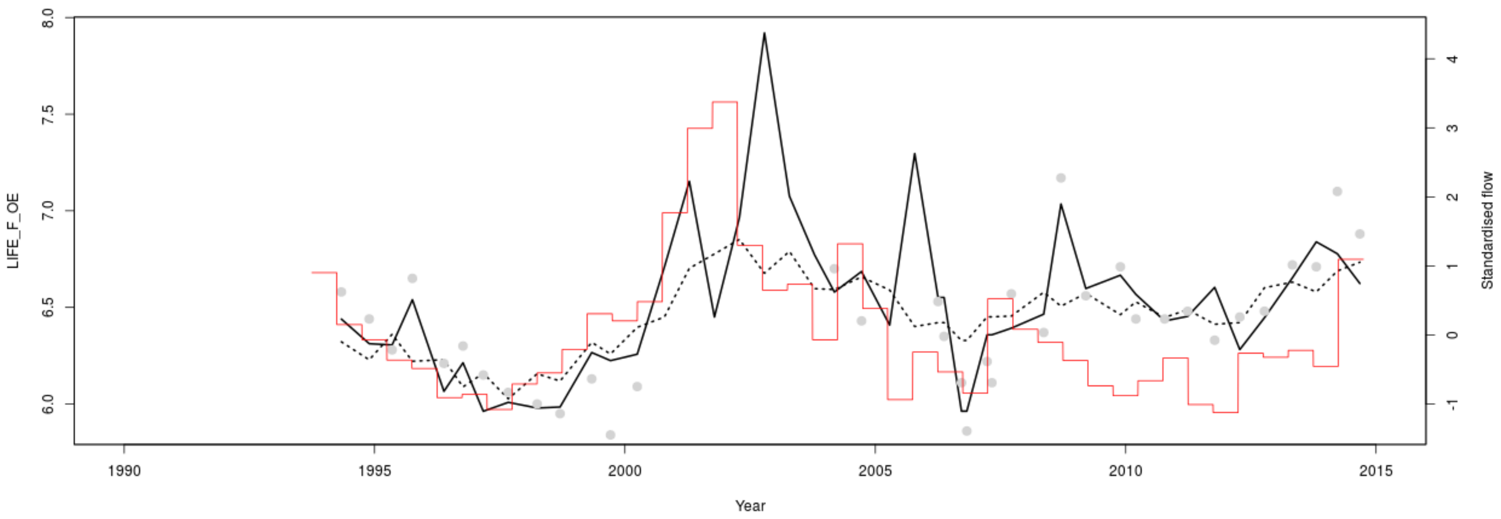

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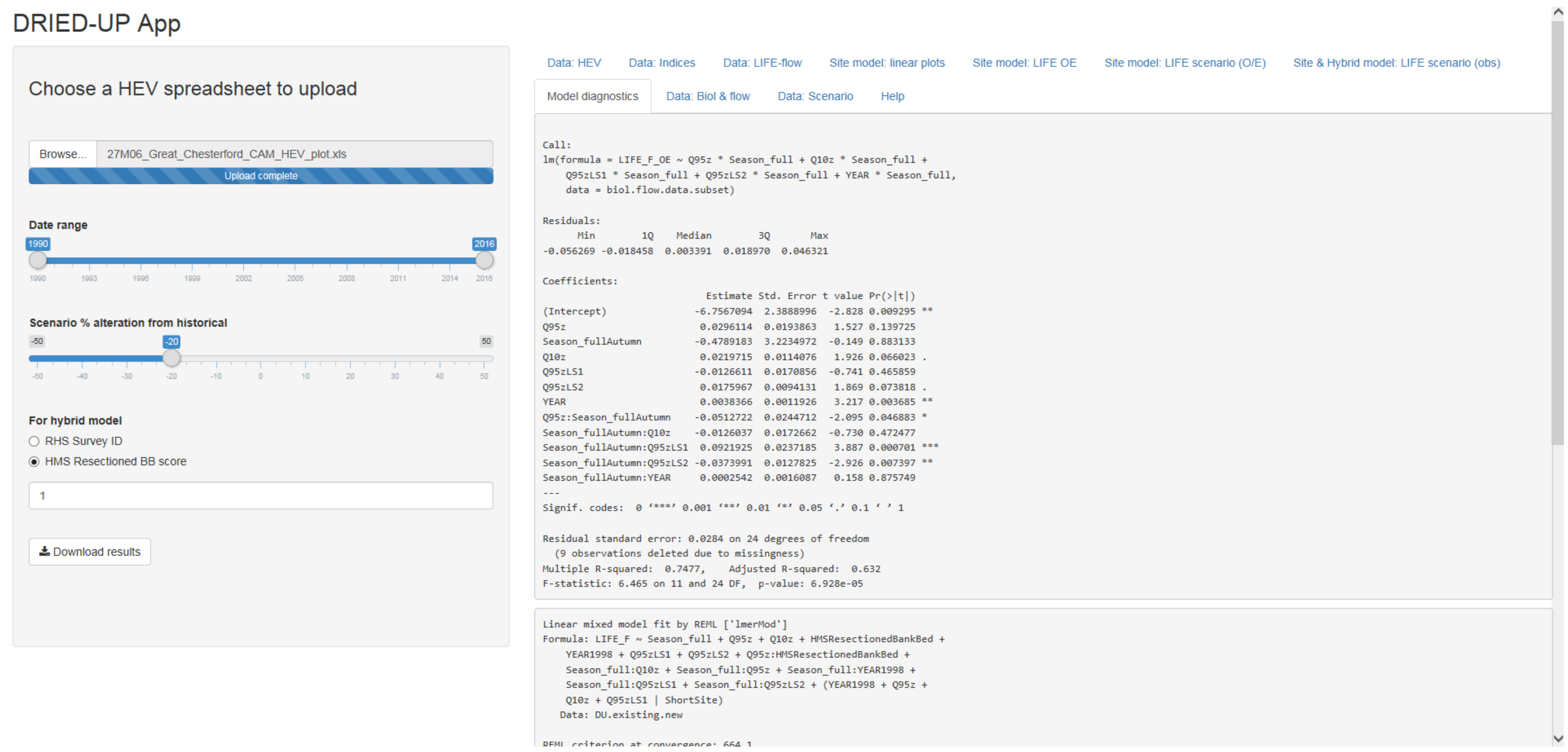

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Season_full	SITE_ID	sample_date	Q95z	Q10z	Q95zLS1	Q95zLS2	LIFE_F_OE	LIFE_F_OE_site_mod	LIFE_F	LIFE_F_O_hybrid_mod
Spring	56065	1994-05-04	0.90	0.96	-0.35	-1.19	0.94	0.92	6.58	6.32
Autumn	56065	1994-11-23	0.15	1.06	-0.35	-1.19	0.94	0.92	6.44	6.23
Spring	56065	1995-05-09	-0.07	0.84	0.15	-0.35	0.90	0.91	6.28	6.36
Autumn	56065	1995-10-04	-0.36	0.51	0.15	-0.35	0.97	0.96	6.65	6.22
Spring	56065	1996-05-21	-0.49	-1.04	-0.36	0.15	0.89	0.87	6.21	6.23
Autumn	56065	1996-10-07	-0.91	-0.86	-0.36	0.15	0.92	0.91	6.30	6.09
Spring	56065	1997-03-04	-0.86	-1.29	-0.91	-0.36	0.88	0.86	6.15	6.16
Autumn	56065	1997-09-02	-1.08	-1.36	-0.91	-0.36	0.89	0.88	6.06	6.03
Spring	56065	1998-04-01	-0.71	-1.22	-1.08	-0.91	0.86	0.86	6.00	6.16
Autumn	56065	1998-09-15	-0.55	-0.64	-1.08	-0.91	0.87	0.88	5.95	6.12
Spring	56065	1999-05-04	-0.21	0.25	-0.55	-1.08	0.88	0.90	6.13	6.32
Autumn	56065	1999-09-18	0.31	-0.21	-0.55	-1.08	0.85	0.91	5.84	6.26
Spring	56065	2000-03-31	0.20	-0.47	0.31	-0.55	0.87	0.90	6.09	6.40
Autumn	NA	2000-10-15	0.48	1.17	0.31	-0.55	NA	0.98	NA	6.45
Spring	NA	2001-04-15	1.77	2.51	0.48	0.31	NA	1.03	NA	6.70
Autumn	NA	2001-10-15	2.99	2.83	0.48	0.31	NA	0.94	NA	6.78
Spring	NA	2002-04-15	3.37	0.25	2.99	0.48	NA	1.00	NA	6.85
Autumn	NA	2002-10-15	1.30	0.51	2.99	0.48	NA	1.16	NA	6.68
Spring	NA	2003-04-15	0.65	1.49	1.30	2.99	NA	1.02	NA	6.79
Autumn	NA	2003-10-15	0.74	0.52	1.30	2.99	NA	0.99	NA	6.60
Spring	56065	2004-03-08	-0.07	0.07	0.74	1.30	0.96	0.94	6.70	6.59