

# Understanding downstream migration timing of European eel



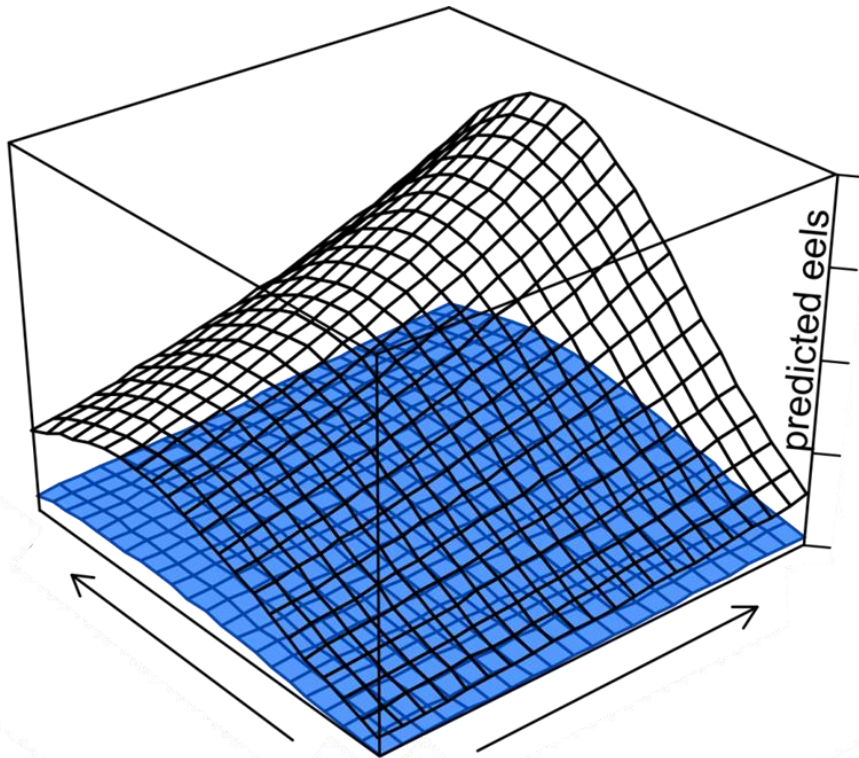
**Approved schedule, spring 2012**

| Year                   | 2012                                         |                               |   |                                          |                |                |   |    |    |                                                |
|------------------------|----------------------------------------------|-------------------------------|---|------------------------------------------|----------------|----------------|---|----|----|------------------------------------------------|
| Month                  | 3                                            | 4                             | 5 | 6                                        | 7              | 8              | 9 | 10 | 11 | 12                                             |
| <b>Data processing</b> | Model adjustment, preparation of field work  | World Fisheries Congress 2012 |   | Data analysis, preparation of field work |                |                |   |    |    | Data implementation & Model adjustment, Report |
| <b>Kävlingeån</b>      |                                              | Data recording                |   |                                          |                |                |   |    |    |                                                |
| <b>Säveån</b>          |                                              |                               |   |                                          |                | Data recording |   |    |    |                                                |
| <b>Mörrumsån</b>       |                                              | Data recording                |   |                                          |                | Data recording |   |    |    |                                                |
| <b>Skärhultaån</b>     |                                              |                               |   |                                          |                | Data recording |   |    |    |                                                |
|                        |                                              |                               |   |                                          |                |                |   |    |    |                                                |
| Year                   | 2013                                         |                               |   |                                          |                |                |   |    |    |                                                |
| Month                  | 3                                            | 4                             | 5 | 6                                        | 7              | 8              | 9 | 10 | 11 | 12                                             |
| <b>Data processing</b> | model predictions, preparation of field work |                               |   | Data analysis, preparation of field work |                |                |   |    |    | Report, Publication                            |
| <b>Kävlingeån</b>      |                                              | Data recording                |   |                                          |                |                |   |    |    |                                                |
| <b>Säveån</b>          |                                              |                               |   |                                          |                | Data recording |   |    |    |                                                |
| <b>Mörrumsån</b>       |                                              | Data recording                |   |                                          |                | Data recording |   |    |    |                                                |
| <b>Skärhultaån</b>     |                                              |                               |   |                                          | Data recording |                |   |    |    |                                                |
|                        |                                              |                               |   |                                          |                |                |   |    |    |                                                |

## Status-Quo, August 2013

| Year                   | 2012                                        |                                                         |   |                                          |   |                       |                |    |    |                                                |
|------------------------|---------------------------------------------|---------------------------------------------------------|---|------------------------------------------|---|-----------------------|----------------|----|----|------------------------------------------------|
| Month                  | 3                                           | 4                                                       | 5 | 6                                        | 7 | 8                     | 9              | 10 | 11 | 12                                             |
| <b>Data processing</b> | Model adjustment, preparation of field work | World Fisheries Congress 2012                           |   | Data analysis, preparation of field work |   |                       |                |    |    | Data implementation & Model adjustment, Report |
| <b>Kävlingeån</b>      |                                             | Data recording                                          |   |                                          |   | Data recording        |                |    |    |                                                |
| <b>Rönne å</b>         |                                             |                                                         |   |                                          |   | Data recording        |                |    |    |                                                |
| <b>Mörrumsån</b>       |                                             | Data recording                                          |   |                                          |   |                       | Data recording |    |    |                                                |
| <b>Skärhultaån</b>     |                                             |                                                         |   |                                          |   | Data recording        |                |    |    |                                                |
| <b>Ätran</b>           |                                             |                                                         |   |                                          |   | Data recording (E.ON) |                |    |    |                                                |
| Year                   | 2013                                        |                                                         |   |                                          |   |                       |                |    |    |                                                |
| Month                  | 3                                           | 4                                                       | 5 | 6                                        | 7 | 8                     | 9              | 10 | 11 | 12                                             |
| <b>Data processing</b> | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) RADIO feature |   | Data analysis, preparation of field work |   | Report to KTÅ         |                |    |    | Report, Publication                            |
| <b>Kävlingeån</b>      |                                             | Data recording                                          |   |                                          |   |                       |                |    |    |                                                |
| <b>Rönne å</b>         |                                             |                                                         |   |                                          |   | Data recording        |                |    |    |                                                |
| <b>Mörrumsån</b>       |                                             | Data recording                                          |   |                                          |   |                       | Data recording |    |    |                                                |
| <b>Skärhultaån</b>     |                                             | Data recording                                          |   |                                          |   | Data recording        |                |    |    |                                                |
| <b>Ätran</b>           |                                             |                                                         |   |                                          |   | Data recording (E.ON) |                |    |    |                                                |
| <b>realized</b>        |                                             | not realized                                            |   |                                          |   | additional            |                |    |    |                                                |
| <b>daily data</b>      |                                             | unlikely                                                |   |                                          |   | changed site          |                |    |    |                                                |

## Model surfaces



### Predictors:

Measured environmental data : Precipitation, Water temperature, Luminosity, Barometric pressure, Water level)

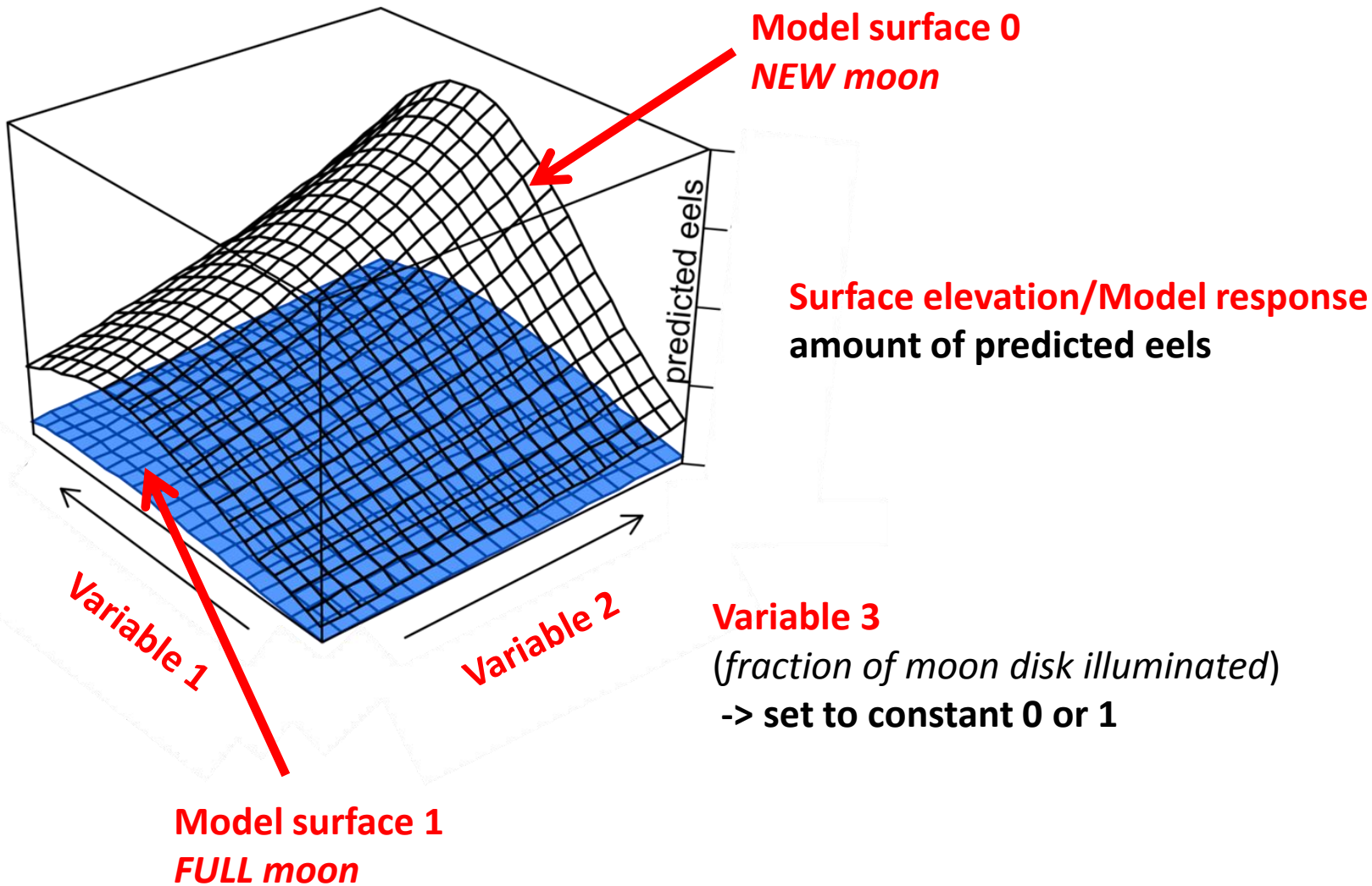
+ **additionally generated** variables (sums & differences)

>>> **capture** their **dynamics**

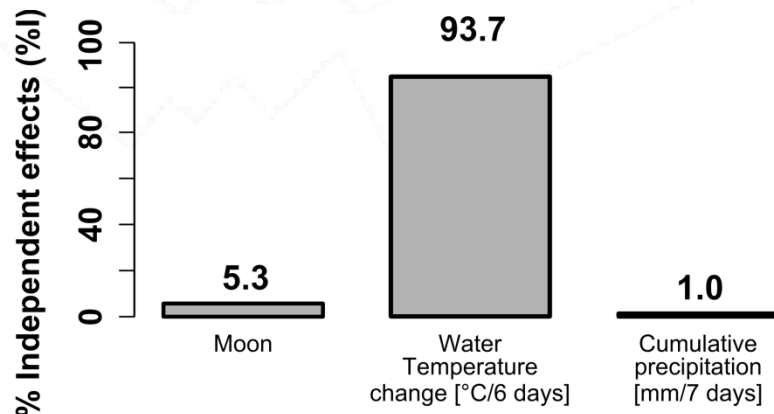
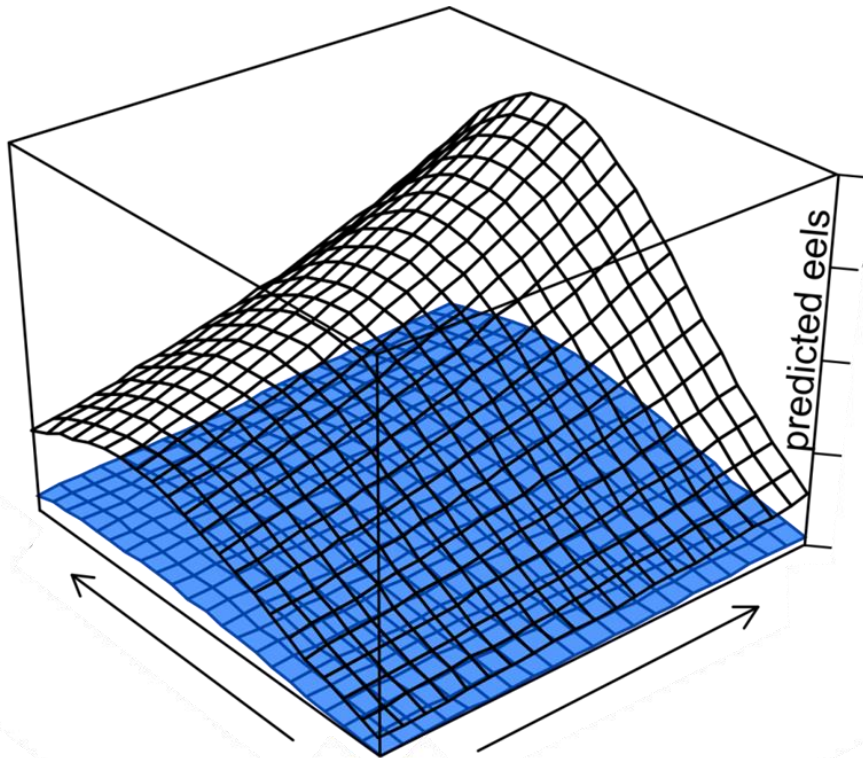
**GLM** = Generalized Linear Model



## Model surfaces



## Model surfaces



| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.33103  | 0.30255    | 5.000   | 3.68e-08 *** |
| moon               |          |            |         | 0.389003     |
| wtemp.dif6         |          |            |         | 3.09e-07 *** |
| l(wtemp.dif6^2)    | -0.04557 | 0.01298    | -3.512  | 0.000686 *** |
| Prec.sum7          | 0.02252  | 0.01494    | 1.508   | 0.134921     |

## Model summary

## Model Performance

Spearman r 0.57

1 = absolutely outstanding (not achievable)

0 = bad

Explained Deviance 0.37

~ example: explains 37 % of deviance/'variance'

Model performance  
,Model quality'

Independent effects  
(,Hierarchial Partitioning')

## Model surfaces

| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.33103  | 0.20255    | 5.999   | 3.68e-08 *** |
| moon               |          |            |         | 0.389003     |
| wtemp.dif6         |          |            |         | 3.09e-07 *** |
| l(wtemp.dif6^2)    | -0.04557 | 0.01298    | -3.512  | 0.000686 *** |
| Prec.sum7          | 0.02252  | 0.01494    | 1.508   | 0.134921     |

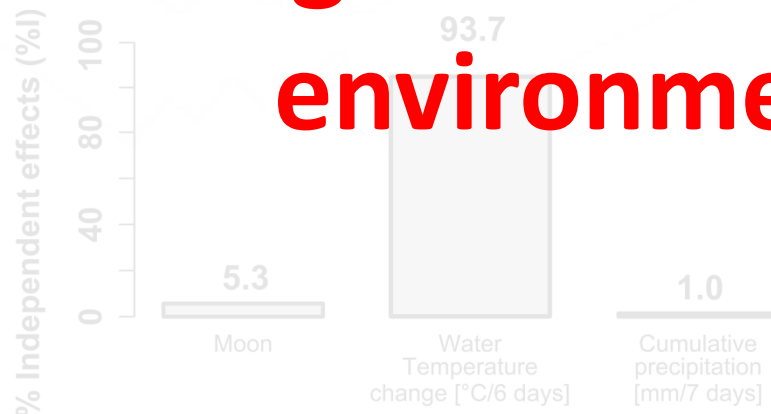
# The goal

## Model Performance

- Explained Deviance 0.37

Spearman R<sup>2</sup> 0.57

# Find the best models that explain migration activity based on environmental factors!



Independent effect  
(,Hierarchial Partitioning')

## Kävlingeån

| Year                   | 2012                                        |                                                         |   |                                          |   |                       |                       |    |    |                                                |
|------------------------|---------------------------------------------|---------------------------------------------------------|---|------------------------------------------|---|-----------------------|-----------------------|----|----|------------------------------------------------|
| Month                  | 3                                           | 4                                                       | 5 | 6                                        | 7 | 8                     | 9                     | 10 | 11 | 12                                             |
| <b>Data processing</b> | Model adjustment, preparation of field work | World Fisheries Congress 2012                           |   | Data analysis, preparation of field work |   |                       |                       |    |    | Data implementation & Model adjustment, Report |
| <b>Kävlingeån</b>      |                                             | <b>176 eels</b>                                         |   |                                          |   | <b>388 eels</b>       |                       |    |    |                                                |
| <b>Rönne å</b>         |                                             |                                                         |   |                                          |   | Data recording        |                       |    |    |                                                |
| <b>Mörrumsån</b>       |                                             | Data recording                                          |   |                                          |   | Data recording        |                       |    |    |                                                |
| <b>Skärhultaån</b>     |                                             |                                                         |   |                                          |   | Data recording        |                       |    |    |                                                |
| <b>Ätran</b>           |                                             |                                                         |   |                                          |   | Data recording (E.ON) |                       |    |    |                                                |
| Year                   | 2013                                        |                                                         |   |                                          |   |                       |                       |    |    |                                                |
| Month                  | 3                                           | 4                                                       | 5 | 6                                        | 7 | 8                     | 9                     | 10 | 11 | 12                                             |
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| <b>Kävlingeån</b>      |                                             | <b>476 eels</b>                                         |   |                                          |   |                       |                       |    |    |                                                |
| <b>Rönne å</b>         |                                             |                                                         |   |                                          |   |                       | Data recording        |    |    |                                                |
| <b>Mörrumsån</b>       |                                             | Data recording                                          |   |                                          |   |                       | Data recording        |    |    |                                                |
| <b>Skärhultaån</b>     |                                             | Data recording                                          |   |                                          |   |                       | Data recording        |    |    |                                                |
| <b>Ätran</b>           |                                             |                                                         |   |                                          |   |                       | Data recording (E.ON) |    |    |                                                |
|                        |                                             |                                                         |   |                                          |   |                       |                       |    |    |                                                |
| <b>realized</b>        |                                             | <b>not realized</b>                                     |   |                                          |   | <b>additional</b>     |                       |    |    |                                                |
| <b>daily data</b>      |                                             | <b>unlikely</b>                                         |   |                                          |   | <b>changed site</b>   |                       |    |    |                                                |



## Kävlingeån, Spring 2012 &amp; 2013

| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.22102  | 0.20355    | 5.999   | 3.68e-08 *** |
| moon               | 0.20898  | 0.24148    | 0.865   | 0.389003     |
| wtemp.dif6         | 0.46736  | 0.08479    | 5.512   | 3.09e-07 *** |
| l(wtemp.dif6^2)    | -0.04557 | 0.01298    | -3.512  | 0.000686 *** |
| prec.sum7          | 0.02252  | 0.01494    | 1.508   | 0.134921     |

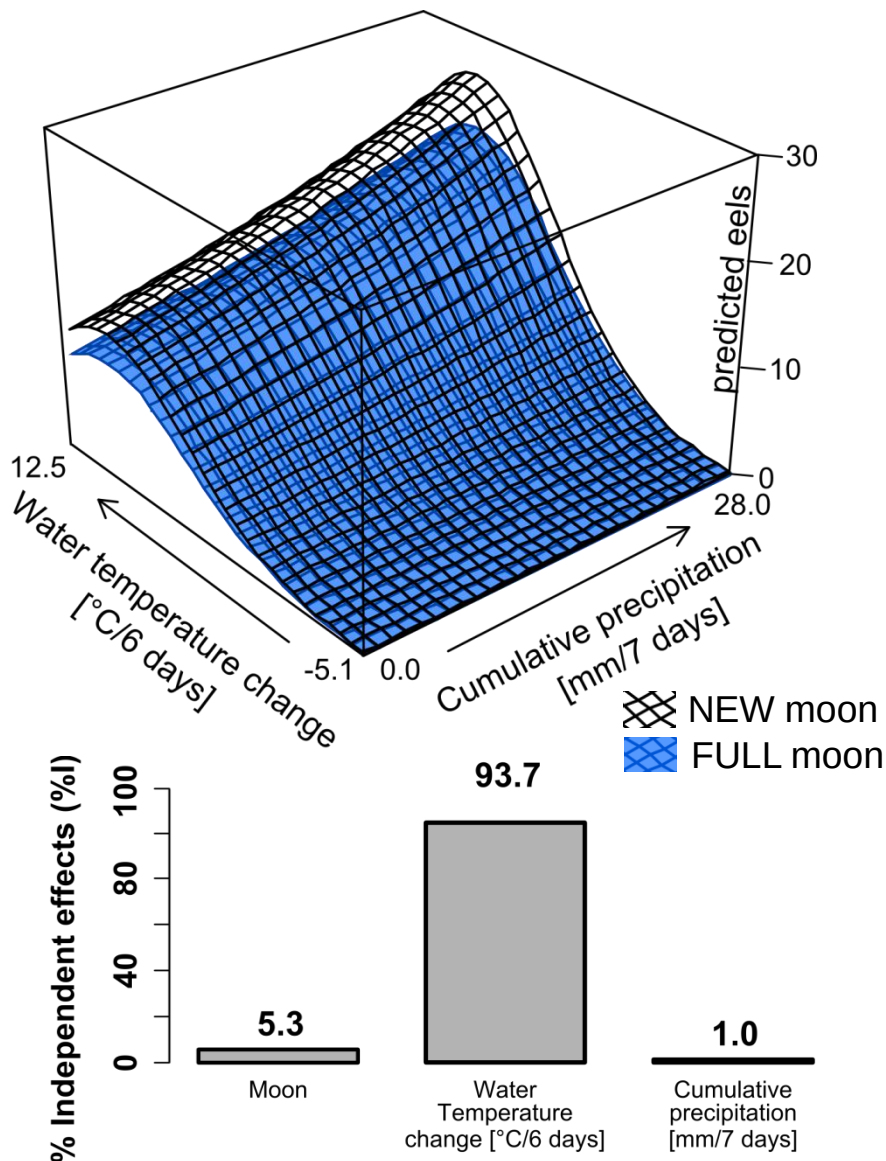
## Model Performance

(internally cross-validated)

**Spearman r**                      **0.51**  
**Explained Deviance**        **0.39**

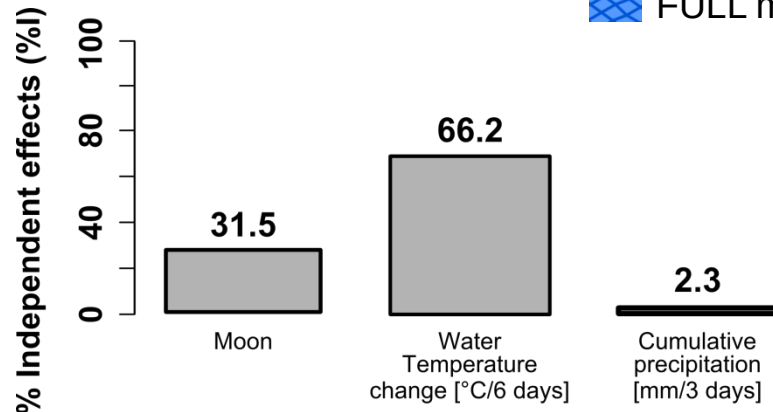
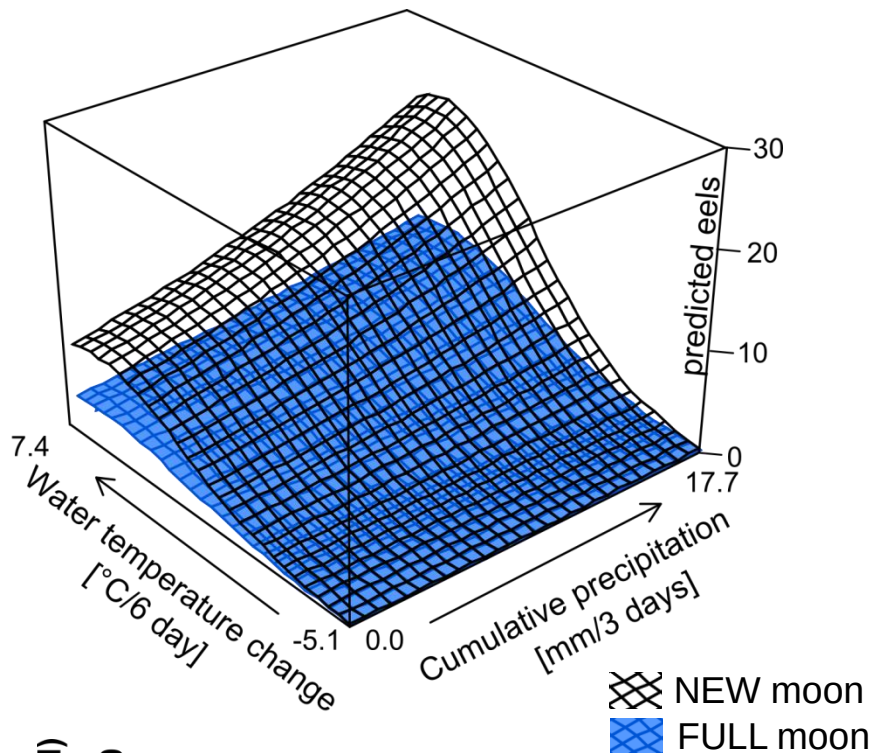
**Alternative Model, containing ONLY wtemp.dif6:**

**Spearman r**                      **0.55**  
**Explained deviance**        **0.35**



**99 Days**  
**648 Eels**

## Kävlingeån, Spring 2012



| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.47139  | 0.17701    | 8.313   | 8.43e-10 *** |
| moon               | -0.89667 | 0.25954    | -3.455  | 0.00146 **   |
| l(wtemp.dif6 ^2)   | -0.03308 | 0.01073    | -3.082  | 0.00400 **   |
| wtemp.dif6         | 0.37475  | 0.07118    | 5.265   | 7.19e-06 *** |
| prec.sum3          | 0.04931  | 0.01732    | 2.846   | 0.00734 **   |

## Model Performance

(internally crossvalidated)

**Spearman r**                      **0.79**  
**Explained Deviance**        **0.74**

**Alternative Model, containing ONLY wtemp.dif6:**  
**Spearman r**                      **0.62**  
**Explained deviance**        **0.61**

**40 Days**  
**175 Eels**

## Kävlingeån, Spring 2013

| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | -5.56814 | 1.97442    | -2.820  | 0.006700 **  |
| moon               | 1.19815  | 0.30076    | 3.984   | 0.000205 *** |
| wtemp              | -0.04228 | 0.01115    | -3.791  | 0.000380 *** |
| l(wtemp^2)         | -0.51356 | 0.37435    | -1.372  | 0.175775     |
| prec.sum3          | -0.01046 | 0.03554    | -0.294  | 0.769689     |

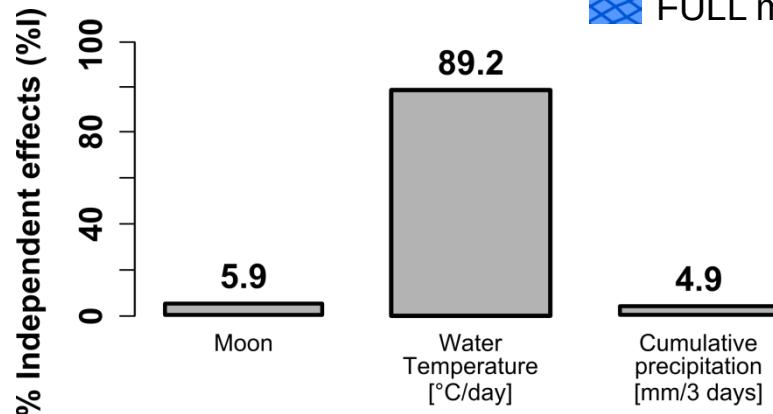
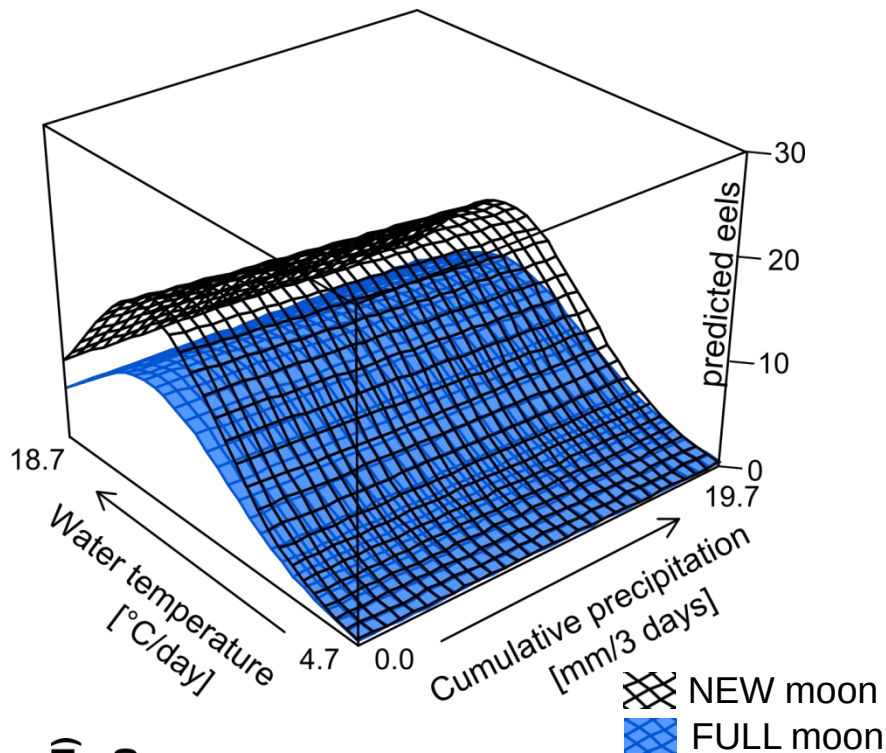
## Model Performance

(internally crossvalidated)

**Spearman r**                      **0.60**  
**Explained Deviance**        **0.45**

**Alternative Model, containing ONLY wtemp:**

**Spearman r**                      **0.43**  
**Explained deviance**        **0.40**



**59 Days**  
**473 Eels**

## Kävlingeån, Fall 2012

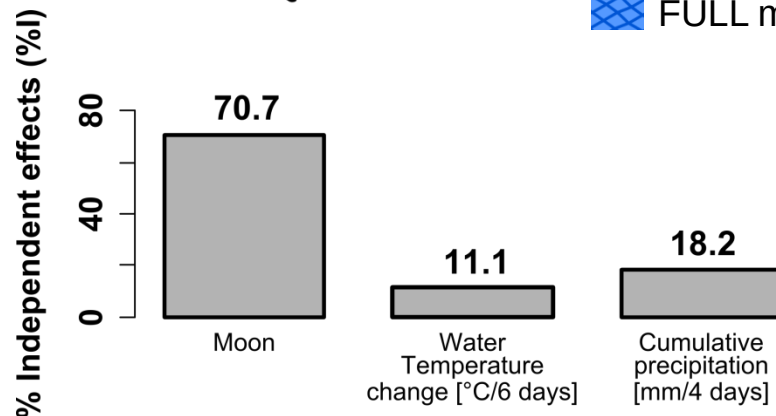
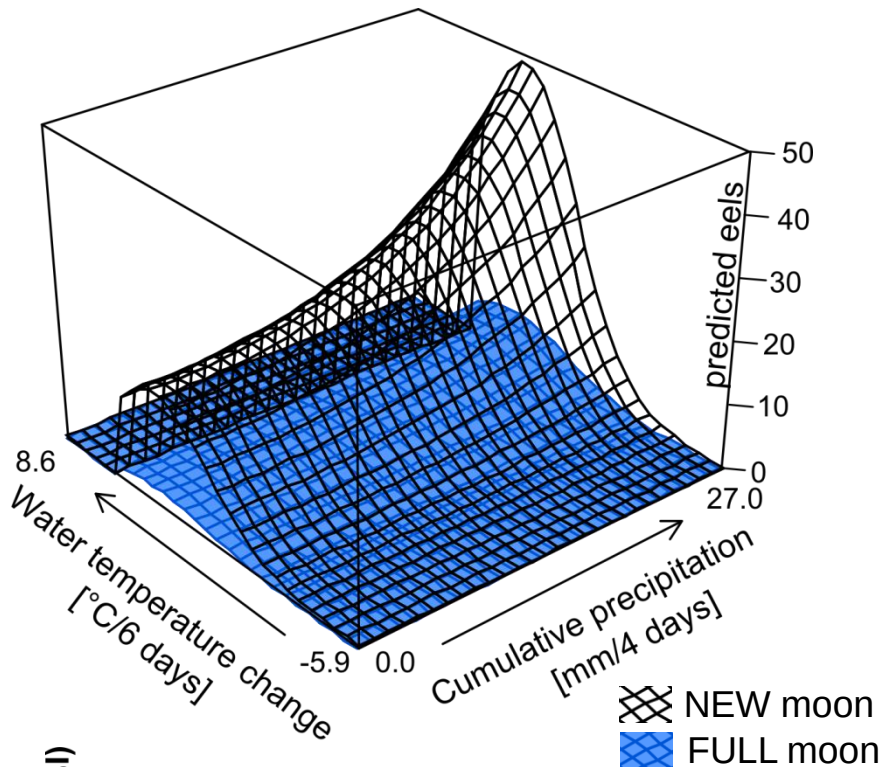
| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 2.79569  | 0.24708    | 11.315  | 2.85e-15 *** |
| moon               | -1.95712 | 0.37804    | -5.177  | 4.20e-06 *** |
| wtemp.dif6         | -0.16148 | 0.14777    | -1.093  | 0.27983      |
| l(wtemp.dif6^2)    | -0.23266 | 0.09336    | -2.492  | 0.01614 *    |
| prec.sum4          | 0.03637  | 0.01302    | 2.793   | 0.00742 **   |

## Model Performance

(internally crossvalidated)

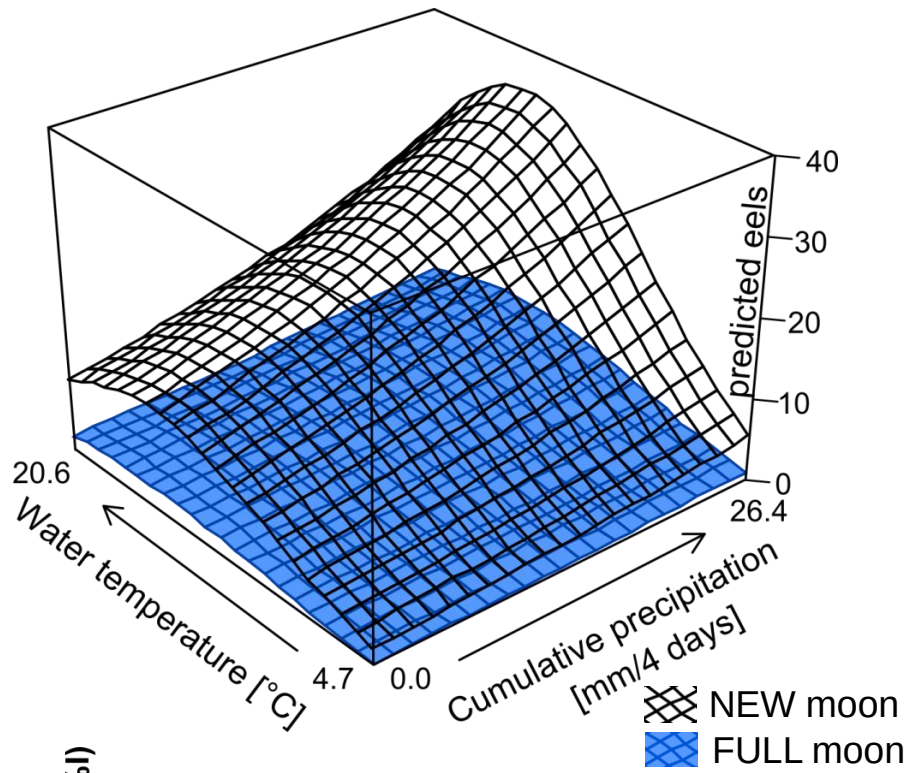
**Spearman r**                      **0.59**  
**Explained Deviance**        **0.51**

**Alternative Model, containing ONLY moon:**  
**Spearman r**                      **0.51**  
**Explained deviance**        **0.35**

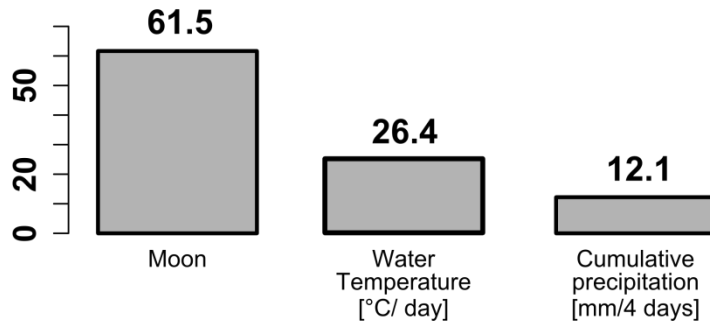


**54 Days**  
**368 Eels**

## Kävlingeån, 2012 &amp; 2013



% Independent effects (%)



| Model Coefficients | Estimate  | Std. Error | t value | Pr (> t )    |
|--------------------|-----------|------------|---------|--------------|
| (Intercept)        | -0.962667 | 0.400036   | -2.406  | 0.0161 *     |
| moon               | -1.481471 | 0.097385   | -15.212 | < 2e-16 ***  |
| wtemp              | -0.448276 | 0.060696   | 7.386   | 1.52e-13 *** |
| l(wtemp^2)         | -0.014212 | 0.002244   | -6.333  | 2.41e-10 *** |
| prec.sum4          | 0.037101  | 0.004682   | 7.924   | 2.31e-15 *** |

## Model Performance

(internally crossvalidated)

**Spearman r**                      **0.51**  
**Explained Deviance**        **0.28**

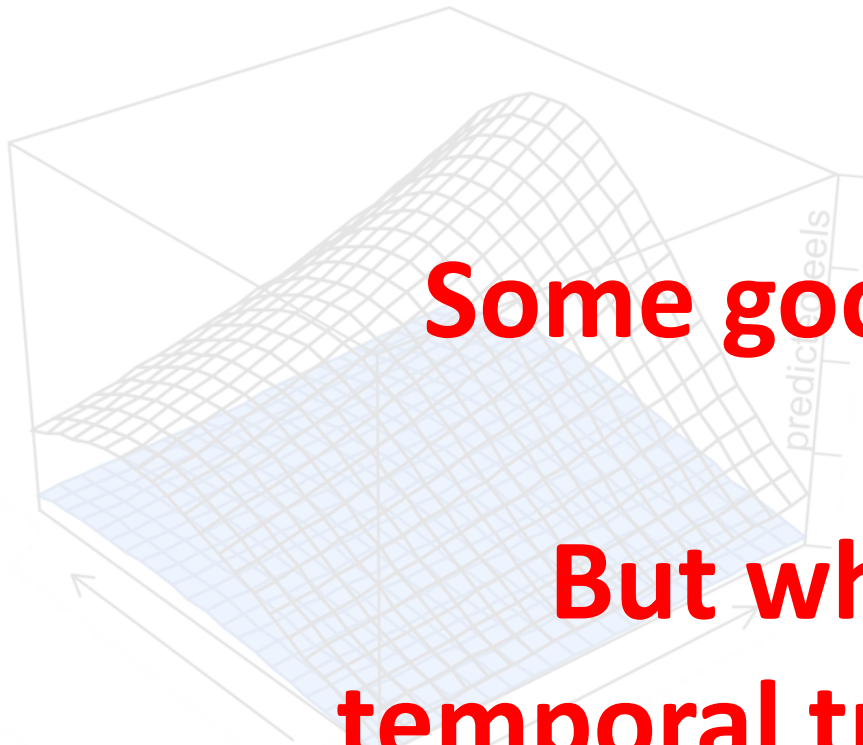
**Alternative Model, containing ONLY moon:**

**Spearman r**                      **0.34**  
**Explained deviance**        **0.13**

**153 Days**  
**1016 Eels**



## Model surfaces



| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.33103  | 0.20255    | 5.999   | 3.68e-08 *** |
| moon               |          |            |         | 0.389003     |
| wtemp.dif6         |          |            |         | 3.09e-07 *** |
| l(wtemp.dif6^2)    | -0.04557 | 0.01298    | -3.512  | 0.000686 *** |
| Prec.sum7          | 0.02252  | 0.01494    | 1.508   | 0.134921     |

### Model summary

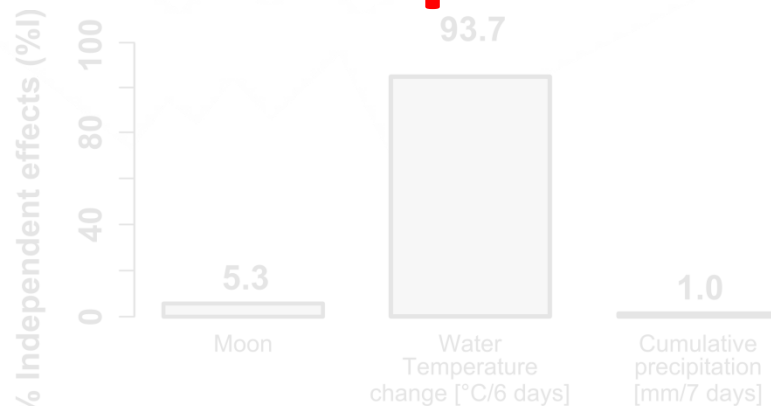
### Model Performance

|                         |      |
|-------------------------|------|
| - Explained Deviance    | 0.37 |
| Spearman R <sup>2</sup> | 0.57 |

### Model performance

**Some good models ...**

**But what about temporal transferability?**



**Independent effect  
(,Hierarchial Partitioning')**

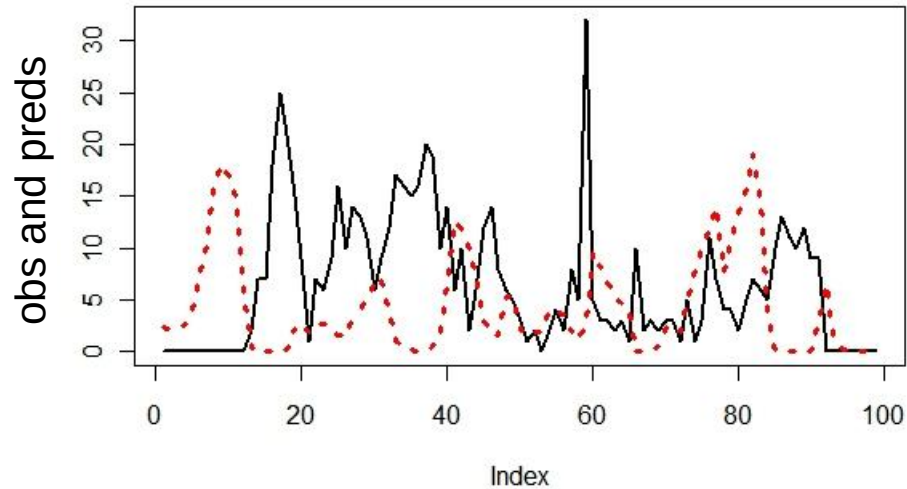
**Kävlingeån, Summary model validation**

|                   |                                                                                                      | <b>Validation Data</b> |                      |                        |                      |                         |
|-------------------|------------------------------------------------------------------------------------------------------|------------------------|----------------------|------------------------|----------------------|-------------------------|
|                   |                                                                                                      | <b>Spring<br/>2012</b> | <b>Fall<br/>2012</b> | <b>Spring<br/>2013</b> | <b>All<br/>12/13</b> | <b>Spring<br/>12/13</b> |
| <b>Train Data</b> | <b>Spring<br/>2012</b>                                                                               | 0.79                   | 0.42                 | 0.29                   | 0.45                 | 0.48                    |
|                   | <b>Fall<br/>2012</b>                                                                                 | 0.04                   | 0.59                 | -0.5                   | 0.08                 | -0.25                   |
|                   | <b>Spring<br/>2013</b>                                                                               | -0.05                  | 0.43                 | 0.60                   | 0.34                 | 0.30                    |
|                   | <b>All<br/>12/13</b>                                                                                 | 0.59                   | 0.69                 | 0.52                   | 0.51                 | 0.49                    |
|                   | <b>Spring<br/>12/13</b>                                                                              | 0.70                   | 0.11                 | 0.51                   | 0.37                 | 0.51                    |
|                   | <b>Model performance (Spearman r) for internal cross-validation and external temporal validation</b> |                        |                      |                        |                      |                         |

## Kävlingeån, Summary model validation

|                                                                                               |              | Validation Data |             |             |             |              |
|-----------------------------------------------------------------------------------------------|--------------|-----------------|-------------|-------------|-------------|--------------|
|                                                                                               |              | Spring 2012     | Fall 2012   | Spring 2013 | All 12/13   | Spring 12/13 |
| Train Data                                                                                    | Spring 2012  | 0.79            | 0.42        | 0.29        | 0.45        | 0.48         |
|                                                                                               | Fall 2012    | <b>0.04</b>     | 0.59        | <b>-0.5</b> | <b>0.08</b> | <b>-0.25</b> |
|                                                                                               | Spring 2013  | <b>-0.05</b>    | 0.43        | 0.60        | 0.34        | 0.30         |
|                                                                                               | All 12/13    | 0.59            | 0.69        | 0.52        | 0.51        | 0.49         |
|                                                                                               | Spring 12/13 | 0.70            | <b>0.11</b> | 0.51        | 0.37        | 0.51         |
| Model performance (Spearman r) for internal cross-validation and external temporal validation |              |                 |             |             |             |              |

## Kävlingeån, Summary model validation



| Data                                                                                          | All 12/13    | 0.59 | 0.69 | 0.52 | 0.51 | 0.49 |
|-----------------------------------------------------------------------------------------------|--------------|------|------|------|------|------|
|                                                                                               | Spring 12/13 | 0.70 | 0.11 | 0.51 | 0.37 | 0.51 |
| Model performance (Spearman r) for internal cross-validation and external temporal validation |              |      |      |      |      |      |

Data

Spring  
12/13

0.48

**-0.25**

0.30

## Kävlingeån, Summary model validation

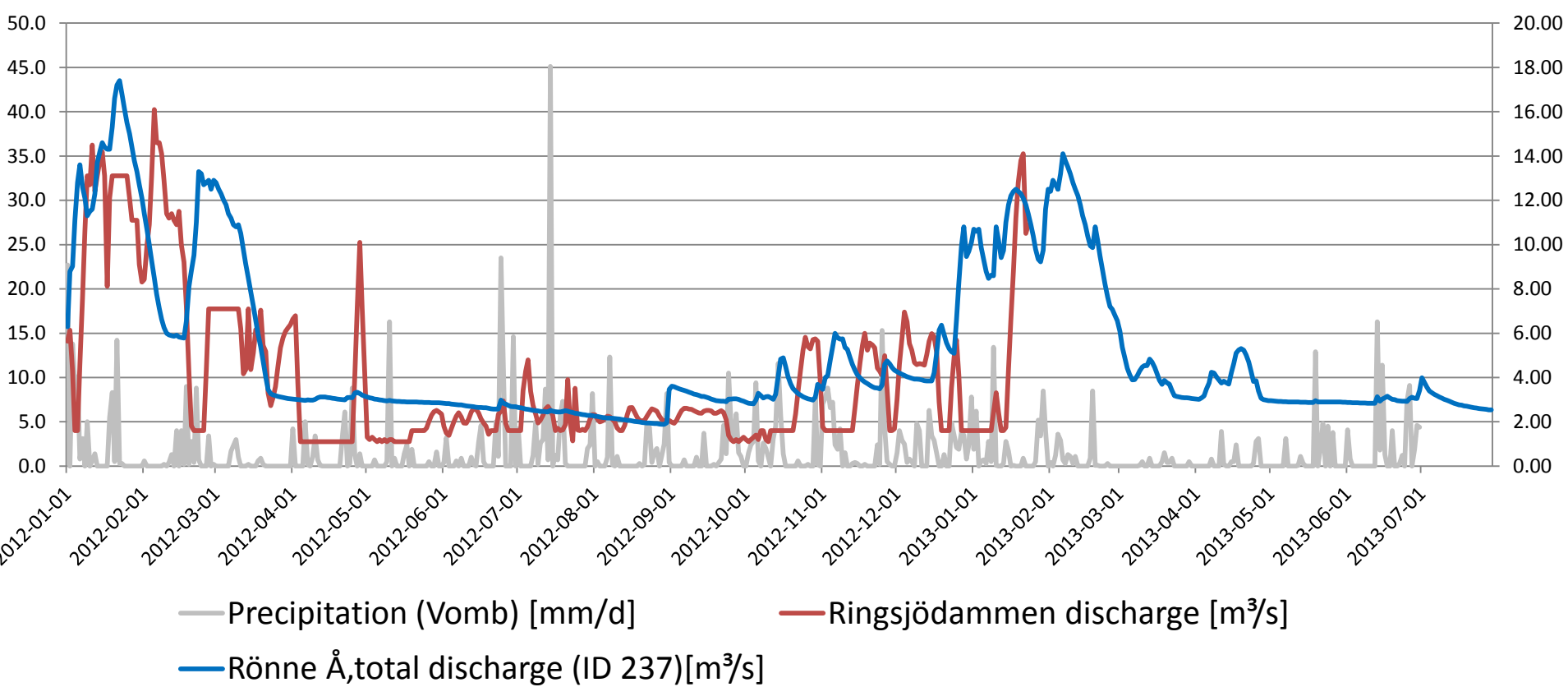
|                                                                                               |              | Validation Data |           |             |           |              |
|-----------------------------------------------------------------------------------------------|--------------|-----------------|-----------|-------------|-----------|--------------|
|                                                                                               |              | Spring 2012     | Fall 2012 | Spring 2013 | All 12/13 | Spring 12/13 |
| Train Data                                                                                    | Spring 2012  | 0.79            | 0.42      | 0.29        | 0.45      | 0.48         |
|                                                                                               | Fall 2012    | 0.04            | 0.59      | -0.5        | 0.08      | -0.25        |
|                                                                                               | Spring 2013  | -0.05           | 0.43      | 0.60        | 0.34      | 0.30         |
|                                                                                               | All 12/13    | 0.59            | 0.69      | 0.52        | 0.51      | 0.49         |
|                                                                                               | Spring 12/13 | 0.70            | 0.11      | 0.51        | 0.37      | 0.51         |
| Model performance (Spearman r) for internal cross-validation and external temporal validation |              |                 |           |             |           |              |



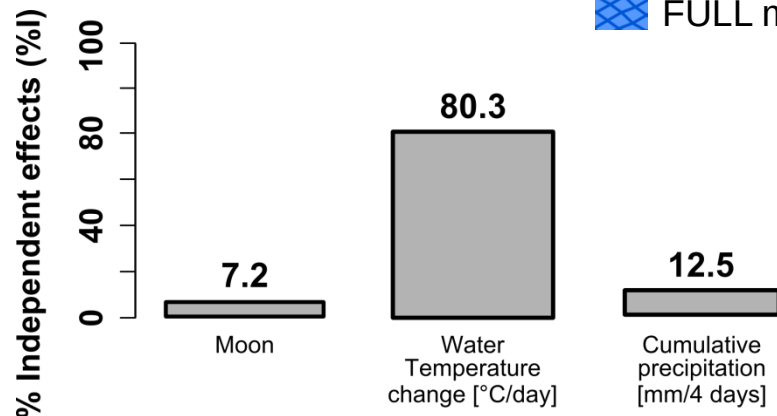
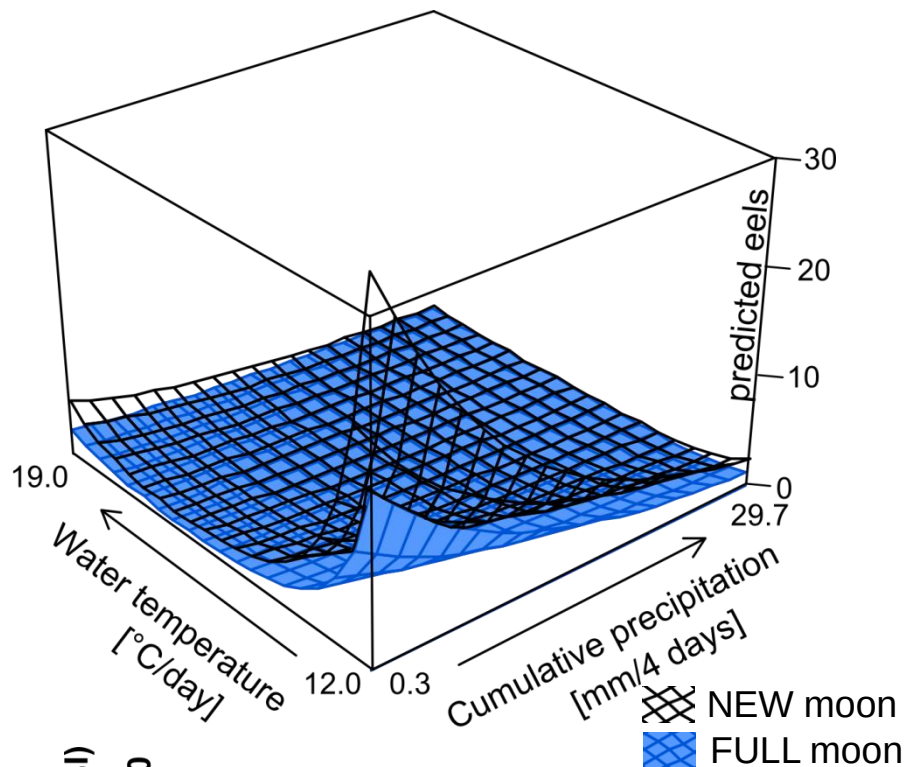
## Rönne Å

| Year            | 2012                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
|-----------------|---------------------------------------------|-------------------------------------------|---|------------------------------------------|-----------------------|----------------|---|----|----|------------------------------------------------|
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Model adjustment, preparation of field work | World Fisheries Congress 2012             |   | Data analysis, preparation of field work |                       |                |   |    |    | Data implementation & Model adjustment, Report |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | 40 eels        |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
| Year            | 2013                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) |   | Data analysis, preparation of field work |                       | Report to KTÅ  |   |    |    | Report, Publication                            |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       |                |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             | Data recording                            |   |                                          | Data recording        |                |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
|                 |                                             |                                           |   |                                          |                       |                |   |    |    |                                                |
| realized        |                                             | not realized                              |   |                                          | additional            |                |   |    |    |                                                |
| daily data      |                                             | unlikely                                  |   |                                          | changed site          |                |   |    |    |                                                |

## Rönne Å



## Rönne Å



| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )  |
|--------------------|----------|------------|---------|------------|
| (Intercept)        | 44.37198 | 15.22124   | 2.915   | 0.00356 ** |
| moon               | -0.74958 | 0.85825    | -0.873  | 0.38246    |
| wtemp              | -5.38442 | 1.97134    | -2.731  | 0.00631 ** |
| l(wtemp^2)         | 0.16514  | 0.06411    | 2.576   | 0.01000 ** |
| prec.sum4          | -0.08774 | 0.03564    | -2.462  | 0.01382 *  |

## Model Performance

(internally crossvalidated)

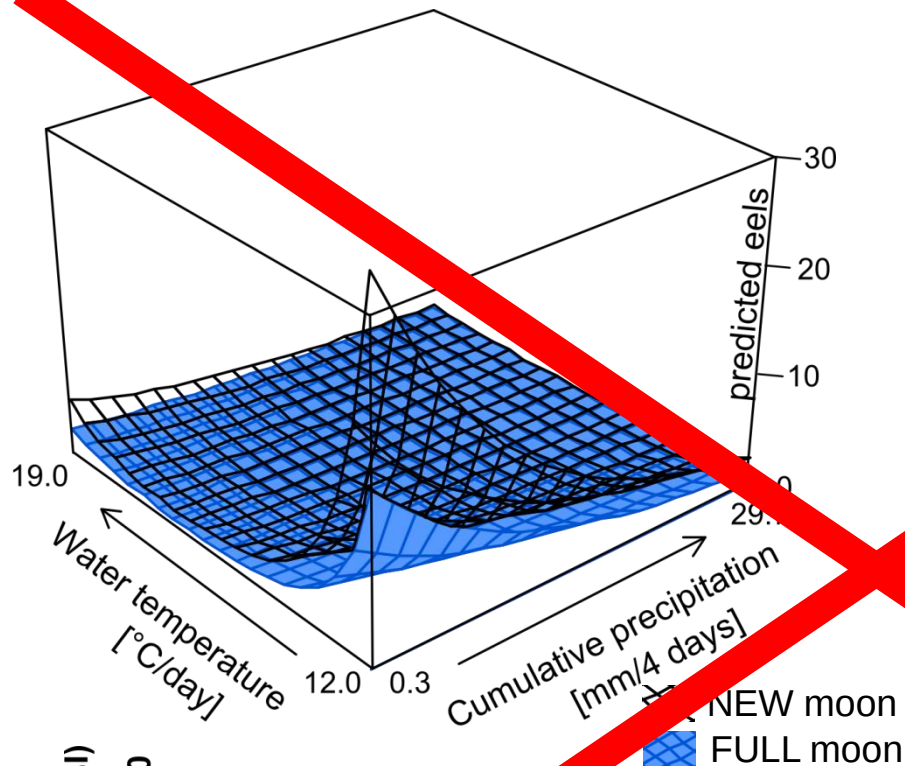
**Spearman r**                      **0.61**  
**Explained Deviance**        **0.43**

**Alternative Model, containing ONLY wtemp:**

**Spearman r**                      **0.48**  
**Explained deviance**        **0.25**

**31 Days**  
**40 Eels**

## Rönne Å



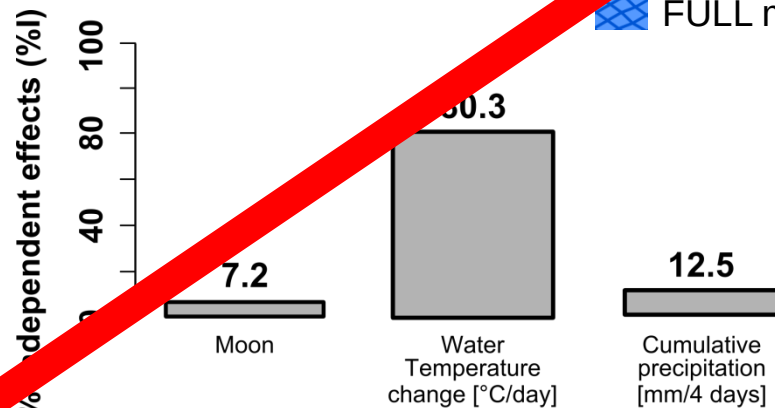
| Model Coefficients | Estimate | Std. Error | t value | Pr(> t )   |
|--------------------|----------|------------|---------|------------|
| (Intercept)        | 44.37198 | 15.22124   | 2.915   | 0.0053 **  |
| moon               | -0.74958 | 0.85825    | -0.873  | 0.38246    |
| wtemp              | -5.38442 | 1.97134    | -2.73   | 0.00631 ** |
| l(wtemp^2)         | 0.16514  | 0.06411    | 2.576   | 0.01000 ** |
| prec.sum4          | -0.08774 | 0.03564    | -2.462  | 0.01382 *  |

## Model Performance

(internally crossvalidated)

Spearman r                      **0.61**  
 Explained Deviance        **0.43**

Alternative Model, containing ONLY wtemp:  
 Spearman r                      **0.48**  
 Explained deviance        **0.25**

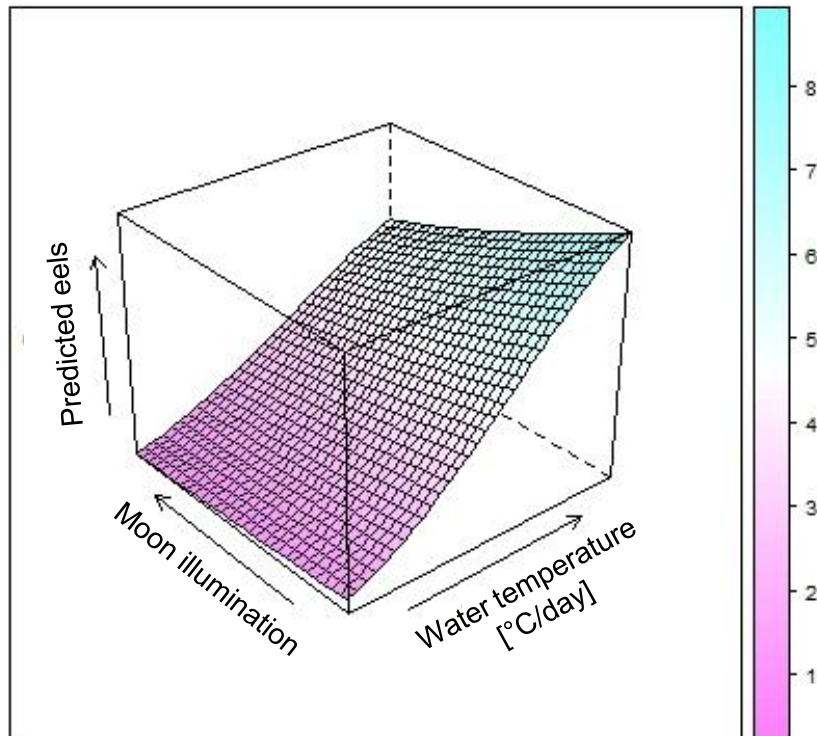


30 Days  
 40 Eels

**Mörrumsån / Granö, August 2013**

| Year            | 2012                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
|-----------------|---------------------------------------------|-------------------------------------------|---|------------------------------------------|-----------------------|----------------|---|----|----|------------------------------------------------|
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Model adjustment, preparation of field work | World Fisheries Congress 2012             |   | Data analysis, preparation of field work |                       |                |   |    |    | Data implementation & Model adjustment, Report |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Telemetry data 62 tagged eels             |   |                                          |                       |                |   |    |    |                                                |
| Skärhultaån     |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
| Year            | 2013                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) |   | Data analysis, preparation of field work |                       | Report to KTÅ  |   |    |    | Report, Publication                            |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       |                |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       | Telemetry data                              |                                           |   |                                          |                       |                |   |    |    |                                                |
| Skärhultaån     |                                             | Data recording                            |   |                                          | Data recording        |                |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
|                 |                                             |                                           |   |                                          |                       |                |   |    |    |                                                |
| realized        |                                             | not realized                              |   |                                          | additional            |                |   |    |    |                                                |
| daily data      |                                             | unlikely                                  |   |                                          | changed site          |                |   |    |    |                                                |

## Granö, telemetry 2012 &amp; 2013



| Model Coefficients | Estimate  | Std. Error | t value | Pr (> t )    |
|--------------------|-----------|------------|---------|--------------|
| (Intercept)        | -0.214881 | 0.336205   | -0.639  | 0.522735     |
| moon               | -0.474663 | 0.117551   | -4.038  | 5.39e-05 *** |
| wtemp              | 0.187285  | 0.055033   | 3.403   | 0.000666 *** |
| l(wtemp^2)         | -0.003643 | 0.002180   | -1.671  | 0.094792 .   |

## Model Performance

(internally crossvalidated)

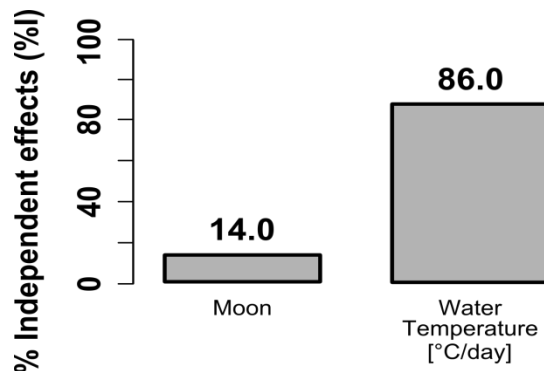
**Spearman r**                      **0.14**

**Explained Deviance**        **0.14**

**Alternative Model, containing ONLY wtemp:**

**Spearman r**                      **0.14**

**Explained deviance**        **0.12**



**161 Days**  
**593 activity signals**

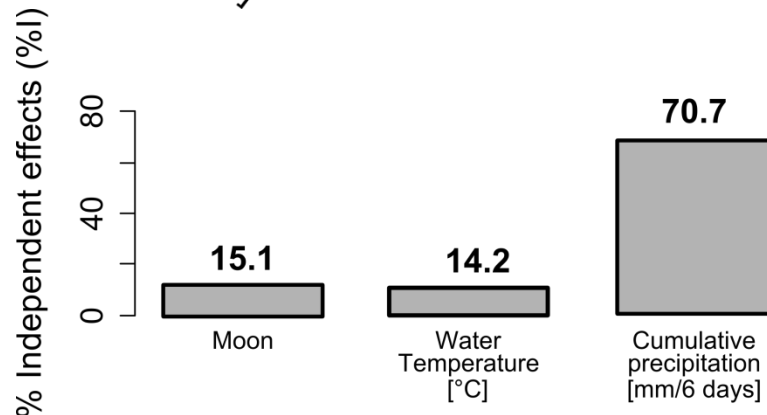
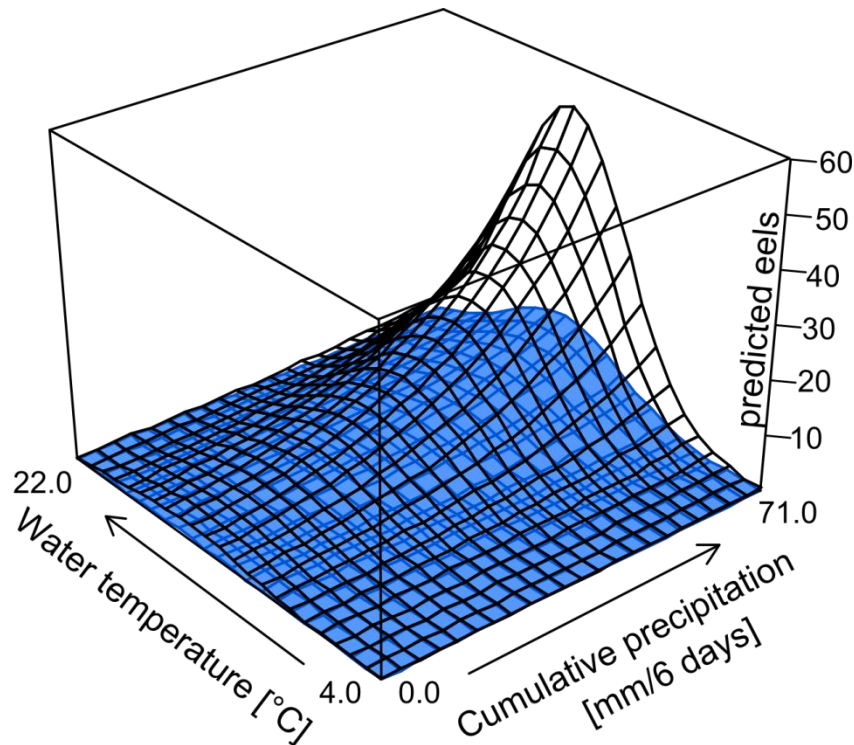
Stein FM, Doering-Arjes P, Fladung E, Brämick U, Bendal B, Schröder B (2013):  
**Downstream migration of European eels (*Anguilla anguilla*): Patterns, Speeds and Triggers.** *In prep. for Movement Ecology*



## Skärhultaån, August 2013

| Year            | 2012                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
|-----------------|---------------------------------------------|-------------------------------------------|---|------------------------------------------|-----------------------|----------------|---|----|----|------------------------------------------------|
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Model adjustment, preparation of field work | World Fisheries Congress 2012             |   | Data analysis, preparation of field work |                       |                |   |    |    | Data implementation & Model adjustment, Report |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             |                                           |   |                                          |                       | 331 eels       |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
| Year            | 2013                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) |   | Data analysis, preparation of field work |                       | Report to KTÅ  |   |    |    | Report, Publication                            |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       |                |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             | 3 eels                                    |   | 2 eels                                   | Data recording        |                |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
|                 |                                             |                                           |   |                                          |                       |                |   |    |    |                                                |
| realized        |                                             | not realized                              |   |                                          | additional            |                |   |    |    |                                                |
| daily data      |                                             | unlikely                                  |   |                                          | changed site          |                |   |    |    |                                                |

## Skärhultaån 2011



| Model Coefficients | Estimate  | Std. Error | t value | Pr (> t )    |
|--------------------|-----------|------------|---------|--------------|
| (Intercept)        | -9.707119 | 2.494460   | -3.891  | 0.000197 *** |
| moon               | -0.821653 | 0.381775   | -2.152  | 0.034218 *   |
| wtemp              | 1.398024  | 0.352242   | 3.969   | 0.000150 *** |
| l(wtemp^2)         | -0.050441 | 0.012365   | -4.079  | 0.000101 *** |
| prec.sum6          | 0.034967  | 0.004253   | 8.222   | 2.02e-12 *** |

## Model Performance

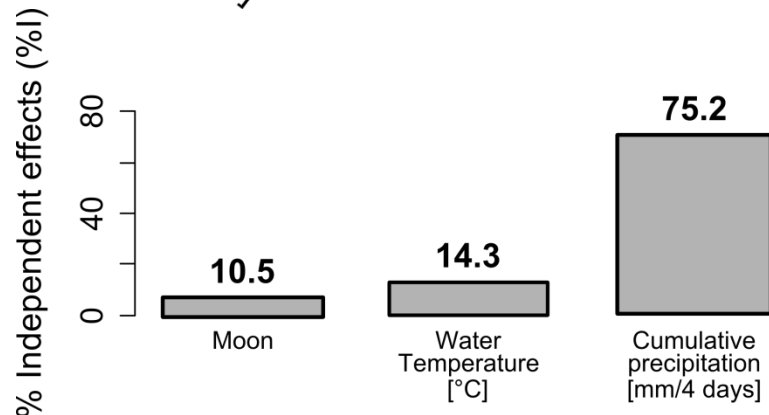
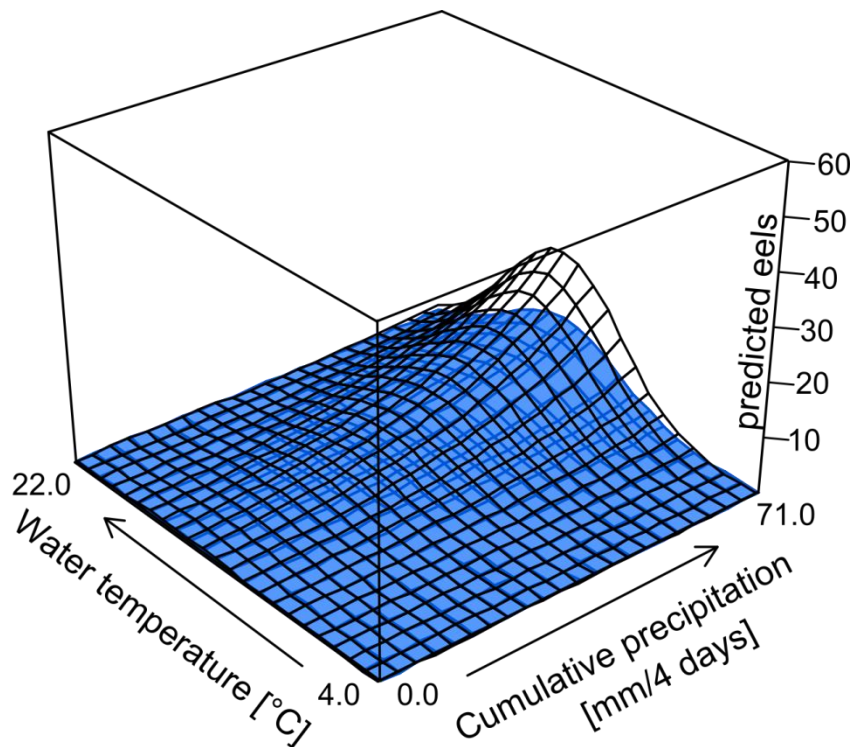
(internally crossvalidated)

**Spearman r**                      **0.58**  
**Explained Deviance**        **0.73**

**Alternative Model, containing ONLY prec.sum6**  
**Spearman r**                      **0.50**  
**Explained deviance**        **0.65**

**84 Days**  
**222 Eels**

## Skärhultaån 2012



| Model Coefficients | Estimate   | Std. Error | t value | Pr(> t )     |
|--------------------|------------|------------|---------|--------------|
| (Intercept)        | -10.097851 | 5.540501   | -1.823  | 0.0745 .     |
| moon               | -1.400372  | 0.599829   | -2.335  | 0.0237 *     |
| wtemp              | 1.415280   | 0.903378   | 1.567   | 0.1236       |
| l(wtemp^2)         | -0.048048  | 0.035873   | -1.339  | 0.1866       |
| prec.sum4          | 0.041276   | 0.008619   | 4.789   | 1.59e-05 *** |

## Model Performance

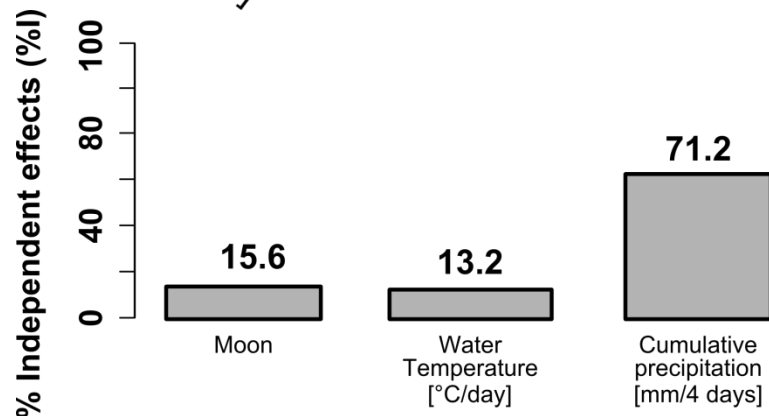
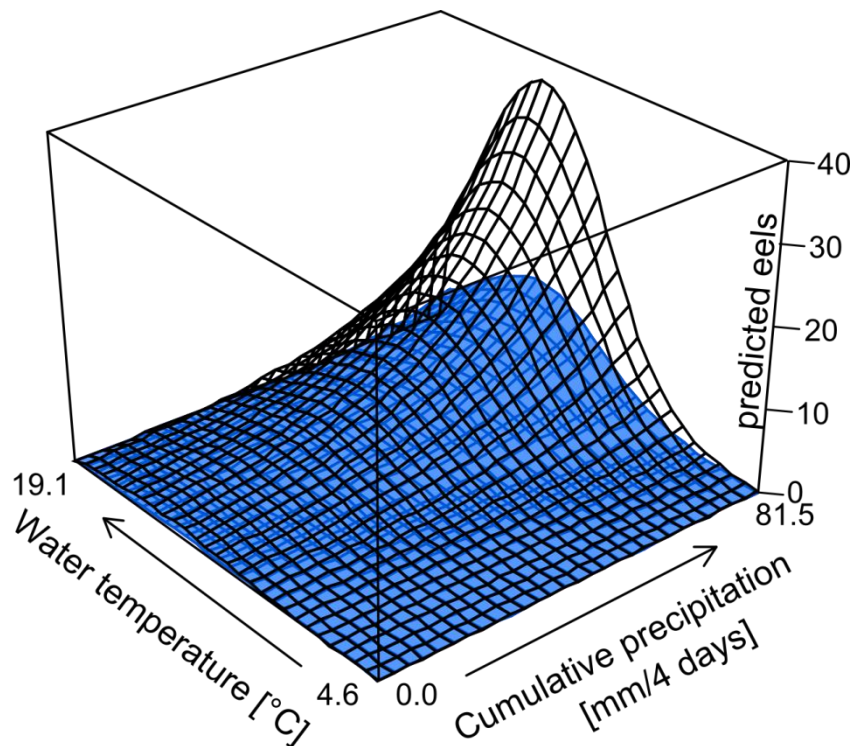
(internally crossvalidated)

**Spearman r**                      **0.62**  
**Explained Deviance**        **0.66**

**Alternative Model, containing ONLY prec.sum4:**  
**Spearman r**                      **0.41**  
**Explained deviance**        **0.40**

**54 Days**  
**96 Eels**

## Skärhultaån 12/13



| Model Coefficients | Estimate   | Std. Error | t value | Pr (> t )    |
|--------------------|------------|------------|---------|--------------|
| (Intercept)        | --11.19515 | 2.42843    | -4.61   | 9.3e-06 ***. |
| moon               | -1.13651   | 0.31249    | -3.64   | 0.00039 ***  |
| wtemp              | 1.61552    | 0.34201    | 4.72    | 5.8e-06 ***  |
| l(wtemp^2)         | -0.05627   | 0.01203    | -4.68   | 7.1e-06 ***  |
| prec.sum4          | 0.03936    | 0.00398    | 9.90    | < 2e-16 ***  |

## Model Performance

(internally crossvalidated)

**Spearman r**                      **0.61**  
**Explained Deviance**        **0.68**

**Alternative Model, containing ONLY prec.sum4:**  
**Spearman r**                      **0.50**  
**Explained deviance**        **0.60**

**138 Days**  
**318 Eels**

## Model surfaces



Again, some good models....

| Model Coefficients | Estimate | Std. Error | t value | Pr (> t )    |
|--------------------|----------|------------|---------|--------------|
| (Intercept)        | 1.33103  | 0.20255    | 5.999   | 3.68e-08 *** |
| moon               |          |            |         | 0.389003     |
| wtemp.dif6         |          |            |         | 3.09e-07 *** |
| l(wtemp.dif6^2)    | -0.04557 | 0.01298    | -3.512  | 0.000686 *** |
| Prec.sum7          | 0.02252  | 0.01494    | 1.508   | 0.134921     |

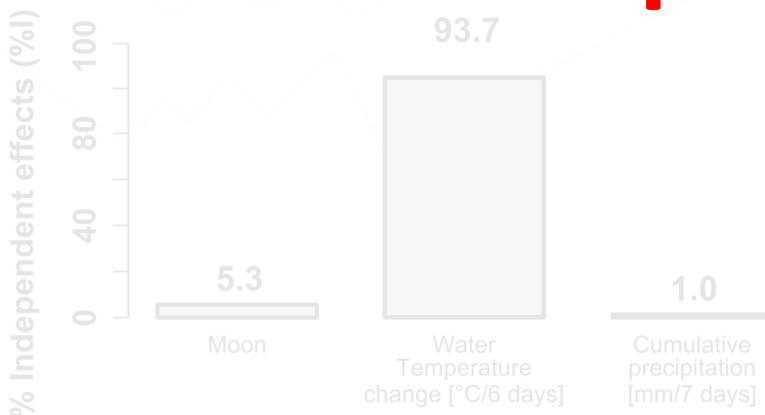
## Model summary

## Model Performance

- Explained Deviance 0.37

Spearman R<sup>2</sup> 0.57

## Model performance



Independent effect  
(,Hierarchial Partitioning')

## Skärhultaån, Summary Validation

|            |                                                                                                       | Validation Data          |                          |                           |                         |
|------------|-------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|---------------------------|-------------------------|
|            |                                                                                                       | Skärhultaån<br>Fall 2011 | Skärhultaån<br>Fall 2012 | Skärhultaån<br>Fall 11/12 | Kävlingeån<br>Fall 2012 |
| Train Data | Skärhultaån<br>Fall 2011                                                                              | 0.58                     | 0.64                     | 0.67                      | 0.30                    |
|            | Skärhultaån<br>Fall 2012                                                                              | 0.61                     | 0.69                     | 0.65                      | 0.59                    |
|            | Skärhultaån<br>Fall 11/12                                                                             | 0.61                     | 0.68                     | 0.61                      | 0.50                    |
|            | Kävlingeån<br>Fall 2012                                                                               | 0.29                     | 0.35                     | 0.33                      | 0.60                    |
|            | Model performance (Spearman r) for internal cross-validation and external temporal/spatial validation |                          |                          |                           |                         |



## Skärhultaån, Summary Validation

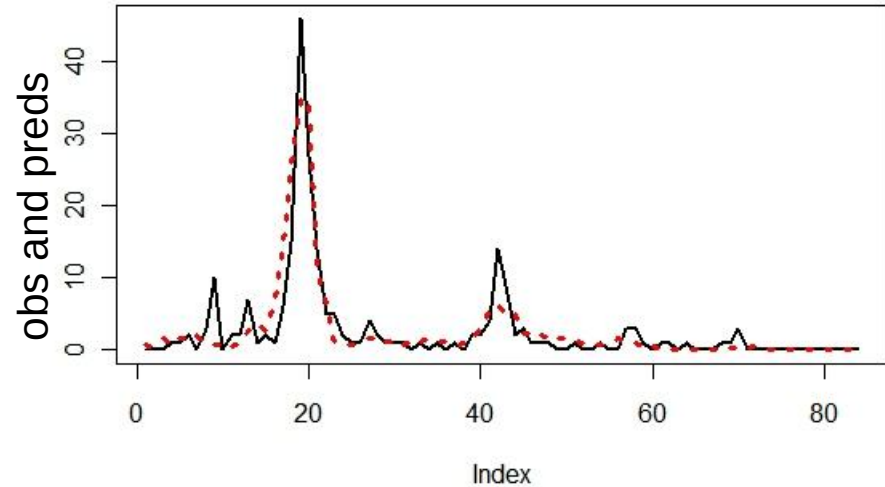
|            |                                                                                                       | Validation Data          |                          |                           |                         |
|------------|-------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|---------------------------|-------------------------|
|            |                                                                                                       | Skärhultaån<br>Fall 2011 | Skärhultaån<br>Fall 2012 | Skärhultaån<br>Fall 11/12 | Kävlingeån<br>Fall 2012 |
| Train Data | Skärhultaån<br>Fall 2011                                                                              | 0.58                     | 0.64                     | 0.67                      | 0.30                    |
|            | Skärhultaån<br>Fall 2012                                                                              | 0.61                     | 0.69                     | 0.65                      | 0.59                    |
|            | Skärhultaån<br>Fall 11/12                                                                             | 0.61                     | 0.68                     | 0.61                      | 0.50                    |
|            | Kävlingeån<br>Fall 2012                                                                               | <b>0.29</b>              | <b>0.35</b>              | <b>0.33</b>               | 0.60                    |
|            | Model performance (Spearman r) for internal cross-validation and external temporal/spatial validation |                          |                          |                           |                         |

## Skärhultaån, Summary Validation

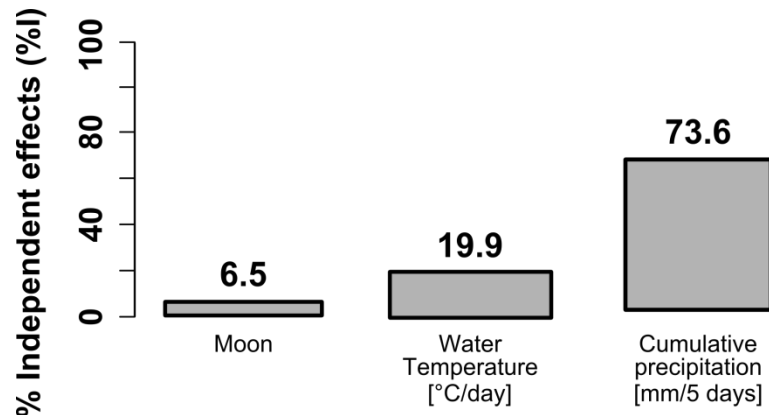
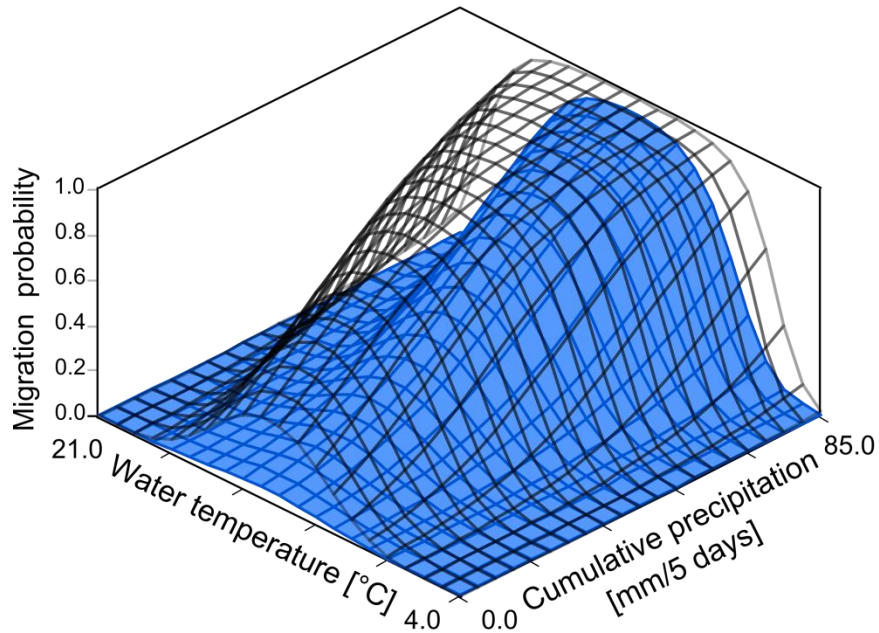
|            |                                                                                                       | Validation Data          |                          |                           |                         |
|------------|-------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|---------------------------|-------------------------|
|            |                                                                                                       | Skärhultaån<br>Fall 2011 | Skärhultaån<br>Fall 2012 | Skärhultaån<br>Fall 11/12 | Kävlingeån<br>Fall 2012 |
| Train Data | Skärhultaån<br>Fall 2011                                                                              | 0.58                     | 0.64                     | 0.67                      | 0.30                    |
|            | Skärhultaån<br>Fall 2012                                                                              | 0.61                     | 0.69                     | 0.65                      | 0.59                    |
|            | Skärhultaån<br>Fall 11/12                                                                             | 0.61                     | 0.68                     | 0.61                      | 0.50                    |
|            | Kävlingeån<br>Fall 2012                                                                               | 0.29                     | 0.35                     | 0.33                      | 0.60                    |
|            | Model performance (Spearman r) for internal cross-validation and external temporal/spatial validation |                          |                          |                           |                         |

## Skärhultaån, Summary Validation

|            |                           | Validation                                                                                            |      |      |      |
|------------|---------------------------|-------------------------------------------------------------------------------------------------------|------|------|------|
|            |                           | Skärhultaån<br>Fall 2011                                                                              |      |      |      |
| Train Data | Skärhultaån<br>Fall 2011  | 0.58                                                                                                  |      |      |      |
|            | Skärhultaån<br>Fall 2012  | 0.61                                                                                                  |      |      |      |
|            | Skärhultaån<br>Fall 11/12 | 0.61                                                                                                  | 0.68 | 0.61 | 0.50 |
|            | Kävlingeån<br>Fall 2012   | 0.29                                                                                                  | 0.35 | 0.33 | 0.60 |
|            |                           | Model performance (Spearman r) for internal cross-validation and external temporal/spatial validation |      |      |      |



## Skärhultaån 2012, high resolution



| Model Coefficients | Estimate  | Std. Error | t value | Pr (> t )     |
|--------------------|-----------|------------|---------|---------------|
| (Intercept)        | -18.67984 | 5.02897    | -3.714  | 0.000204 ***. |
| moon               | -2.52112  | 0.79256    | -3.181  | 0.001468 **   |
| wtemp              | 2.78920   | 0.80034    | 3.485   | 0.000492 ***  |
| l(wtemp^2)         | -0.10737  | 0.03126    | -3.435  | 0.000592 ***  |
| prec.sum5          | 0.06479   | 0.01286    | 5.039   | 4.67e-07 ***  |

## Model Performance

(internally crossvalidated)

**Spearman r**                      **0.62**  
**Explained Deviance**        **0.66**

**Alternative Model, containing ONLY prec.sum5:**  
**Spearman r**                      **0.41**  
**Explained deviance**        **0.40**

**15433 records**  
**101 Eels**

## Skärhultaån 2013





## Skärhultaån 2013





## Skärhultaån, August 2013

| Year            | 2012                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
|-----------------|---------------------------------------------|-------------------------------------------|---|------------------------------------------|-----------------------|----------------|---|----|----|------------------------------------------------|
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Model adjustment, preparation of field work | World Fisheries Congress 2012             |   | Data analysis, preparation of field work |                       |                |   |    |    | Data implementation & Model adjustment, Report |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             |                                           |   |                                          |                       | 331 eels       |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
| Year            | 2013                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) |   | Data analysis, preparation of field work |                       | Report to KTÅ  |   |    |    | Report, Publication                            |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       |                |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             | 3 eels                                    |   | 2 eels                                   | Data recording        |                |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
|                 |                                             |                                           |   |                                          |                       |                |   |    |    |                                                |
| realized        |                                             | not realized                              |   |                                          | additional            |                |   |    |    |                                                |
| daily data      |                                             | unlikely                                  |   |                                          | changed site          |                |   |    |    |                                                |

## Ätrafors , August 2013

| Year            | 2012                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
|-----------------|---------------------------------------------|-------------------------------------------|---|------------------------------------------|-----------------------|----------------|---|----|----|------------------------------------------------|
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Model adjustment, preparation of field work | World Fisheries Congress 2012             |   | Data analysis, preparation of field work |                       |                |   |    |    | Data implementation & Model adjustment, Report |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | 369 eels (E.ON)       |                |   |    |    |                                                |
| Year            | 2013                                        |                                           |   |                                          |                       |                |   |    |    |                                                |
| Month           | 3                                           | 4                                         | 5 | 6                                        | 7                     | 8              | 9 | 10 | 11 | 12                                             |
| Data processing | Report to KTÅ (O. Calles)                   | Poster at BIOHYDROLOGY (Stein et al 2013) |   | Data analysis, preparation of field work |                       | Report at KTÅ  |   |    |    | Report, Publication                            |
| Kävlingån       |                                             | Data recording                            |   |                                          |                       |                |   |    |    |                                                |
| Rönne å         |                                             |                                           |   |                                          |                       | Data recording |   |    |    |                                                |
| Mörrumsån       |                                             | Data recording                            |   |                                          |                       | Data recording |   |    |    |                                                |
| Skärhultaån     |                                             | Data recording                            |   |                                          | Data recording        |                |   |    |    |                                                |
| Ätrafors        |                                             |                                           |   |                                          | Data recording (E.ON) |                |   |    |    |                                                |
|                 |                                             |                                           |   |                                          |                       |                |   |    |    |                                                |
| realized        |                                             | not realized                              |   |                                          | additional            |                |   |    |    |                                                |
| daily data      |                                             | unlikely                                  |   |                                          | changed site          |                |   |    |    |                                                |

## Summary

- 1. Reliable models can be estimated on 3 predictors**  
(Moon, Water temperature and Precipitation)
- 2. Importance of predictors seem to depend on site and season**  
Spring: Water temperature  
Fall: Moon / Precipitation
- 3. Validations exhibit reliable model transferability in time**
- 4. Spatial transferability between different sites works only in *some cases***

## Outlook

1. **Temporal external validation will be expanded by additional data from 2013** (*temporal transferability*)
2. **Additional sites (Ätrafors, Granö) will enable further spatial validations** (*spatial transferability*)

**>>> Improvement of model assessments**

**Thanks for your attention!**

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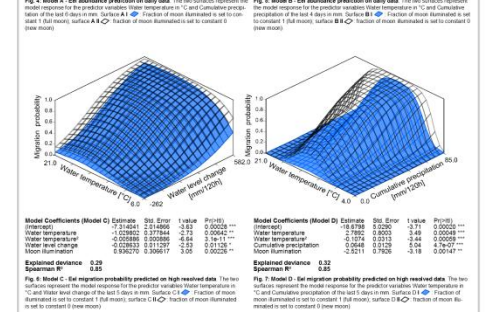
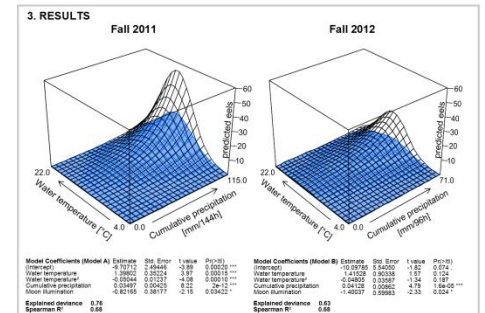
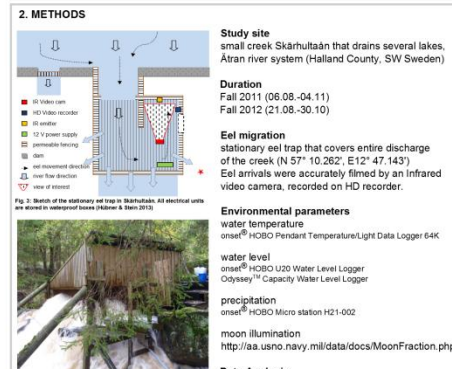
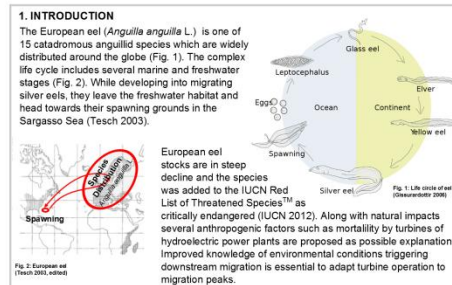
# Investigating downstream migration patterns of European eel (*Anguilla anguilla* L.)

Florian M Stein<sup>1,2</sup>, Eric Hübner<sup>2,3</sup>, N Loes MB van Schaik<sup>1,2</sup>, Olle Calles<sup>3</sup> and Boris Schröder<sup>1</sup>

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[LISTEN](#) to short radio feature on the research project by the national radio station Deutschlandfunk (2013-05-22, Forschung Aktuell, Deutschlandfunk, 04:33 min)

Stein F, Hübner E, van Schaik NLMB, Calles O, Schröder B (2013): Investigating downstream migration of European eel (*Anguilla anguilla* L.). Biohydrology 2013. [DOWNLOAD](#) Poster



Models on daily data sets from 2011 (A) and 2012 (B) show similar tendencies. Maximum abundances are predicted if cumulative precipitation of several days is maximal while water temperature ranges between ~10 and 18°C. Abundance level is generally higher under new moon condition. The predictions roughly match the recorded abundances (2011: max 48; 2012: max 18).

Model D, estimated on the high resolved data set, shows a similar tendency. Migration probability gains the maximum if water temperature ranges within a certain range and cumulative precipitation is maximal. The effect of new moon seems to be more distinctive under low precipitation conditions. The temperature range is clearly marked with no migration probability below 6 °C and above 20 °C under full moon conditions (D I) and a very low probability under new moon conditions (D II).

Model C does not show a clear temperature range and the effect of moon illumination is lower. The cumulative precipitation does not appear significant but the correlated (0.77) variable water level change does.

- 4. CONCLUSIONS**
- Increased migration activity under new moon conditions matches with their nocturnal behaviour. Both behavioral patterns lead to the conclusion that eels tend to avoid illumination in order to minimize exposure to predators.
  - Moderate water temperatures usually appear in spring and fall - seasons of heavy rains and floods. The results match with the assumption, that eels are quite inactive during hot summer and cold winter temperatures.
  - High discharge conditions (also expressed in water level and precipitation) can temporarily connect lentic waters to river systems for the migrant escapement. Additionally, the conditions enable the eels to save energy by using the water flow for a passive downstream migration ('passive drift').
  - The application of GLMs seems to be a reliable method to identify preferable migration conditions on the basis of a low number of environmental parameters.

- 5. REFERENCES**
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- 6. ACKNOWLEDGEMENT**
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