Ecological time series for the Celtic Sea

Olga Lyashevska

Objectives:

- Collate existing data resources for the Celtic Sea;
- Tidy, filter and remove duplicates;
- Understand relationships between biological data and environment;
- Develop models for identifying synchronous changes across multiple species/taxa, detecting step changes and potential regime shifts

Questions:

1. Have there been gradual or sudden changes in abundance or life history traits (e.g. growth) of selected species?

2. Has the occurence of unusual events increased over time?

3. Are such trends related to changes in environment (e.g. wind, circulation patterns and temperature)?

4. Are there synchronous changes across multiple species?

Media

theguardian

Marine life
The eco audit

Are jellyfish going to take over the oceans?

Like a karmic device come to punish our planetary transgressions, jellyfish thrive on the environmental chaos humans create. Is the age of the jellyfish upon us?

2,350 39

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@karlmathiesen

email

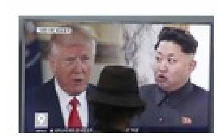
Friday 21 August 2015 15.29 BST

Barrel Jellyfish at Kynance Cove in Cornwall, UK. Photograph: Andrew Pearson/Alamy

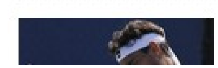
Most popular

North Korea claims successful nuclear test using hydrogen bomb - live

North Korean nuclear test confirmed in major escalation by Kim Jong-un

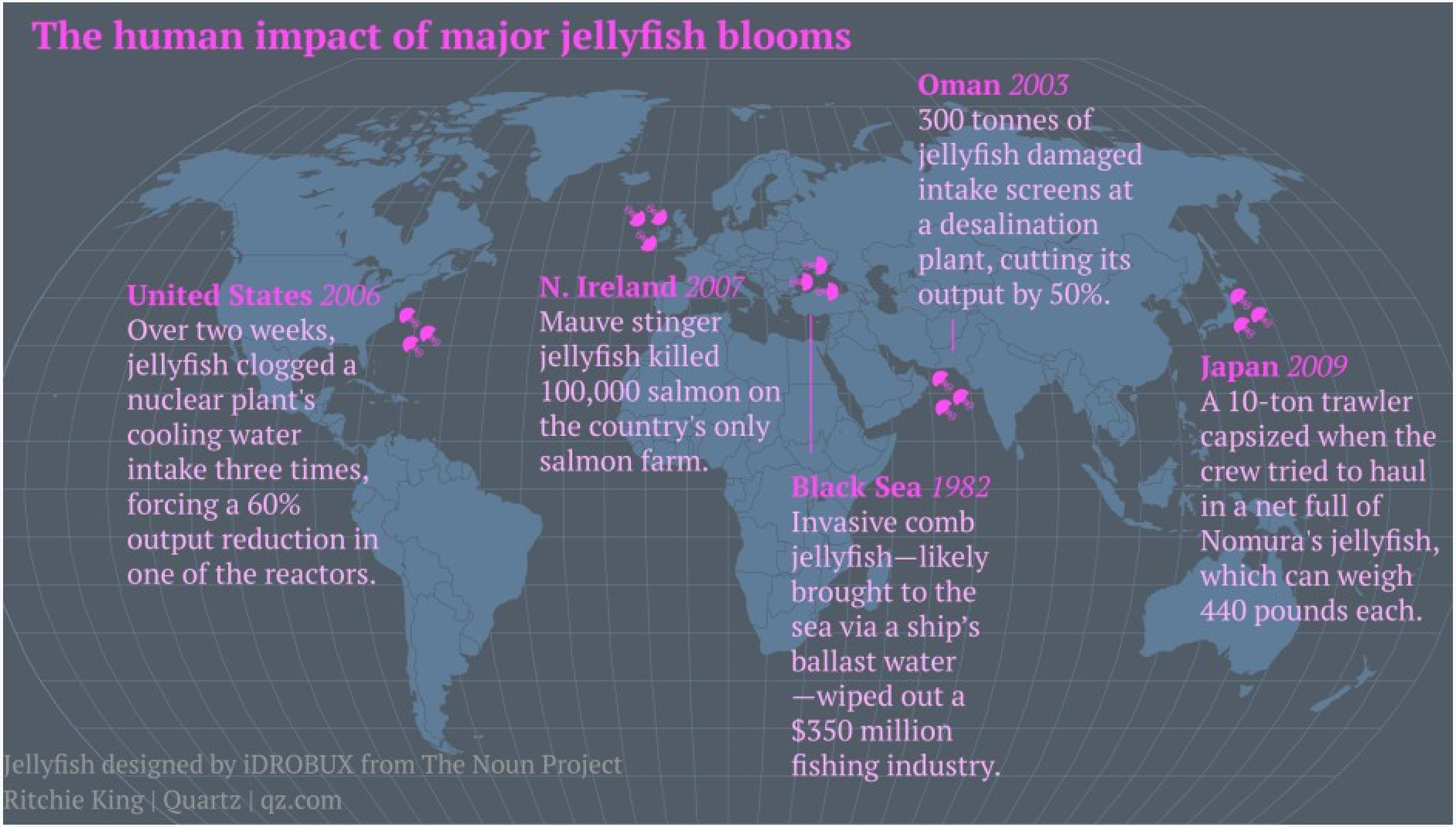


This North Korean nuclear test means Trump must now start talks



Fabio Fognini thrown out of US Open over

Jellyfish are taking over the seas, and it might be too late to stop them



Why this is happening?

"They've got this unique life cycle where they can tolerate harsh conditions and then rapidly thrive when conditions are favourable. So when a stressor like climate change or overfishing opens up a niche for them they can really take advantage of that and rapidly proliferate," said Lucas Brotz, a researcher at the University of British Columbia. Not all species of jelly benefit, rather there tends to be a reduction in the diversity of species and vast, homogenous masses emerge.

"They can make millions and millions of copies of themselves and clone asexually. That's when you get these massive blooms. I think that's the secret to the success of jellyfish, the reason they've been around for hundreds of millions of years."

But whether there is strong evidence of a global increase in jellyfish populations is difficult to answer.

Some believe the current observed rise may represent a natural cycle.

Data description

Biological:

- **Jellyfish blooms** (occurrence, 1890 - 2016);
- Loggerhead turtle strandings (abundance, 1990 - 2015)
- Cape Clear Bird Observatory:
  - Basking sharks sightings (abundance, 1971 - 2008)
  - **Sunfish sightings** (abundance, 1971 - 2008)
  - Leatherback turtle sightings (abundance, 1971 – 2008)

Data provided by Thomas Doyle and Aidan Long from NUIG

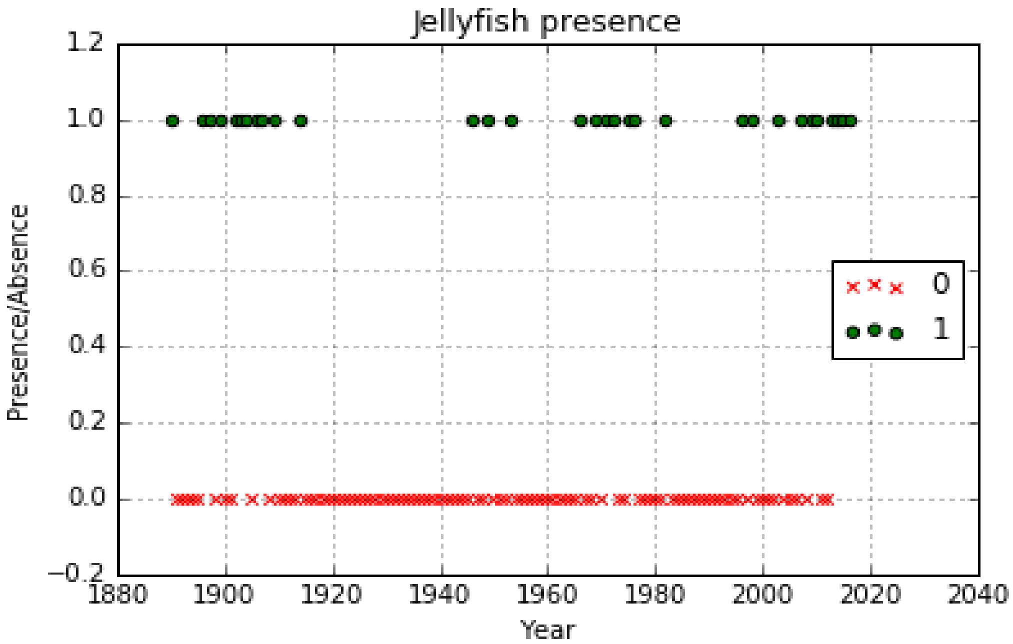
- Phytoplankton and jellyfish data (Continuous Plankton Recorder)
- Zooplankton (Station L4, Plymouth Marine Laboratory)

Environmental:

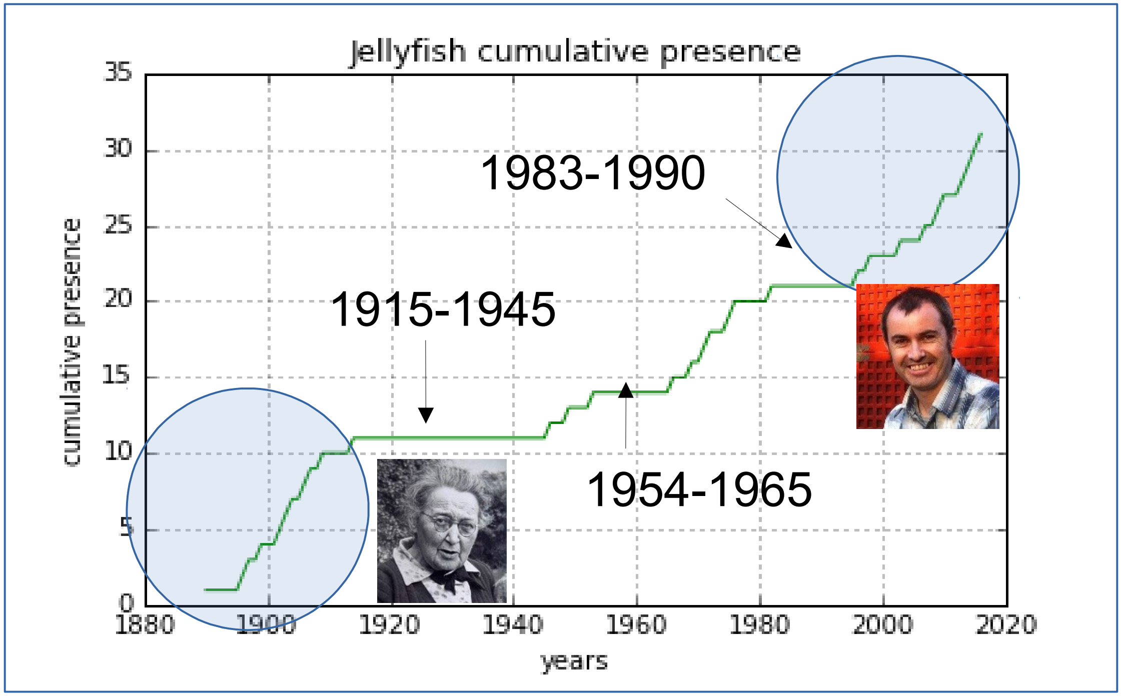
- Wind data (Cork Airport station, hourly 1962 - 2016)
- Sea Surface Temperature (monthly, 1854 – 2017)


Inverness
Aberdeen
SCOTLAND
Dundee
Edinburgh
Glasgow
C4
United Kingdom
NORTHERN IRELAND
Isle of Man
Dublin
Galway
Ireland
Liverpool
Manchester
C3
Limerick
ENGLAND
Cambridge
WALES
Cork
Oxford
London
Bristol
Cardiff
Cape Clear
Brighton
Southampton
Plymouth
D4
English Channel
L4
Guernsey
Jersey

Jellyfish blooms



www.wikipedia.org

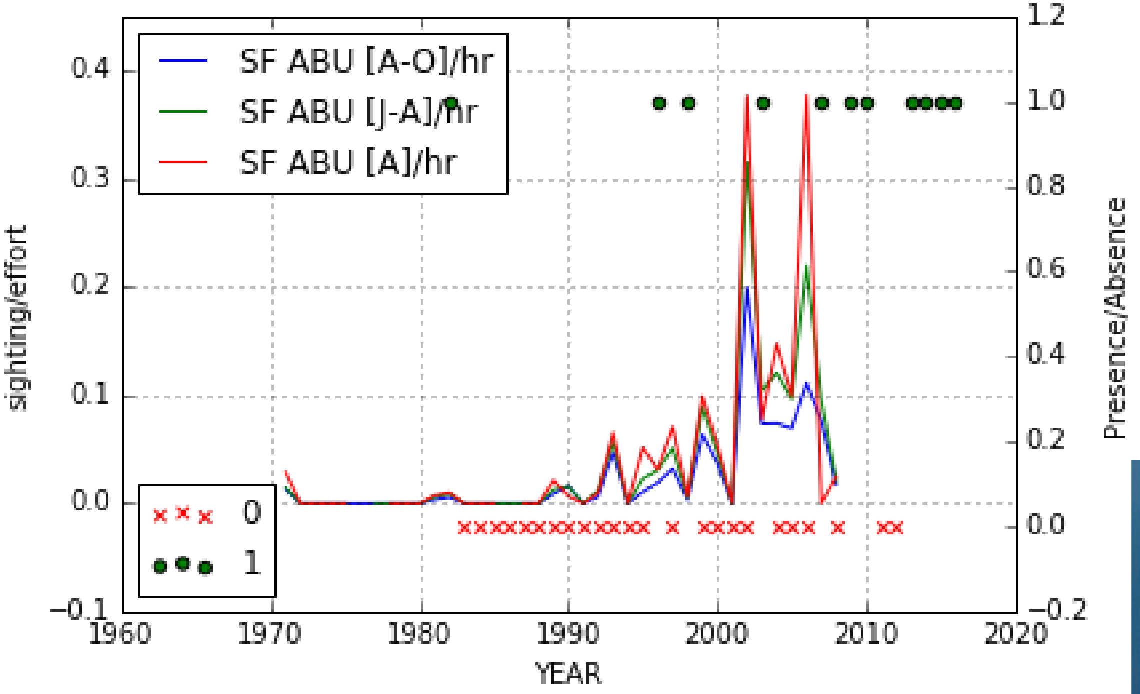


Data compiled from soft reports:
Irish Naturalist Journal, Irish Times, Glaucus, Scottish Naturalist, Marine Fauna

Effort not quantified and inconsistent over time

Two comparable periods: indicates that current swarms similar to historical evidence

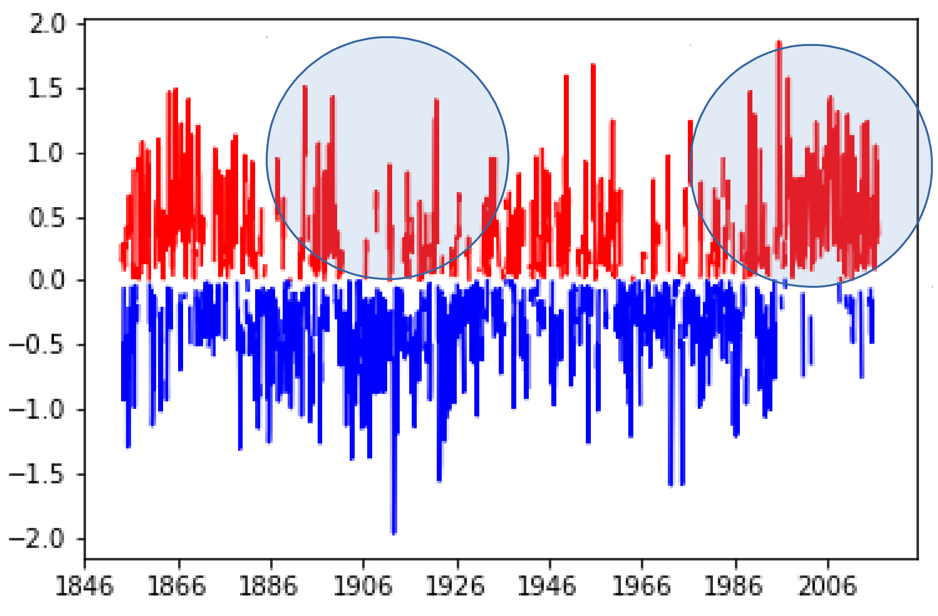
Sunfish sightings

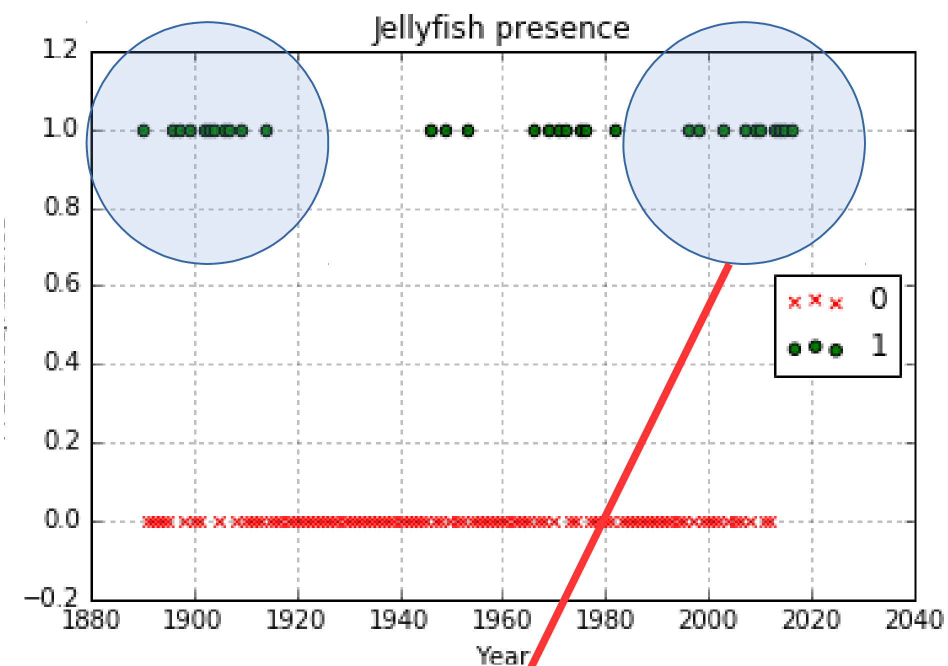


- Jellyfish predator – abundance may correlate with jellyfish swarms
- Data shows a clear increase in sunfish sightings from 1999 onwards

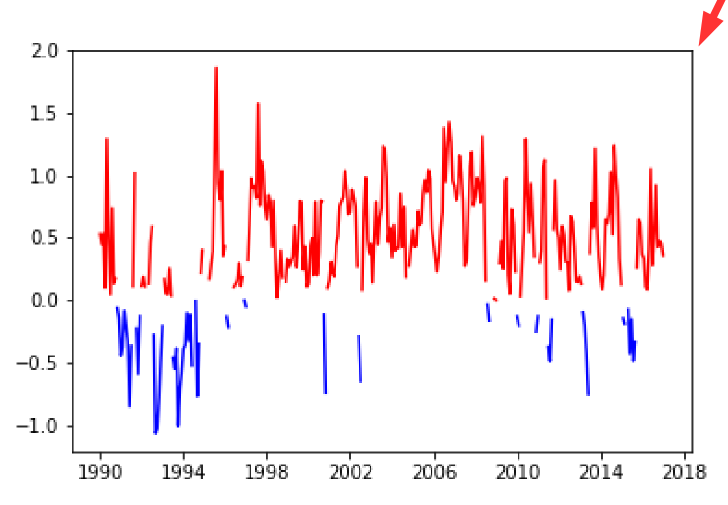
Source: www.montereybayaquarium.org

Examining correlations with temperature





Localized sst anomaly
Average of 163 years

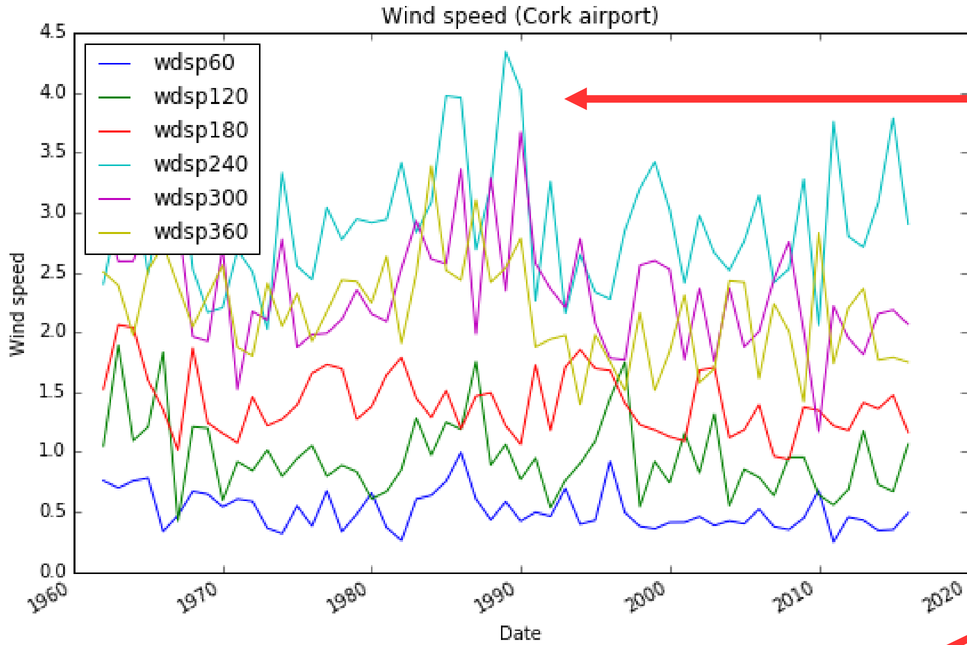


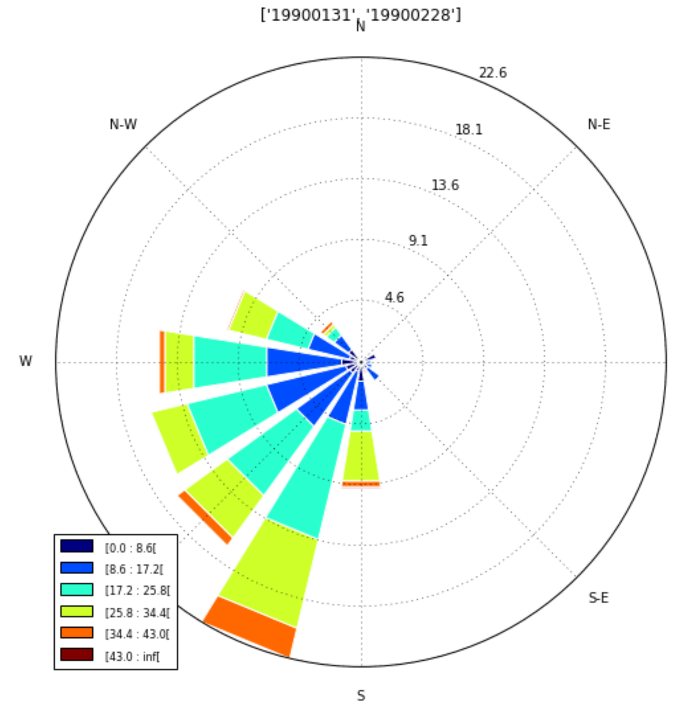
Wind reshape tool

```
def split(c):
    if c['wddir'] in range(0,60):
        val = 1
    else:
        val = 0
    return val

d['wdsp60'] = d.apply(split, axis=1)*d.wdsp

def split(c):
    if c['wddir'] in range(60,120):
        val = 1
    else:
        val = 0
    return val

d['wdsp120'] = d.apply(split, axis=1)*d.wdsp
```

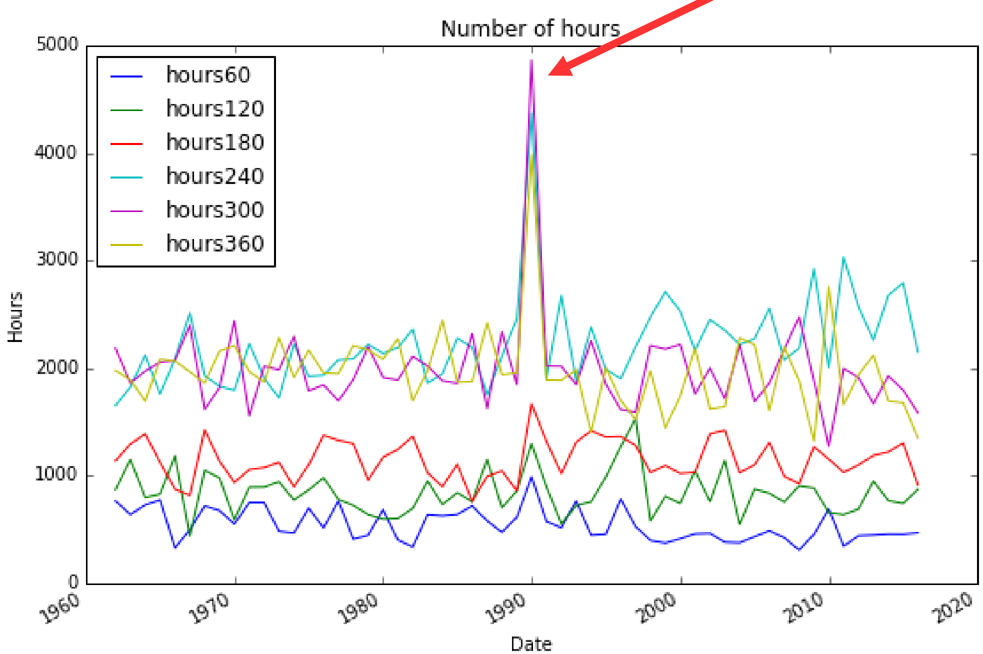
```
In [90]: df.head()
Out[90]:
      presence       wdsp       wddir    wdsp60   wdsp120   wdsp180   wdsp240  \
year
1982         1  10.884018  217.248858  0.259475  0.851256  1.789612  3.415639
1983         0  11.877283  216.304795  0.605936  1.283790  1.448630  2.832192
1984         0  12.249431  225.826503  0.637637  0.973588  1.289959  3.082650
1985         0  12.784932  214.503425  0.754680  1.247831  1.510845  3.974201
1986         0  13.323858  218.509132  0.995776  1.188470  1.193607  3.958790

       wdsp300   wdsp360  curr60    ...      curr300  curr360  hours60  \
year                                ...
1982  2.531279  1.908790     0.0    ...        293.0    297.0    334.0
1983  2.930023  2.488128    64.0    ...        520.0    545.0    633.0
1984  2.611339  3.387978    68.0    ...        268.0    678.0    622.0
1985  2.570776  2.517009   144.0    ...        248.0    436.0    635.0
1986  3.362100  2.434247   189.0    ...        291.0    536.0    714.0

      hours120  hours180  hours240  hours300  hours360  coeffvar        sst
year
1982     691.0    1362.0    2358.0    2106.0    1695.0  0.389622  12.033112
1983     945.0    1022.0    1859.0    2018.0    1975.0  0.450120  12.176555
1984     727.0     893.0    1945.0    1879.0    2445.0  0.425079  12.191222
1985     838.0    1103.0    2277.0    1856.0    1865.0  0.429986  12.067223
1986     753.0     755.0    2189.0    2318.0    1871.0  0.422112  11.561333

[5 rows x 23 columns]
```

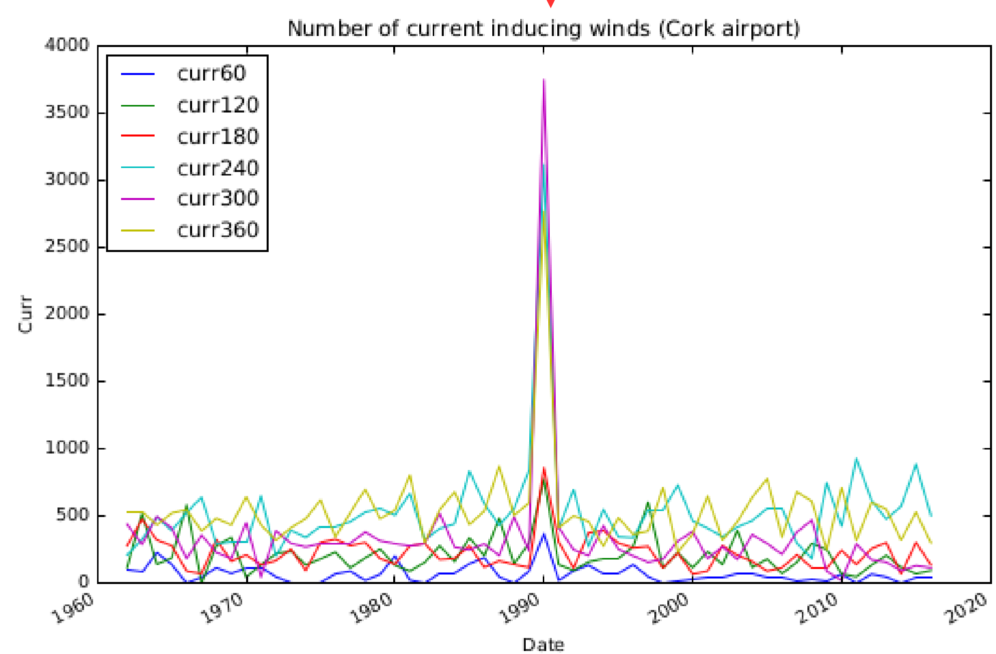
Divide wind data into 6 categories according to direction (60 degrees in each)
Calculate:
- the average speed of the wind from that direction
- the number of hours that the wind blew from that direction
- the total number of current inducing winds from that direction
(winds greater than 5 knots for 20 hours or more).
- coefficient of variation - standard deviation of wind direction relative to the mean

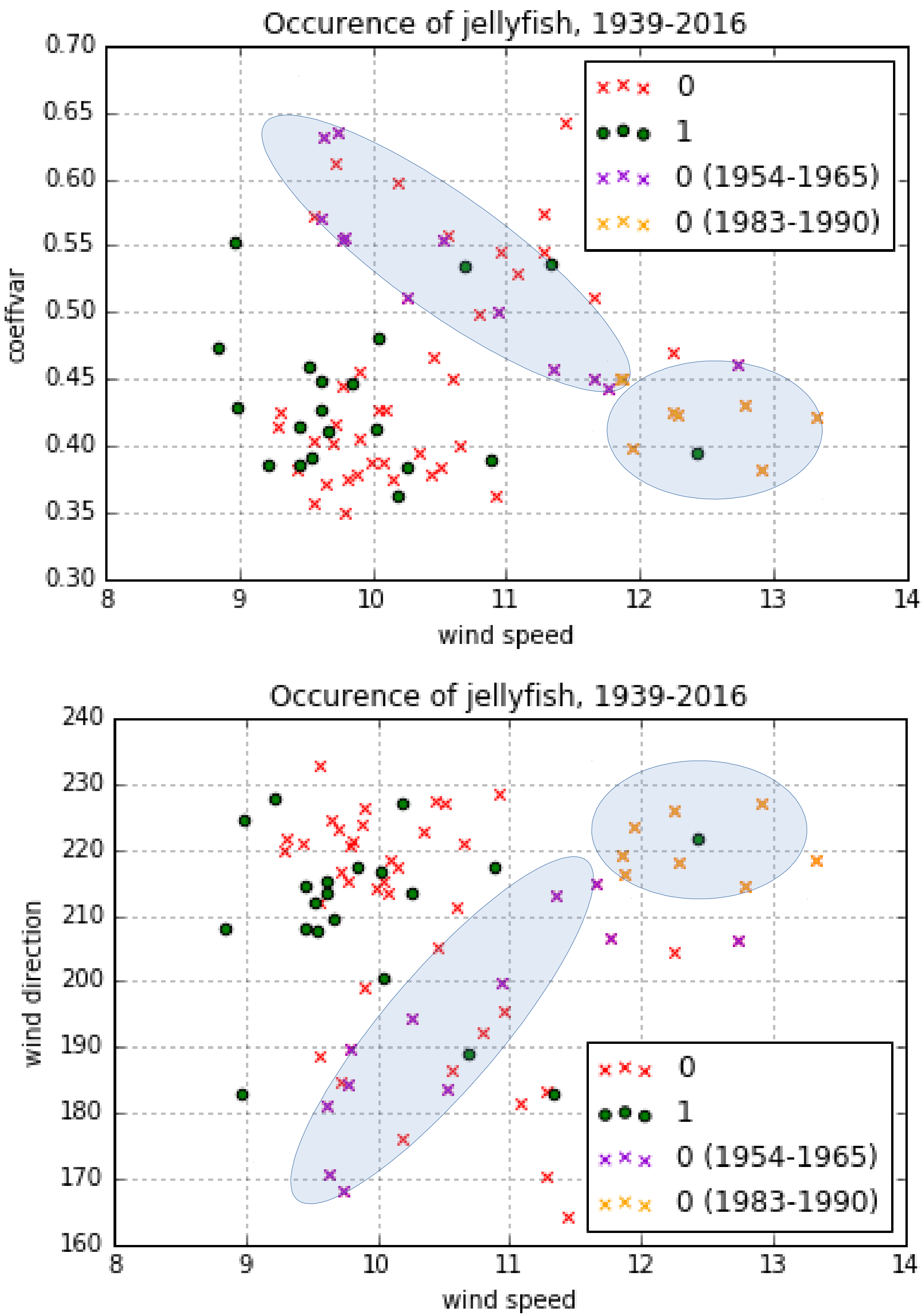




Storm Event: February 1990







Clusters in years:

1954-1965
1983-1990

False zeros?

False zeros

Non-detection does not imply that event did not take place unless the probability of detection is 1.

- **Presence-absence with true zeros**:
  - Consider a subset of jellyfish data where effort was reasonably consistent (i.e. 1890-1915, 1990-2016);
- **Presence-absence with imperfect detectability**:
  - Consider all jellyfish data allowing for zeros using pseudo-absences approach (MacKenzie et al 2002);
- **Presence-only**:
  - Consider all data treating data as presence only, while discarding information on absences
  - Generally not possible to calculate probabilities of presence, only the relative likelihood (Pearce et al 2006).

MacKenzie et al. 2002. Estimating site occupancy rates when detection probabilities are less then one. Ecology, 83(8), 2248—2255
Pearce et al, 2006. Modelling distribution and abundance with presence-only data. Journal of Applied Ecology, 43, 405--412

Statistical models for dealing with false zeros

- Generalized Linear Models (GLM)
  - in particular Zero Inflated Bernoulli or Poisson

- Artificial Neural Networks (ANN)
  - Good at non-linear modelling, requires pseudo-absences

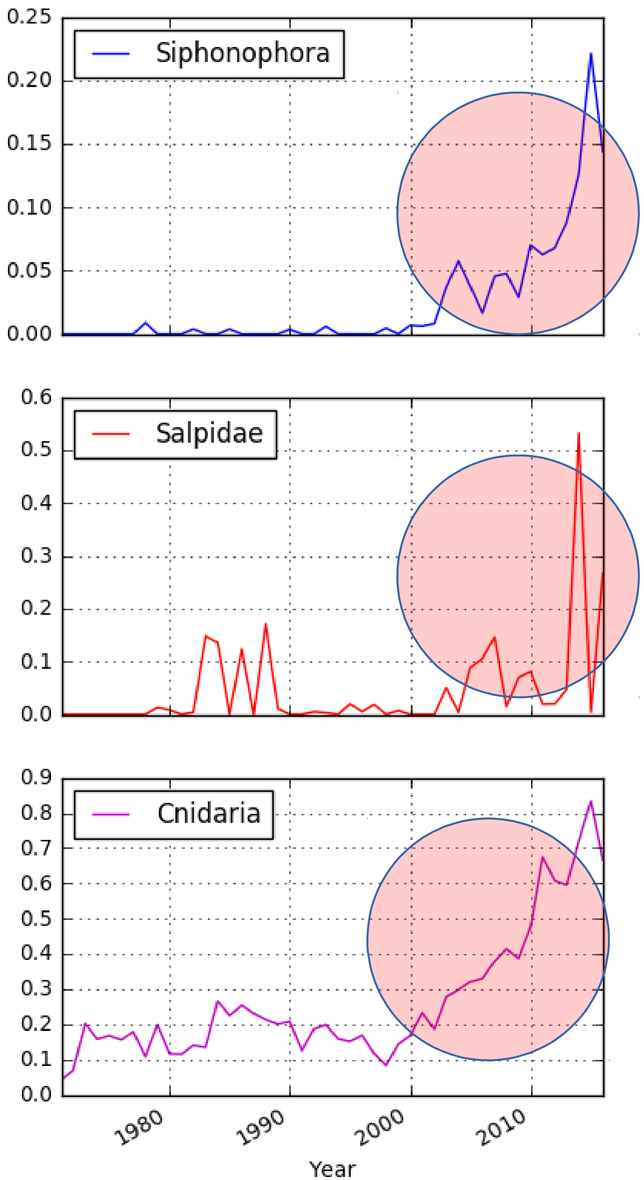
- Maximum Entropy (Maxent)
  - Does not require pseudo-absences

Sunfish Dataset

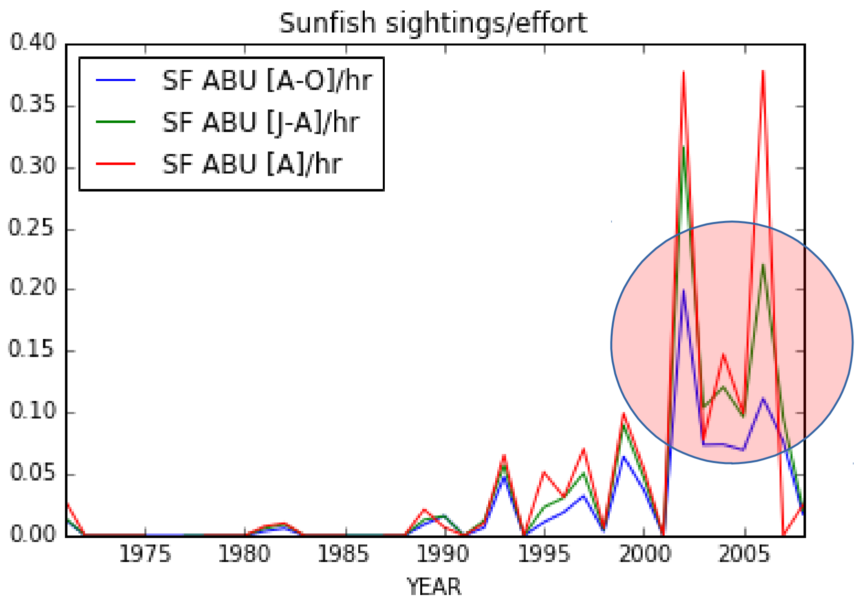
- Time series: 1971 – 2008 (2016)
- April – October
- Count data, daily observations
- Zero-inflated semicontinuos data (95.81% zeros)
- Duration of observation, number of observers, sea state
- External variables: zooplankton, sst, jellies, phytoplankton, latitude of 13 degrees isotherm

Source: Wikimedia Commons

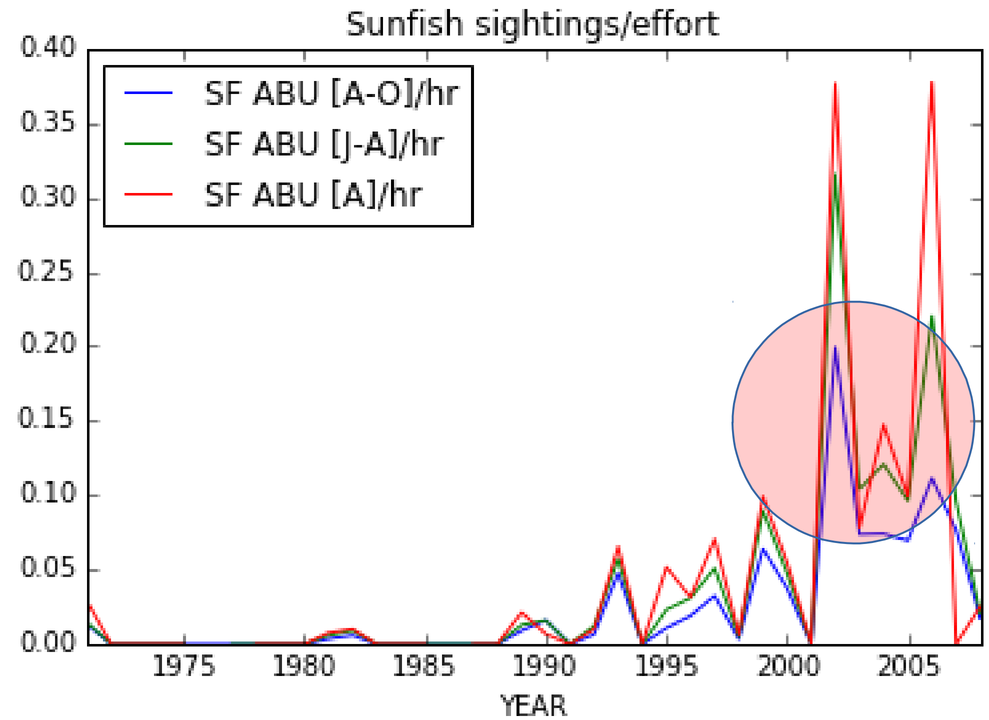
CPR



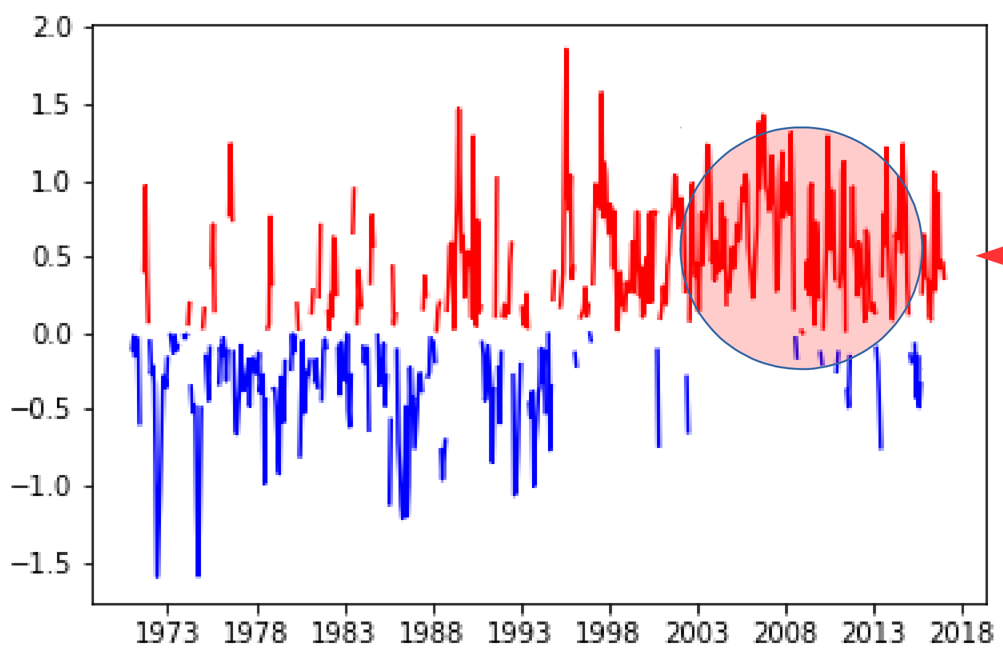
Source: Wikimedia Commons



SST anomaly



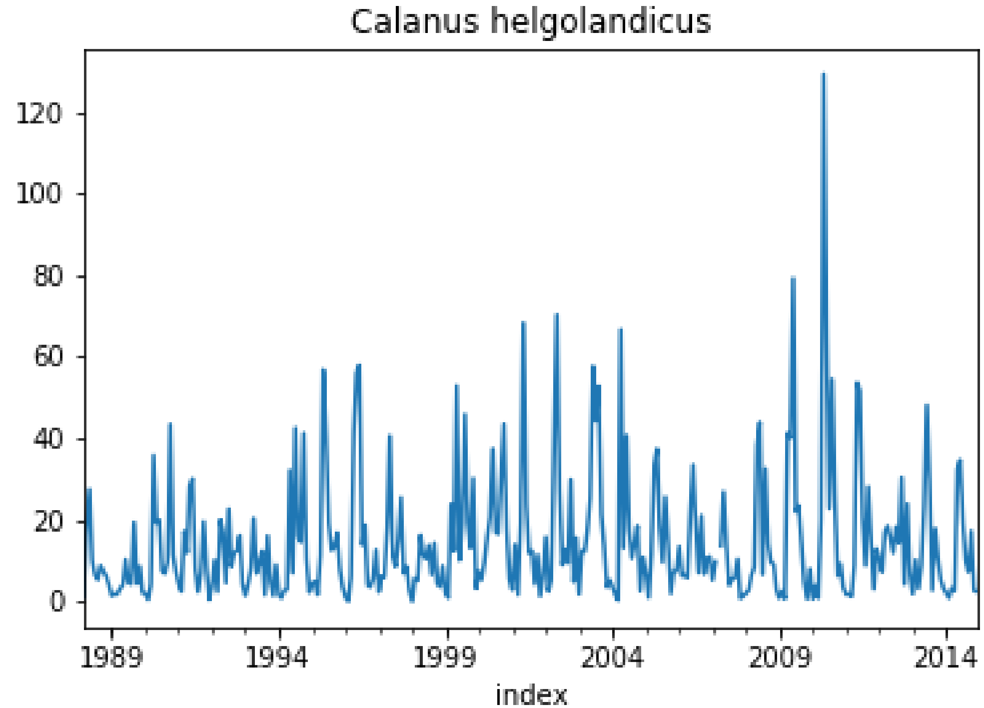
Meaningful anomaly or transient event?

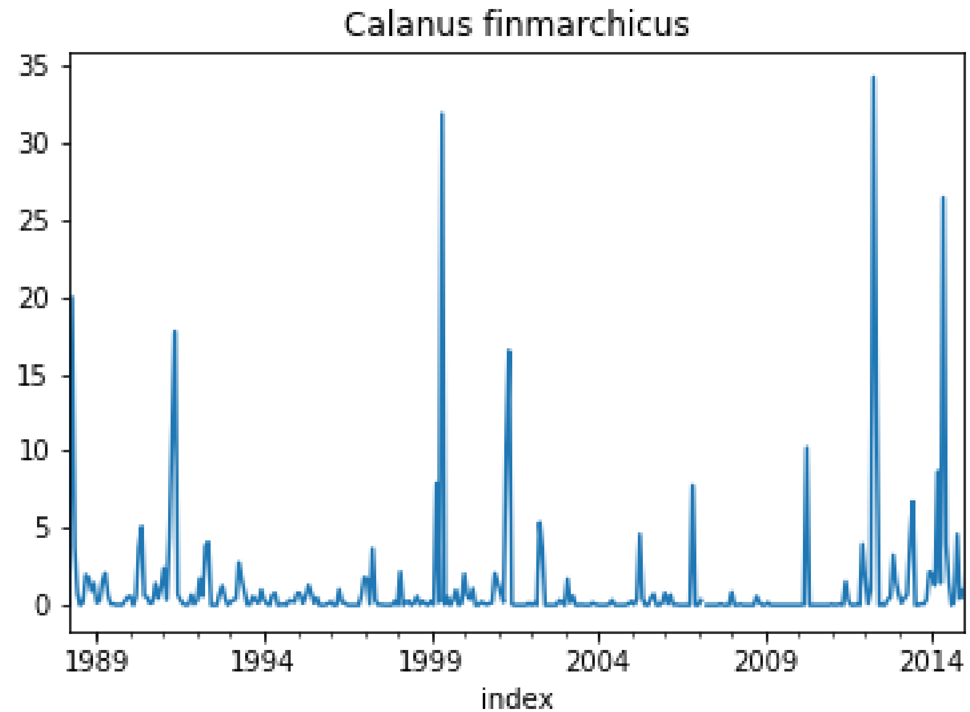


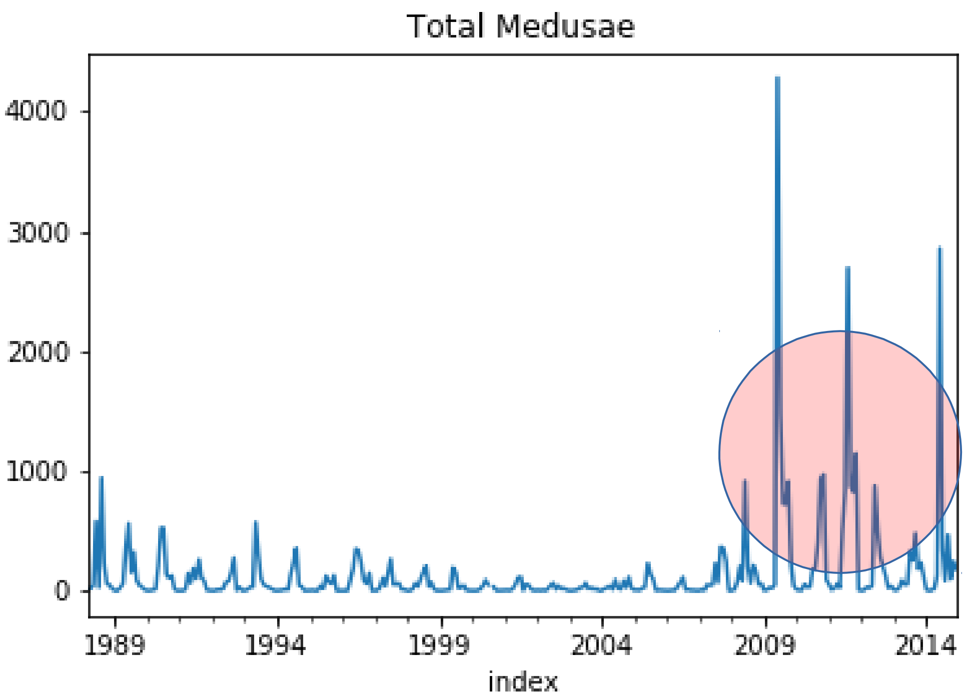
Temperatures are higher than average

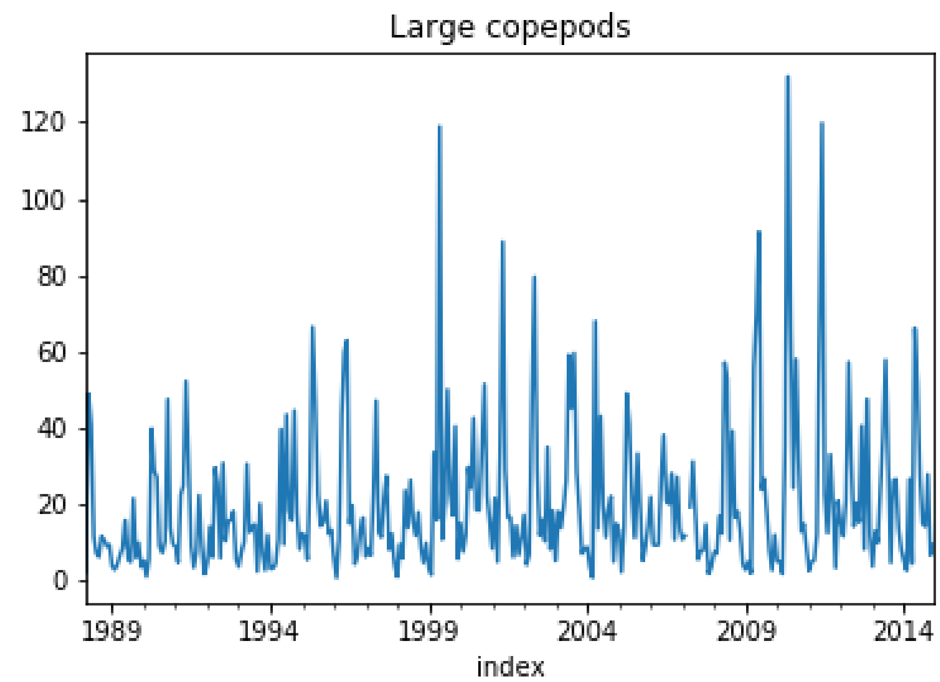
How peaks in sunfish abundance relate to this?

Time series of zooplankton









Methods for dealing with zero-inflated data:

- Modelling the zero and non-zero data with one model and then modelling the truncated-at-zero data with another. This is often called a “hurdle model”;
- Modelling the response variable as a **mixture** of a Bernoulli distribution (a point mass at zero) and a Poisson distribution (or any other count distribution supported on non-negative integers)

Hurdle model

- Hurdle models treats the zeros and non-zeros as two separate processes;
- Allow to model the zeros and non-zeros with different predictors or different roles of the same predictors

Hurdle model results (1):

Intercept only model:

- Probability of non-zero value (**logit model**):

  0.0418

  Confidence intervals:

  2.5 %   97.5 %

  0.0355 0.0488

- Mean of distribution (log link **Gamma model**):

  0.0118

  Confidence intervals:

  2.5 %   97.5 %

  0.0097 0.0147

No better than the average value for the sample

Hurdle model results(2):

Full logit model:

```
Call:
glm(formula = non_zero ~ totzoo + sst + totmedus + xmonth + totsipho +
    chel + lcop, family = binomial(link = logit), data = dat)

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept) -1.372e+01  1.417e+00  -9.677  < 2e-16 ***
totzoo       4.131e-05  1.153e-05   3.582 0.000341 ***
sst          1.017e+00  1.173e-01   8.666  < 2e-16 ***
totmedus    -1.833e-03  1.050e-03  -1.745 0.080950 .
xmonth      -6.355e-01  1.510e-01  -4.209 2.56e-05 ***
totsipho    -8.509e-04  2.969e-04  -2.865 0.004164 **
chel         1.821e-01  4.823e-02   3.774 0.000160 ***
lcop        -1.756e-01  4.505e-02  -3.897 9.73e-05 ***
```

Probability of a positive sunfish record is positively influenced by environmental and biological variables (overall prob 1.104e-06)

Full Gamma model:

```
Call:
glm(formula = nsunfishm ~ seastate + xmonth + chel + lcop, family = Gamma(link = log),
    data = subset(dat, non_zero == 1))


Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.11028    1.06714  -0.103   0.9178
seastate    -0.09432    0.05447  -1.732   0.0856 .
xmonth      -0.56580    0.13659  -4.142    6e-05 ***
chel        -0.15060    0.06509  -2.314   0.0222 *
lcop         0.13946    0.06084   2.292   0.0234 *
---
```

Mean of distribution: 0.8956

Next steps:

- Further analyse sunfish sightings in relation to biological and environmental variables accounting for underlying trends;
- Detect annual trends that are over and above seasonal fluctuations that we would expect;
- Fit multispecies models to examine trends across species and detect potential step changes using state-space modelling