# Effects of ocean climate change on growth of 1SW salmon

Chris Todd
Scottish Oceans Institute
University of St Andrews
[cdt@st-andrews.ac.uk]

# DATA

- Marine Scotland Science, annual monitoring of commercial catches for North Esk, Spey, Tay, Tweed dates back to the 1960s.

- Focus here on 1SW adults, which we know to migrate to the Norwegian Sea.

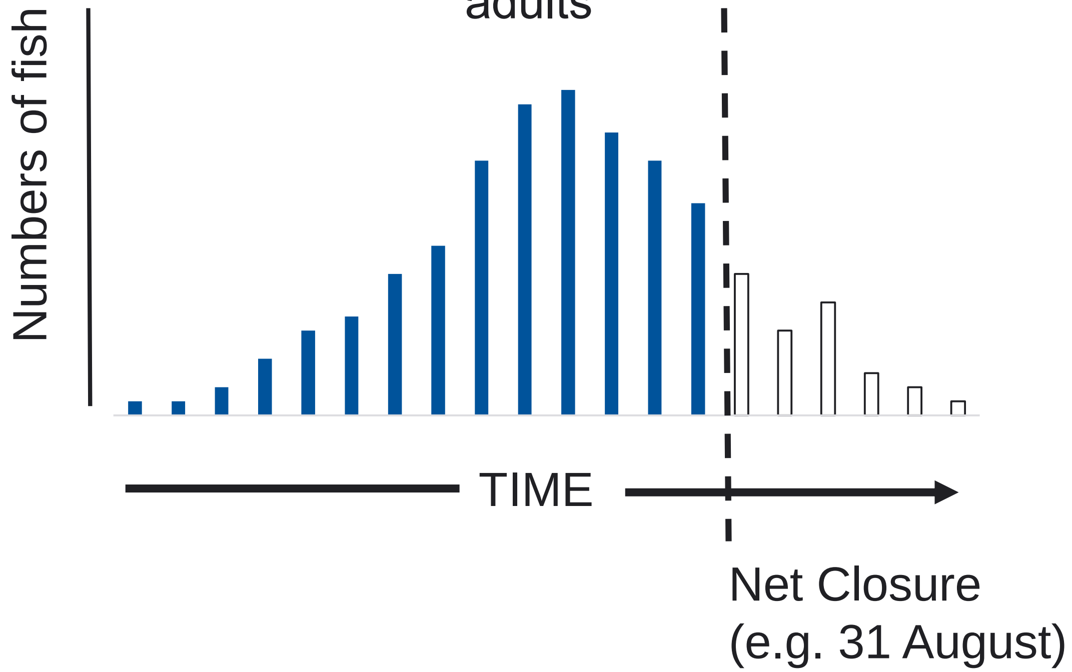
- Time-series changes in average size (with allowance for changes in annual run-timing).

- Correlation analysis (after allowance for Autocorrelation in the data) between salmon size and monthly Sea Surface Temperature (SST) anomalies throughout the marine migration.

(Anomalies are the temperature deviations from the long-term (1971-2000) mean for a given month)

# PROBLEM 1: Entire 1SW cohort never sampled by MSS because of net season closure. PROBLEM 2: Differing run-timing influences the observed cohort proportion and size of adults.

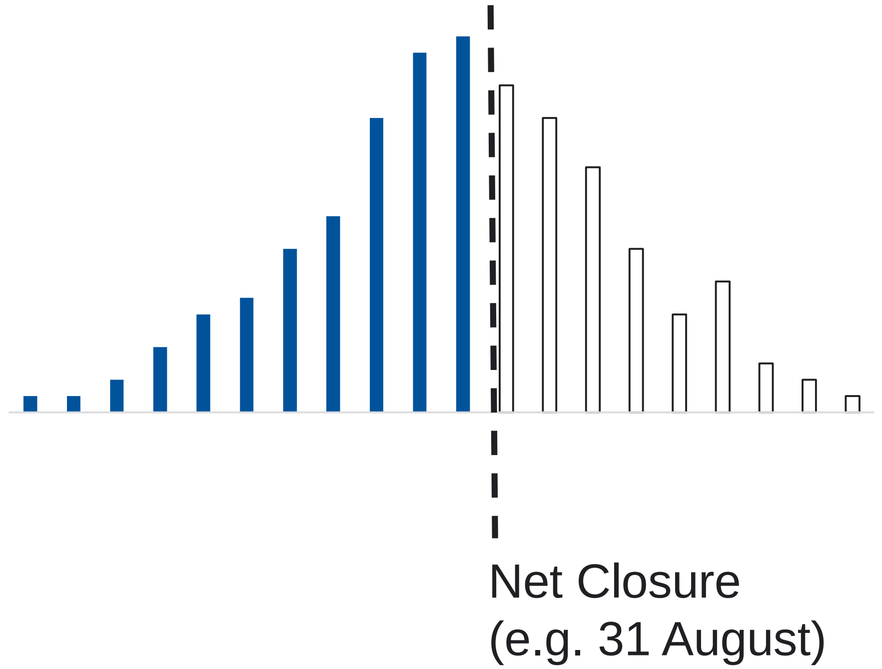
Typical timing of return of 1SW adults




**TRUE average weight = 3.02 kg**

**“OBSERVED” average weight = 2.76 kg**

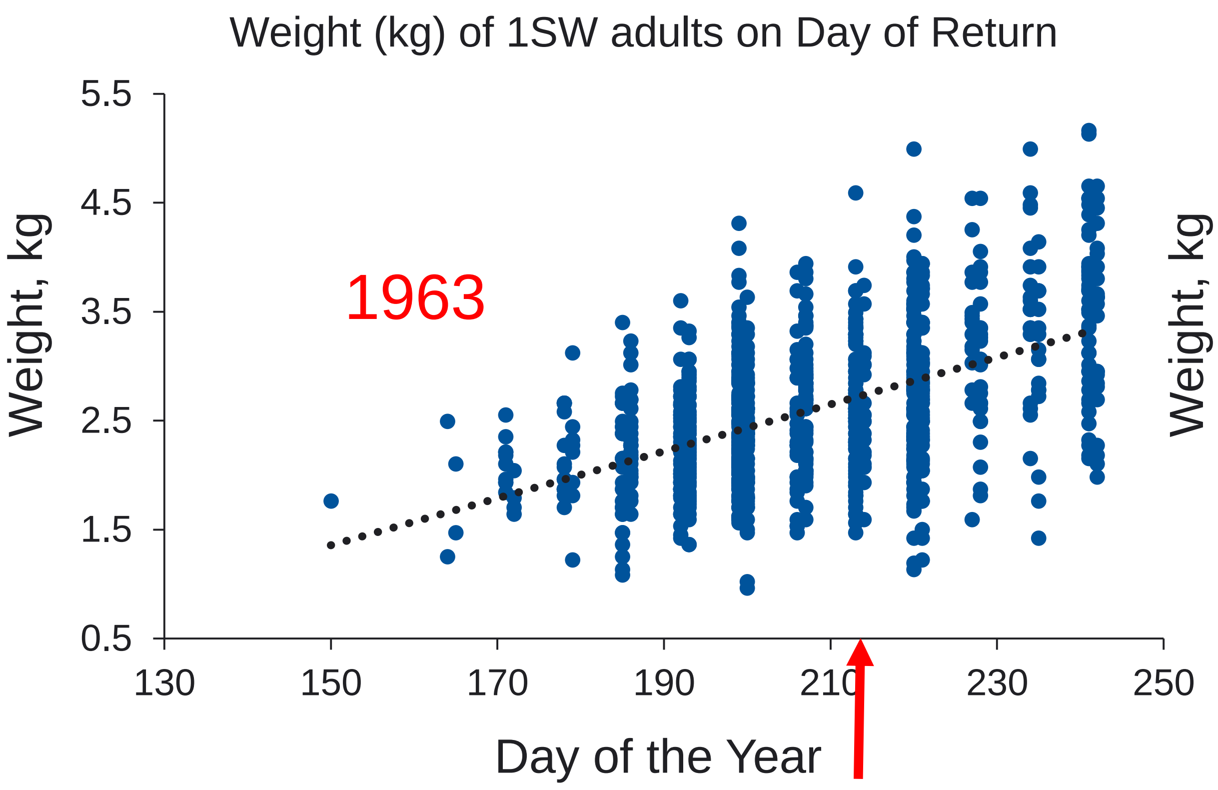
Delayed return of 1SW adults



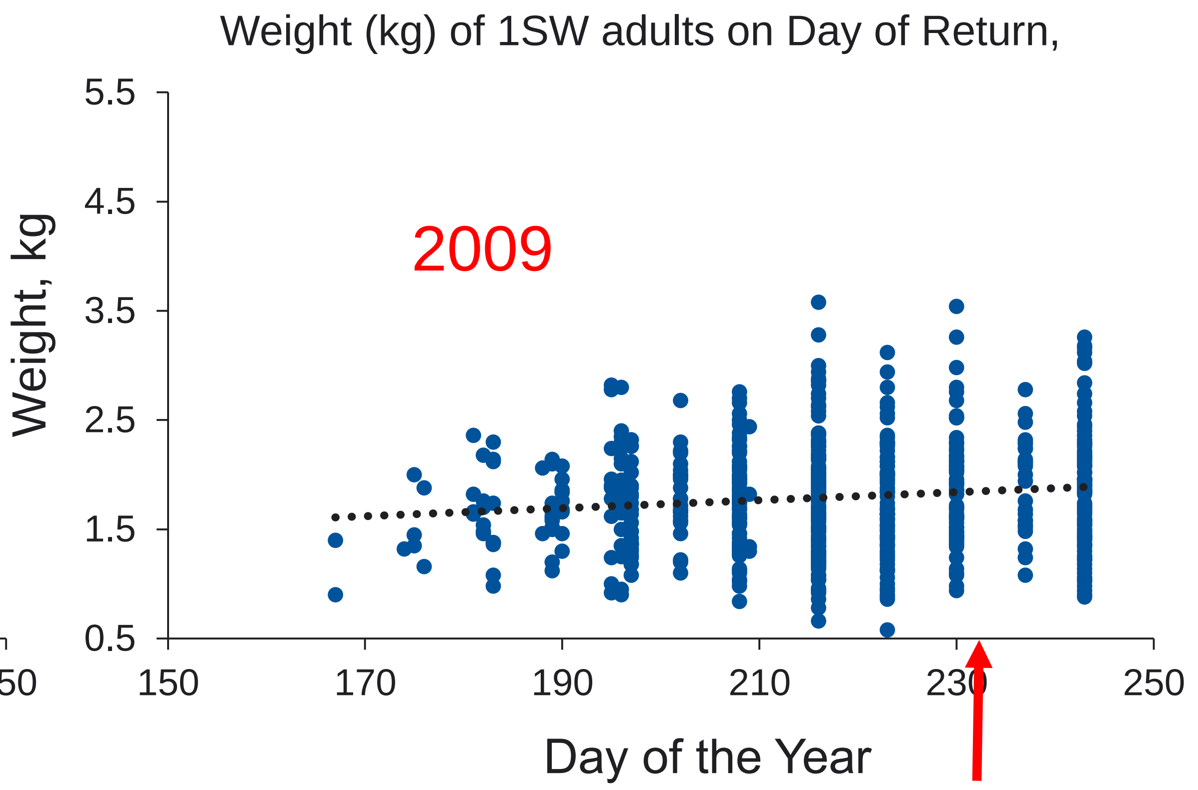

**TRUE average weight = 3.02 kg**

**“OBSERVED” average weight = 1.83 kg**

# NORTH ESK – 1SW ADULTS, 1963 AND 2009. <u>PROBLEM 3:</u> Average size of return adults tends to increase as the summer progresses.

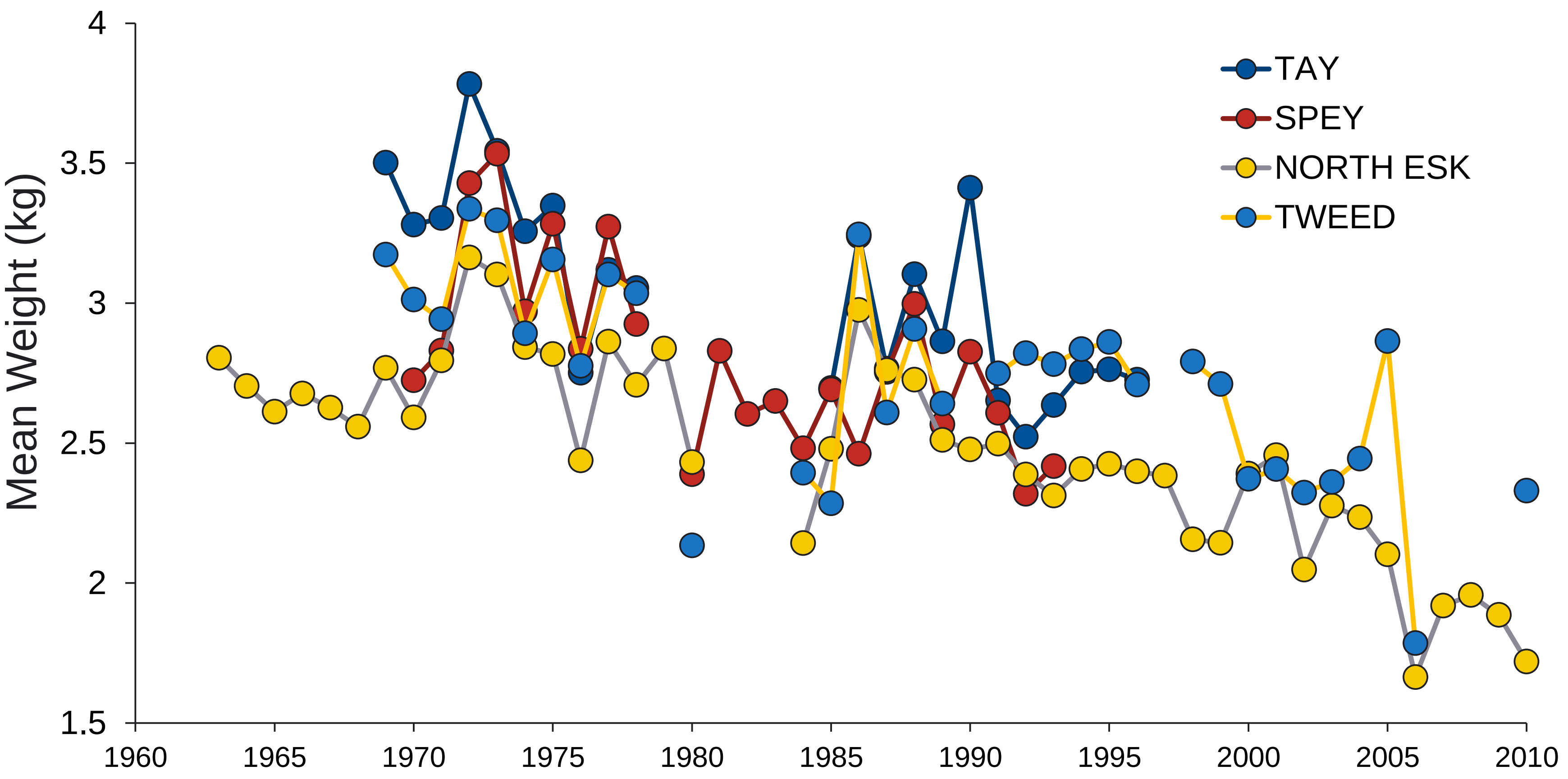



Modal Date of Migratory Return = Day 213 (1 August)




Modal Date of Migratory Return = Day 232 (20 August)

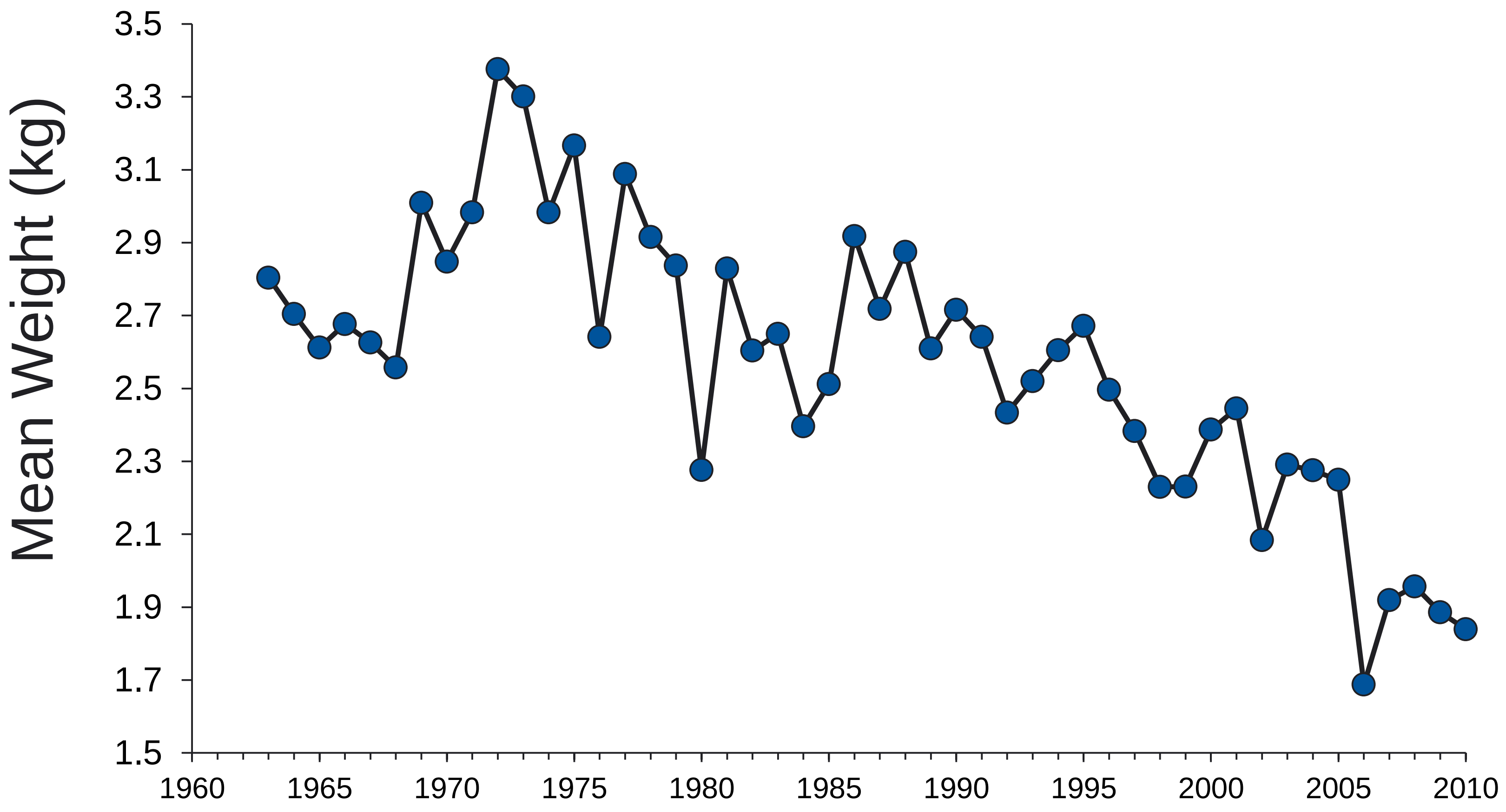
# Mean weight (kg) * for 1SW adults returning to rivers TAY, SPEY, NORTH ESK and TWEED




* Mean weight here is that predicted for 1SW grilse on the peak day of migratory return – i.e., allowance has been made for annual changes in run-timing.

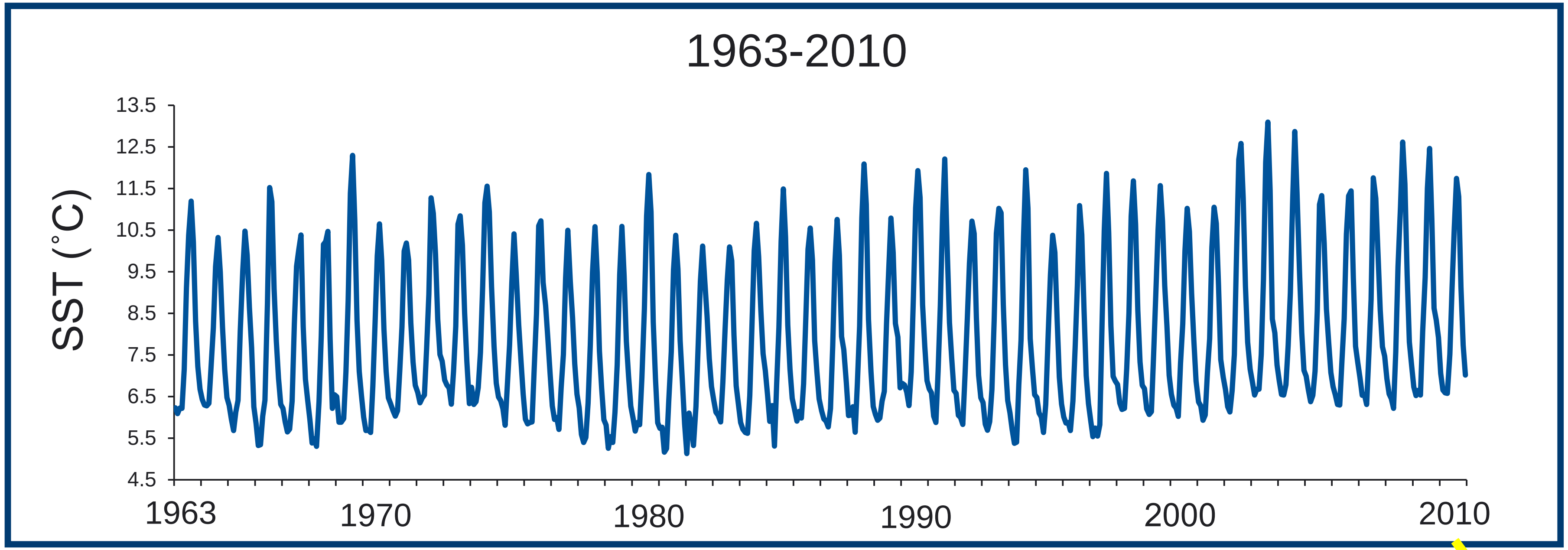
The grilse run has typically shown marked delay, by up to one month, in recent years

# ALL RIVERS (Tay, Spey, North Esk, Tweed) Mean Weight (kg)* at Peak Day of Migratory Return

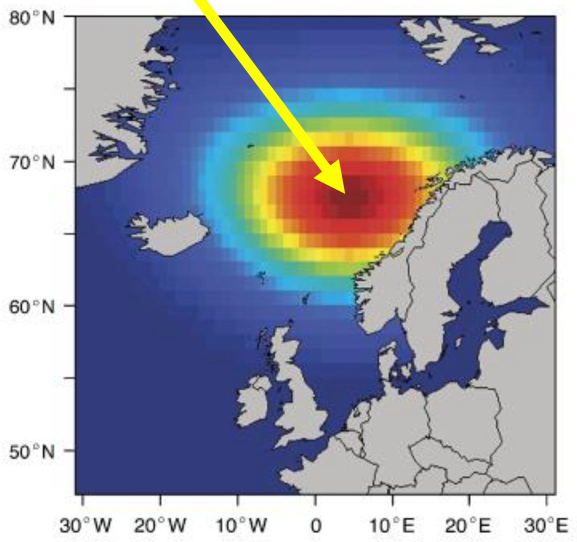



* OVERALL MEAN WEIGHT derived from ALL RIVERS in each year, weighted by annual sample size of each river

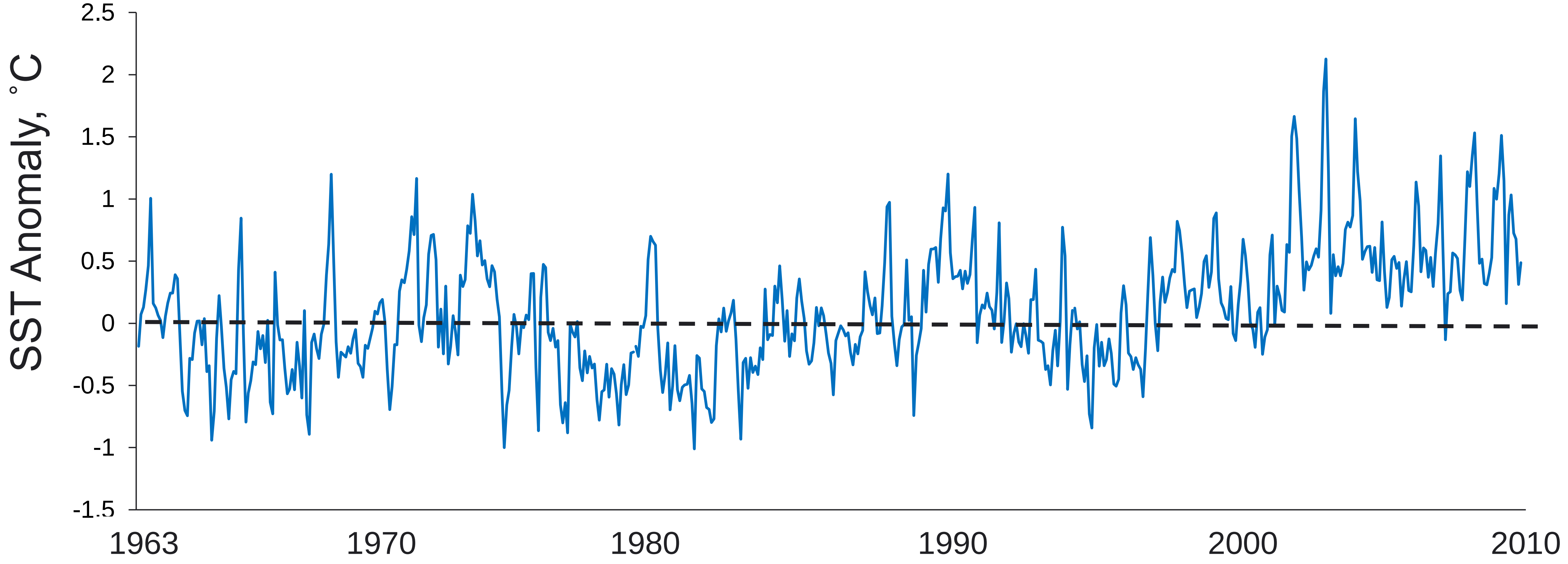
Sea Surface Temperature (SST) at 67.5˚N 4.5˚E (Norwegian Sea). One degree gridbox; data for Hadley ISST




- Salmon are “cold-water” fish: therefore vulnerable to ocean warming?
- Note the restricted annual temperature range in the Norwegian Sea
- Ocean temperature effects on salmon are likely INDIRECT and reflect temperature-induced changes in prey availability
- In assessing ocean warming we analyse temperature anomalies

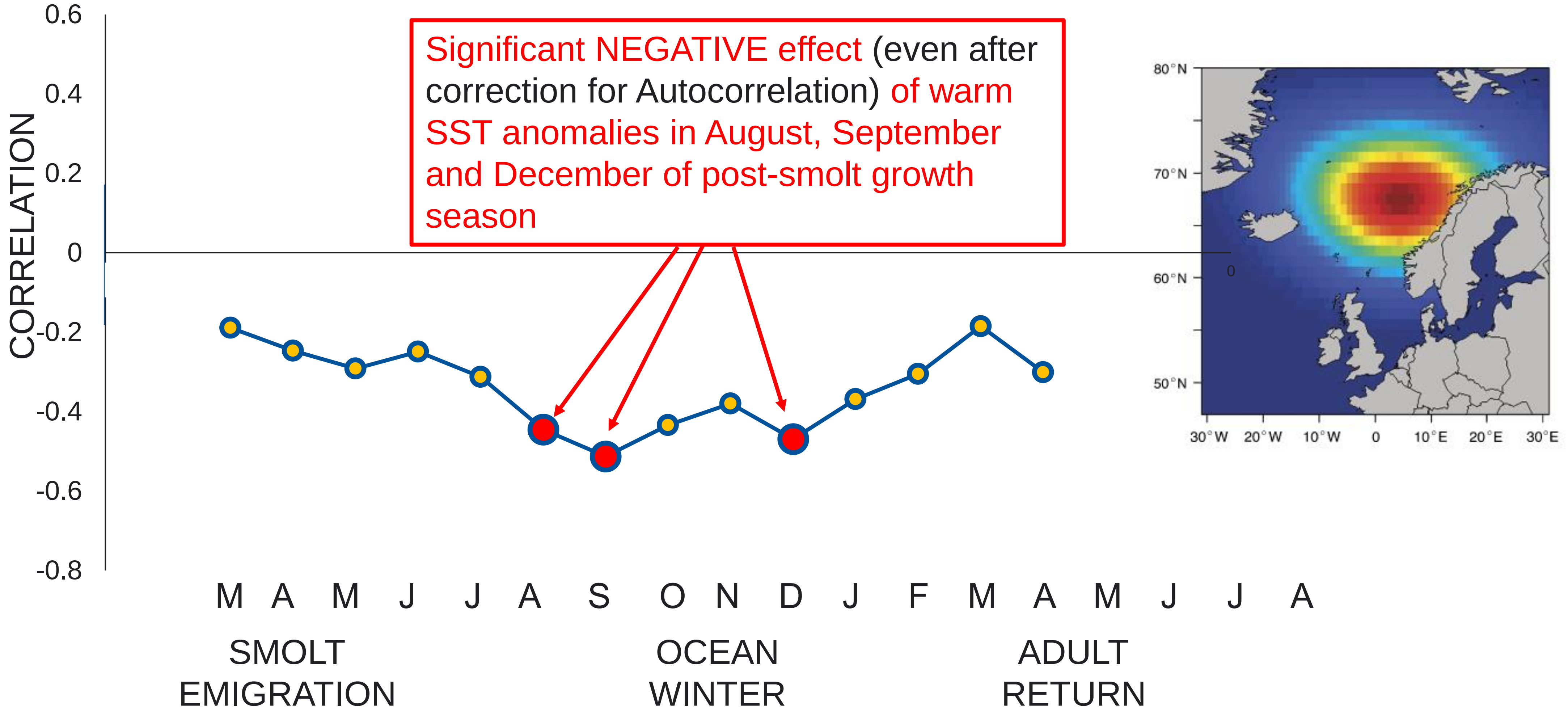


# SST anomaly for 250 km spatially-weighted kernel; focal gridbox 67.4˚N 4.5˚E (Norwegian Sea)



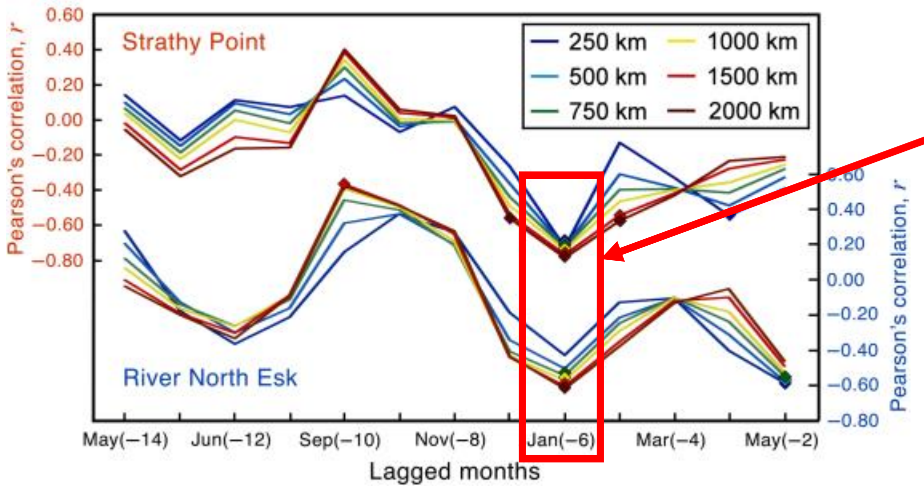

Monthly anomalies here are the deviations from the monthly means for the period 1971-2000

NORTH ESK monthly correlations between 1SW adult Mean Weight (kg) at Peak Day of Migratory Return and SST anomaly, for a spatially-weighted SST “kernel” of standard deviation 250 km (focus 67.5˚N 4.5˚E; Norwegian Sea)



# INITIAL CONCERNS

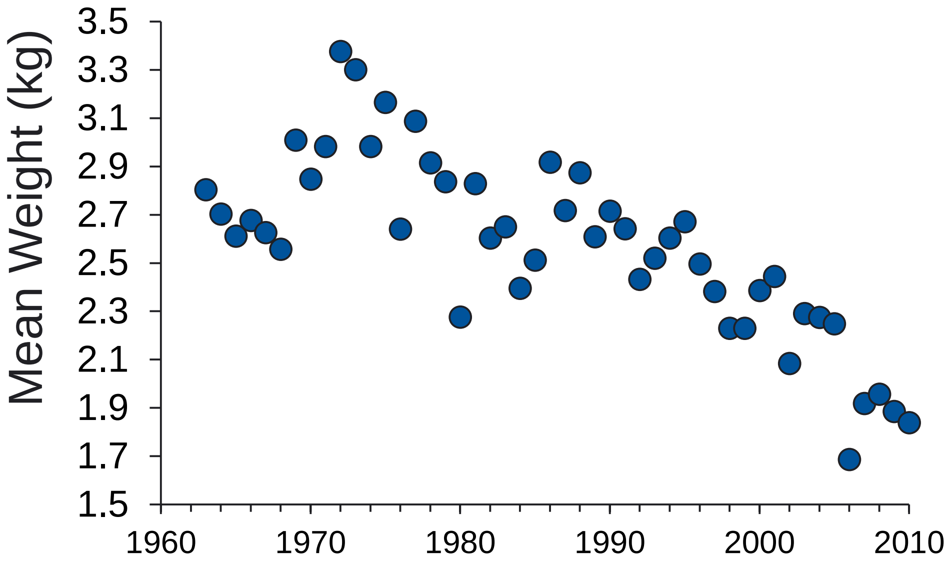
These apparent negative effects of anomalous warming in August and September of the post-smolt growth season, plus midwinter in December – do not accord with our previous findings * for changes in Condition Factor (weight at given length).



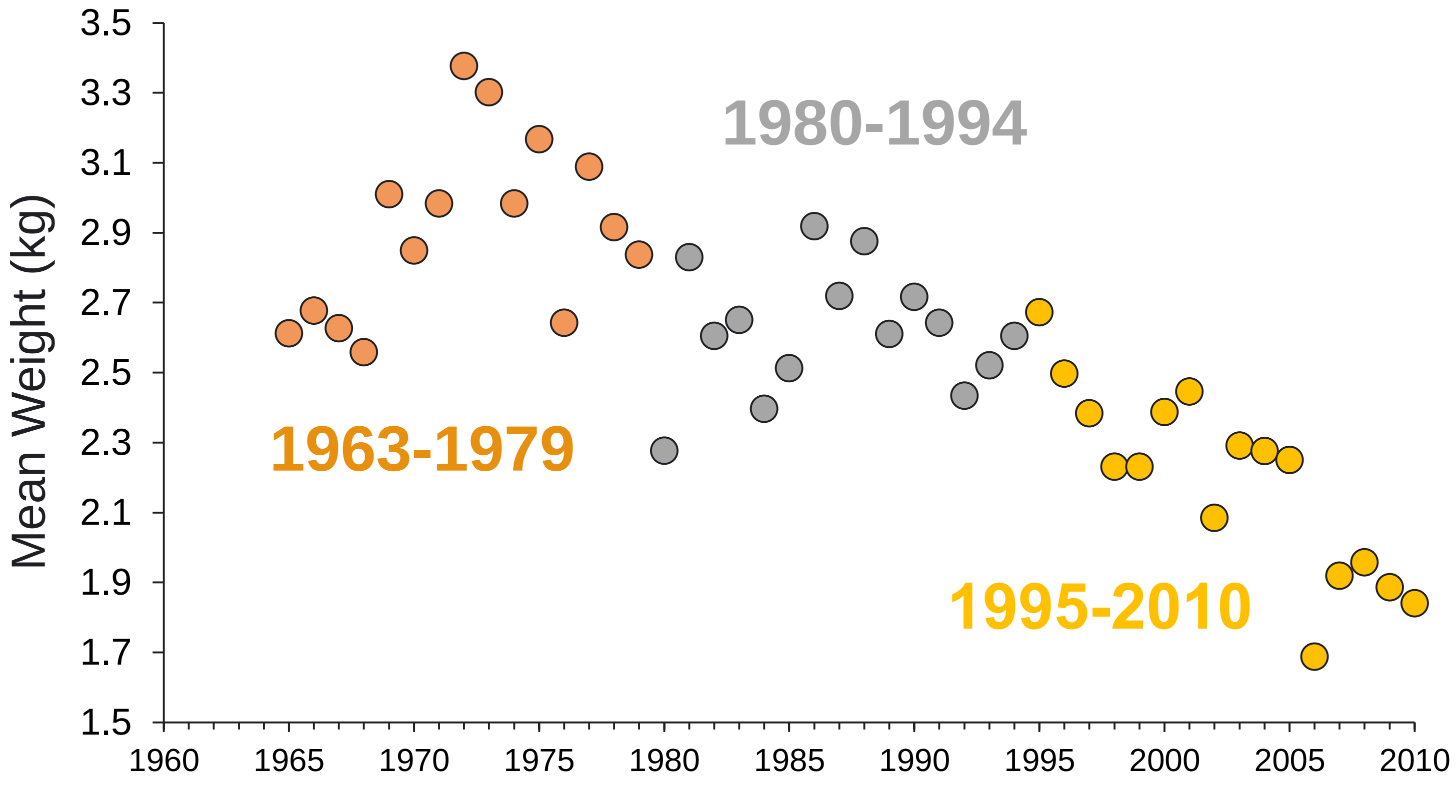

For the period 1993-2006 we previously showed that anomalous SST warming in January led to smaller and skinnier 1SW adults returning that summer

* Todd *et al*. (2008) *Global Change Biology*, **14**: 958-970

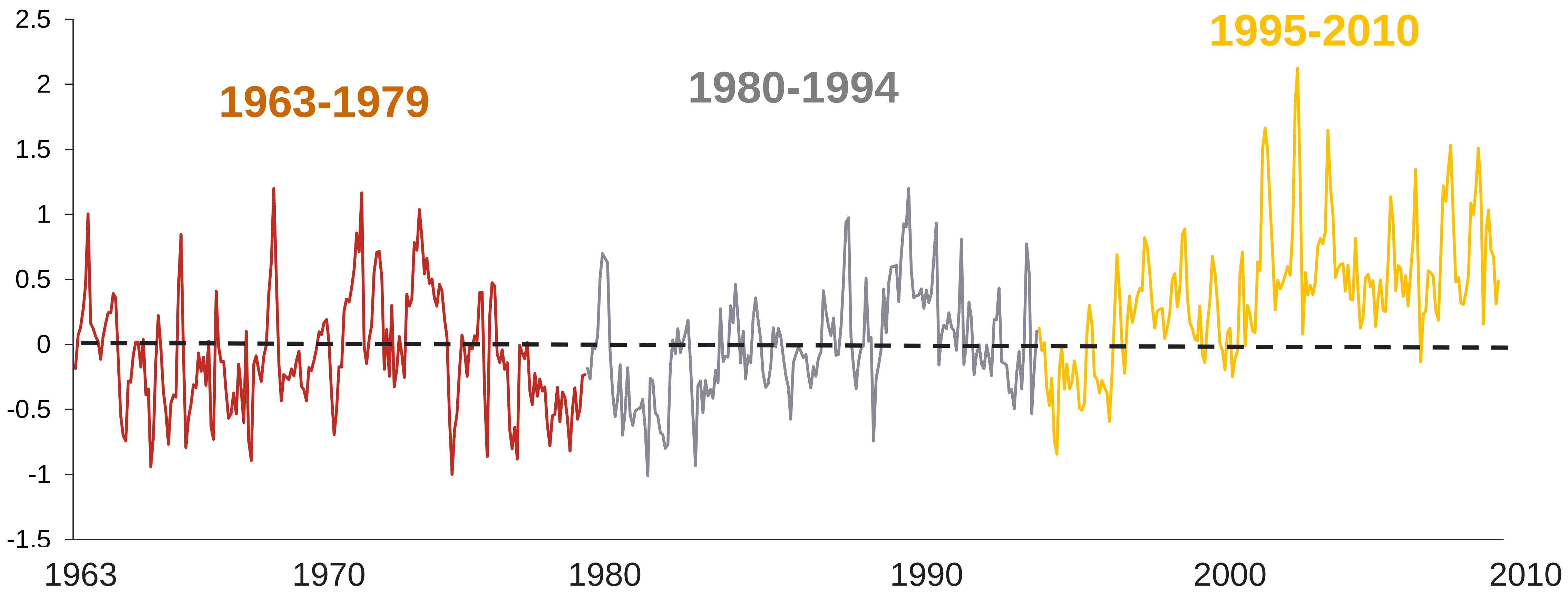
## ALL RIVERS – Mean Weight



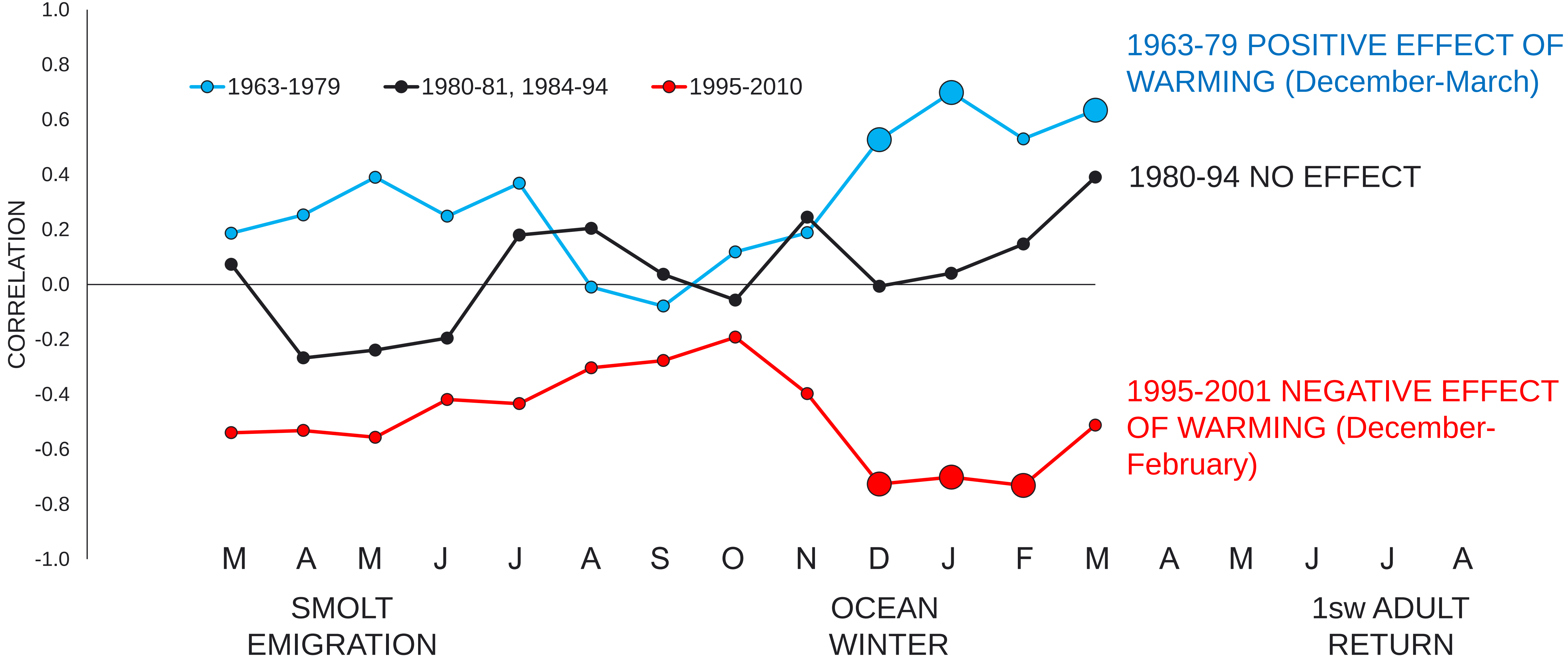

## BREAKPOINT ANALYSIS – to determine “structure” in the Mean Weight time series

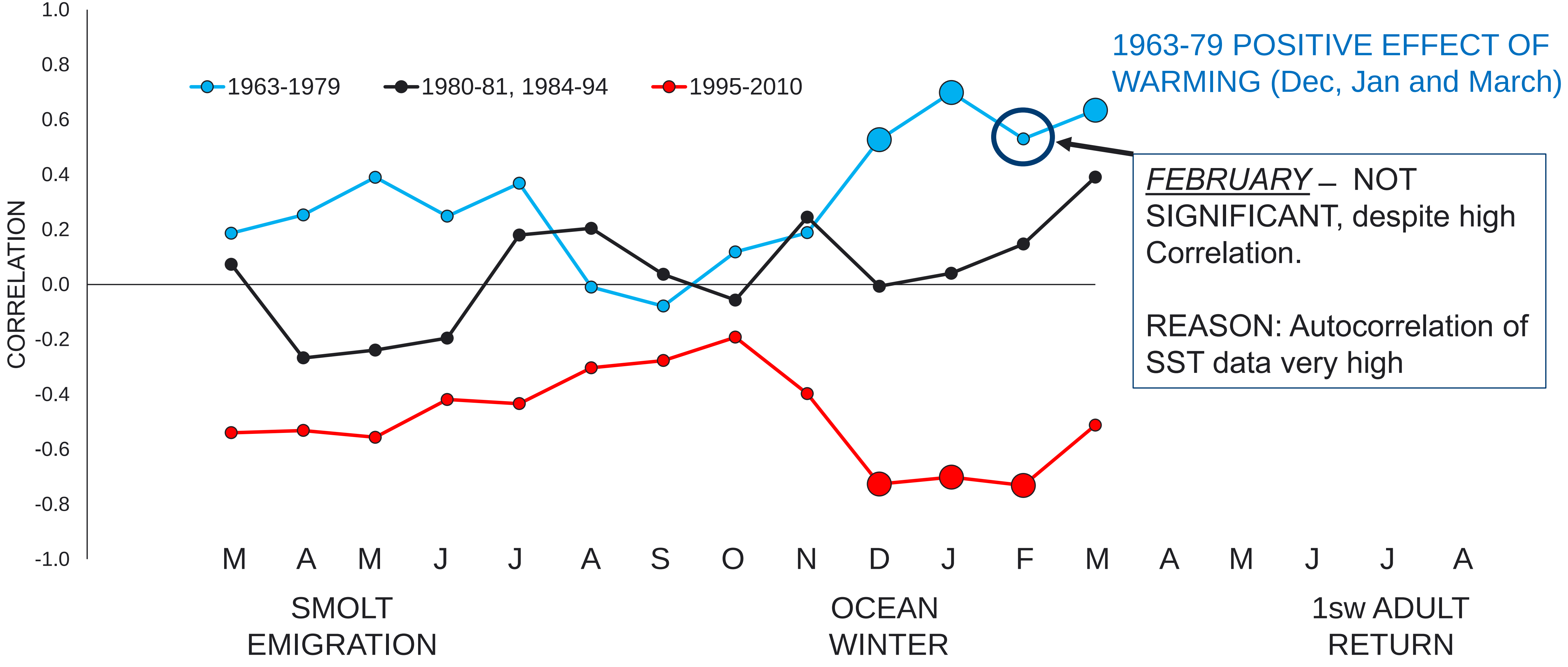


# SST anomaly for 250 km spatially-weighted “kernel”, focus 67.4˚N 4.5˚E (Norwegian Sea)

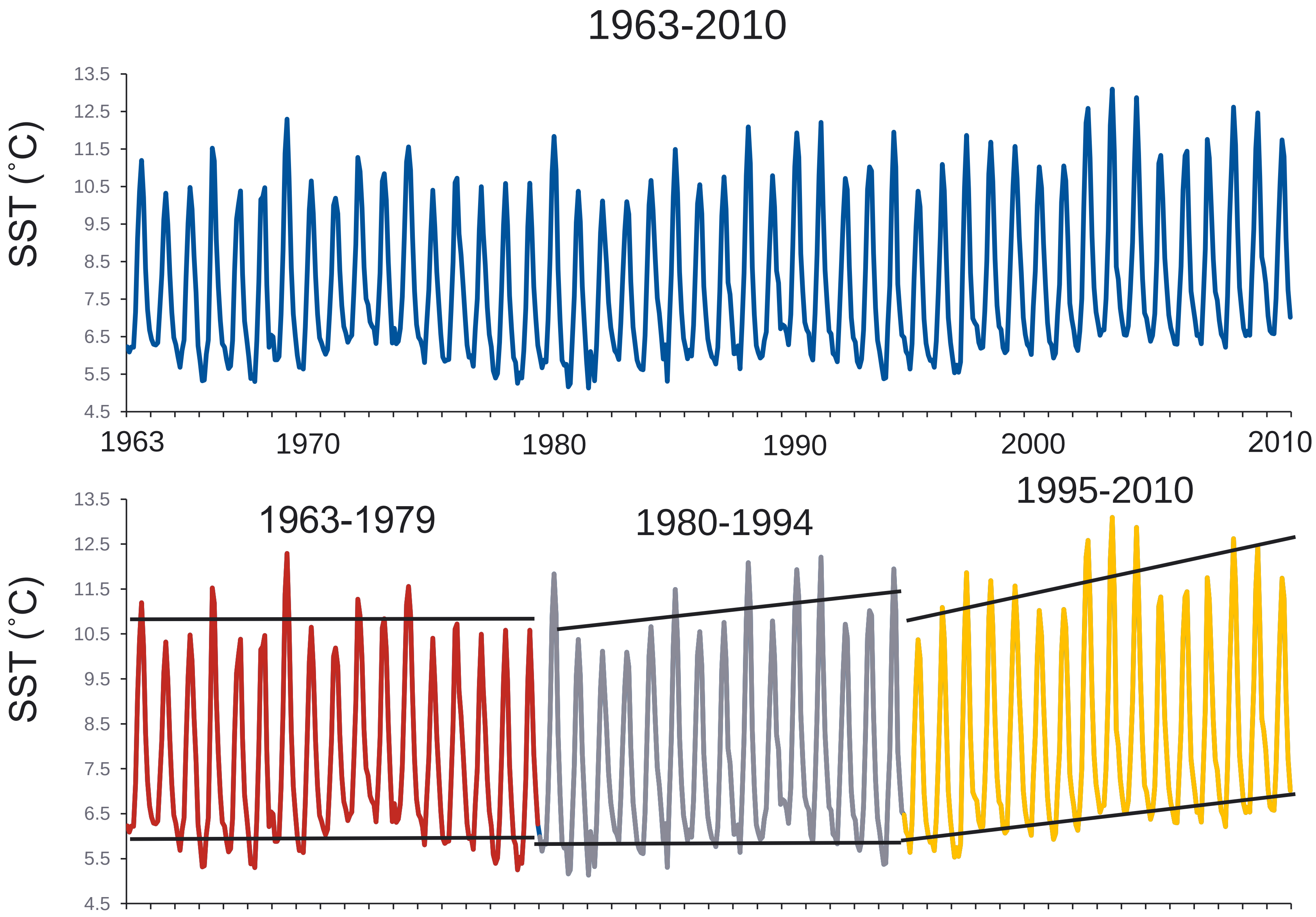


# NORTH ESK monthly correlations between 1SW adult mean weight (kg) at Peak Day of Migratory Return and SST anomaly, for a spatially-weighted SST "kernel" of standard deviation 250 km (focus 67.5˚N 4.5˚E; Norwegian Sea)




1963-79 POSITIVE EFFECT OF WARMING (Dec, Jan and March)
1963-1979
1980-81, 1984-94
1995-2010
CORRELATION
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
M A M J J A S O N D J F M A M J J A
SMOLT EMIGRATION
OCEAN WINTER
1sw ADULT RETURN
*FEBRUARY* – NOT SIGNIFICANT, despite high Correlation.
REASON: Autocorrelation of SST data very high

# Sea Surface Temperature (SST) at 67.5˚N 4.5˚E (Norwegian Sea).  One degree gridbox; data for Hadley ISST



# CONCLUSIONS

- These patterns for North Esk are reflected also by Spey, Tay and Tweed
- Anomalous ocean warming impacts probably are INDIRECT – influencing prey availability to salmon at sea
- For long time-series of data it is essential to (*a*) take account of Autocorrelation in the data and make the significance test more conservative, and (*b*) first assess “structure” in the data
- Warming, during a “cool” period (e.g. 1963-79) can be beneficial to salmon
- Warming, during a “warm” period (e.g. 1995-2010) can be detrimental to salmon

# ACKNOWLEDGEMENTS


- Marine Science Scotland (MSS), for access to their data and scale archives
- Nora Hanson, Gordon Smith, Julian MacLean, John Armstrong at MSS
- Lars Boehme, Tania Mendo at University of St Andrews