Sixty years of water temperature data from Charleston Harbor

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Sixty years of water temperature data from Charleston Harbor

- Daily water temperature records from Charleston Harbor since 1950 – dataset compiled by David Whitaker

- What water temperature changes have occurred?

- How does Charleston Harbor water temperature relate with other climate-related parameters?

- How does Charleston Harbor water temperature affect estuarine fish populations?
Charleston Harbor Water Temperature
1 Jan 1950 - 31 Dec 2011

1950 – 2011 (62 yrs): 22,645 days
Temperature recordings: 16,741 days
Missing data: 5,904 days

Seawater Temp (deg C)
Charleston Harbor Water Temperature
1 Jan 1950 - 31 Dec 2011

1950 – 2011 (62 yrs): 22,645 days
Temperature recordings: 16,741 days
Interpolated data: 5,904 days
Superimposed Charleston Harbor water temperature data: 1950-2011

- Summer: ~5 deg
- Winter: > 10 deg
Mean annual water temperature

$y = 0.013x - 6.255$

$p < 0.001, R^2 = 0.19$

How are these changes associated with global atmospheric and ocean processes?
Atlantic Multidecadal Oscillation (AMO)

- Related to long-term shifts in atmospheric/oceanic heat exchange.

- Associated with small changes in the North Atlantic branch of the thermohaline circulation (‘ocean conveyer belt’).

Relationship between water temperature & Atlantic Multidecadal Oscillation (AMO)

(All data standardized to 1950-2011 mean and SD)

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## Relationship between water temperature & Atlantic Multidecadal Oscillation (AMO)

### Cross-correlation matrix

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**Strongest AMO correlations are with summer water temperatures in Charleston Harbor**

Scale (correlation coeff): -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80 1.00
Relationship between water temperature & Atlantic Multi-decadal Oscillation (AMO)

\[ R^2 = 0.33 \]
\[ p < 0.001 \]

**Relationship between summer means**

- **CH Water Temp (Jul-Aug)**
- **AMO (May-Jul)**

\[ R^2 = 0.33 \]
\[ p < 0.001 \]
Arctic Oscillation (AO)

- Index of difference between atmospheric pressures: High versus Mid-latitudes
- During episodes of high pressure in the Arctic, cold Arctic air penetrates into mid-latitudes.
- Index is closely related to the North Atlantic Oscillation (Iceland vs Azores pressures differentials)

Image: [Link to Arctic_Oscillation.png](http://en.wikipedia.org/wiki/File:Arctic_Oscillation.png)
Arctic Oscillation (AO)

Relationship between winter AO and winter water temperature

![Graph showing the relationship between winter AO and winter water temperature. The graph includes a linear regression line with the following statistics:

- $R^2 = 0.34$
- $p < 0.001$

The graph indicates a positive correlation between the Arctic Oscillation and water temperature during winter months.]
El Niño–Southern Oscillation (ENSO)

http://ciges.washington.edu/cig/pnwc/aboutenso.shtml
El Niño–Southern Oscillation (ENSO)

Relationship between winter ENSO and winter water temperature

Global-SST ENSO Index data: [http://jisao.washington.edu/data/globalsstenso/#digital_values](http://jisao.washington.edu/data/globalsstenso/#digital_values)
Timing of Spring Temperature Thresholds
Timing of Spring and Fall
Temperature Thresholds

OCCURRENCE OF 17°C TEMPERATURE THRESHOLD

**SPRING**

\[ y = -0.16x + 413 \]

\[ R^2 = 0.09 \]

**FALL**

\[ y = 0.21x - 88 \]

\[ R^2 = 0.13 \]

**Temperature Window**

\[ y = 0.37x - 501 \]

\[ R^2 = 0.22 \]

\[ P = 0.015 \]

\[ P = 0.004 \]

\[ P < 0.001 \]
Winter: Most variable season.
How do winter temperatures affect estuarine fish populations?
Relationships between water temperature and estuarine fauna

Spotted seatrout
*Cynoscion nebulosus*

Trammel net survey
(monthly, 1991 – present)
Relationships between water temperature and estuarine fauna

![Graph showing deviation about long-term mean for seatrout and minimum temperature.]

- Seatrout (Cynoscion nebulosus)

Year
- 1990
- 1995
- 2000
- 2005
- 2010

Deviation about long-term mean
- -2.5
- -1.5
- -0.5
- 0.5
- 1.5
- 2.5
- 3.5

"Spotted seatrout Cynoscion nebulosus"
Relationships between water temperature and estuarine fauna

![Graph showing deviations of spotted seatrout and silver perch from long-term mean temperatures from 1990 to 2010.](image)

- **Spotted seatrout** (*Cynoscion nebulosus*)
- **Silver Perch** (*Bairdiella chrysoura*)
Relationships between water temperature and estuarine fauna
Relationships between water temperature and estuarine fauna

\[ R^2 = 0.3197 \]

Seatrout
(SDs from long term mean)

Minimum winter temperature
(SDs from long-term mean)
Relationships between water temperature and estuarine fauna

Cold winter effects on dolphin strandings:
Strandings more common following colder winters, especially when fish numbers are low (McFee & Arnott, unpublished data)
Conclusions

- Water temperatures have changed significantly with time
- General increase in temperatures, with spring arriving earlier and fall arriving later
- Many of the changes are linked with large-scale, climatic-related indices (AMO, AO, ENSO)
- Winter is the most variable season
- Winters affect resident fish, and probably other ecosystem-level processes
- Ongoing studies (e.g. seatrout temperature tolerance & genetic diversity)
Temperature Data Interpolation (i.e. filling in missing data)

CH water temperature data: number and duration of data gaps that were filled by linear interpolation
(n.b. 87.6% were 1 or 2 day gaps; mostly weekends)
Simulating the effects of data interpolation

**Method**
- Used data from 2011 (temperature recorded every day)
- Removed all week-end values and then interpolated them.
- Compared real versus simulated data.

**Results**

*Daily Temperature Values*
- Simulation error ranged from -0.6°C to +0.6°C
- Mean Error = 0.001°C (not sig. dif from zero, 1-sample t-test, \( p = 0.96 \))

*Mean Monthly Temperatures*
- Simulation error ranged from -0.1°C to +0.3°C

Error from data interpolation was negligible
Relationship between water temperature & Atlantic Multi-decadal Oscillation (AMO)

![Graph showing the relationship between water temperature and AMO deviation from long-term mean (st. devs)].

- **AMO**
- **CH mean annual water temp**
Arctic Oscillation (AO)

Annual AO index and CH mean annual water temperature

-3.0  -2.0  -1.0  0.0  1.0  2.0  3.0
Deviation from long-term mean (st. devs)
Year
AO annual index
CH mean annual water temp
Relationship between water temperature & Atlantic Multi-decadal Oscillation (AMO)

Relationship between annual means

\[ R^2 = 0.11 \]
\[ p = 0.01 \]
Relationships between water temperature and estuarine fauna

- **Seatrout** (SDs from long-term mean)
- **Minimum winter temperature** (SDs from long-term mean)

\[ R^2 = 0.3197 \]
Relationships between water temperature and estuarine fauna

Deviation about long-term mean

Year

seatrout
red.drum
min temp
Charleston Hbr

Spotted seatrout
*Cynoscion nebulosus*

Red Drum
*Sciaenops ocellatus*
Relationships between water temperature and estuarine fauna

- Spotted seatrout: *Cynoscion nebulosus*
- Red Drum: *Sciaenops ocellatus*