Quantifying the marine radiocarbon reservoir effect for U.S. mid-Atlantic coastal waters

USGS science for a changing world

GC43D-0974

Claire Masteller[1] (cmast@sas.upenn.edu), E. Robert Thieler[2], Benjamin Horton[1], Candace Grand Pre[3]

1. Earth & Environmental Science, University of Pennsylvania, 2. USGS, Woods Hole, MA, 3. Earth & Environment, Franklin & Marshall College

Sea Level Research University of Pennsylvania

Abstract

The marine radiocarbon reservoir effect is an offset of 14C age between terrestrial and marine samples of the same calendar age due to delay in atmosphere-ocean exchange of CO2 and dilution with older deep waters. Currently, the global average marine reservoir age of surface waters is ~400 radiocarbon years. However, this value can differ regionally based upon climate, ocean circulation, and coastal morphology. Accurate quantification of the local marine reservoir effect is crucial in determining precise chronologies in paleoenvironmental studies that rely heavily on marine samples. This also requires samples collected live prior to the onset of extensive nuclear testing in the 1950s, which greatly increased atmospheric radiocarbon. Regional marine reservoir offset values (ΔR) are poorly known for the U.S. mid-Atlantic. Currently, there are only three specimens from New Jersey to North Carolina for which ΔR values have been calculated. The average marine reservoir correction for these samples is ΔR = 142 ± 34 years. To extend this database, we obtained 19 live-collected marine mollusks spanning coastal areas from New York to North Carolina from museum collections and submitted them for AMS radiocarbon dating. The calibrated ^{14}C ages will be compared to the date of collection, ranging from 1884 to 1945, in order to determine ΔR values for each specimen.

Background & Methods

What is the marine reservoir effect?

The marine reservoir effect is an offset in radiocarbon age between terrestrial and marine samples. The slow mixing of older deep water and younger surface water results in carbon deficiency in the ocean in relation to the atmosphere. Thus, organisms of terrestrial origin are more carbon-rich than their marine counterparts.

How does it vary regionally?

- Regional variation of the marine reservoir effect is heavily dependent on **local ocean currents** and **climate**.
- **Warmer surface currents** tend to have **reduced reservoir ages**, and are considered **younger.**
- **Regions of upwelling** present **greater ΔR values** due to the introduction of **colder, deeper, older waters**.

What data exists for the Mid-Atlantic?

– **From ^{14}CHRONO Database:**

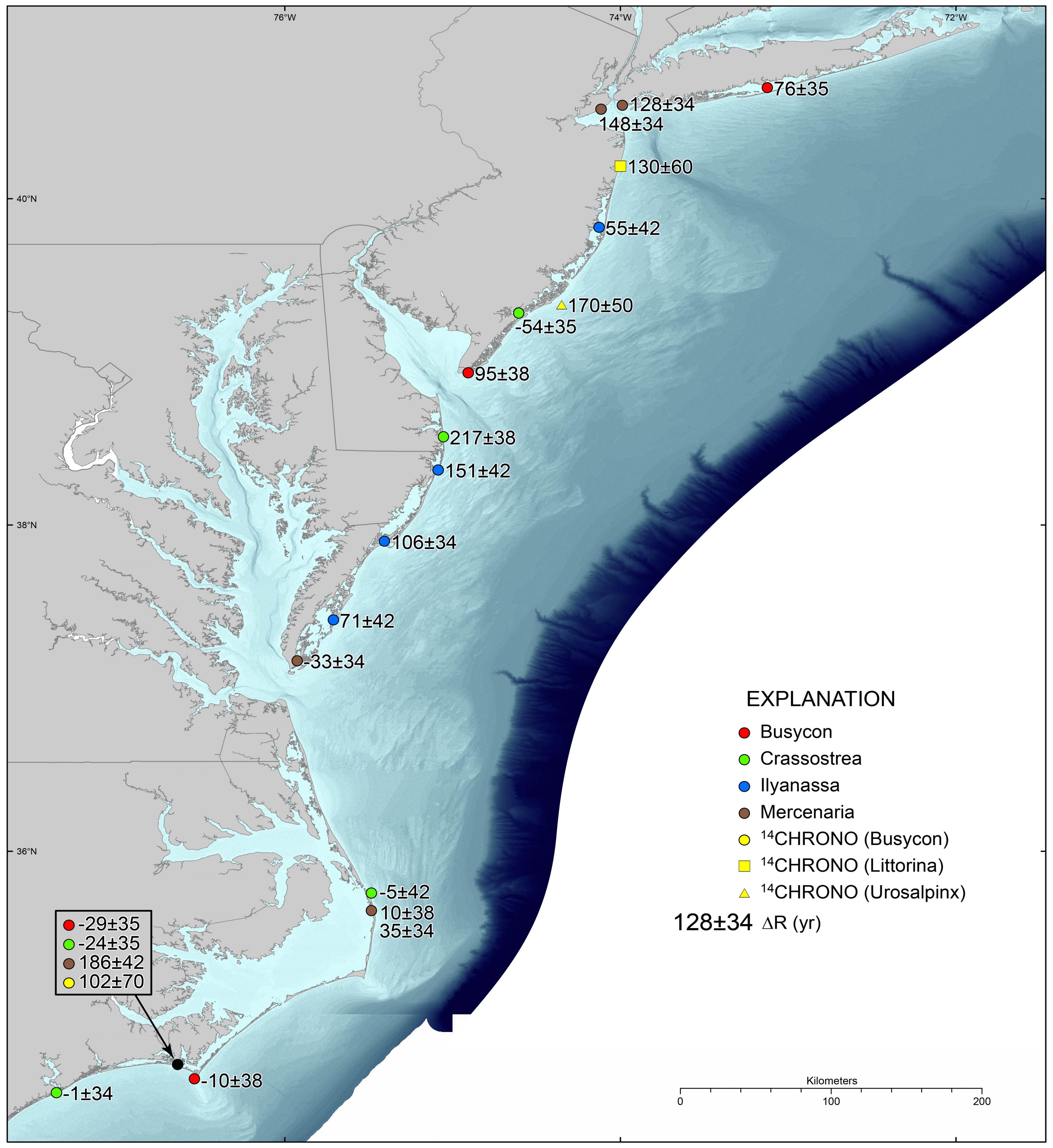
Species	Location	Lat.	Long.	ΔR	(+/-)	Reference
Busycon sp.	Beaufort, NC	37°40'54.95"N	76°40'32.16"W	**102**	70	D.H. Thomas, (2008)
Littorina littorea	Shark River, NJ	37°40'54.97"N	74°0'0.00"W	**130**	60	McNeely et al., (2006)
Urosalpinx cinerea	Atlantic City, NJ	37°33'16.33"N	74°20'60.00"W	**170**	50	McNeely et al., (2006)

How is the marine reservoir effect measured?

- Collect samples from marine species with **known date and location of collection** from museum archives
  - Must be **pre-1950** due to introduction of "bomb-carbon" through atmospheric nuclear weapons testing which almost doubled atmospheric ^{14}C
  - Assume that samples are **collected live**
- Determine **radiocarbon ages** of samples through AMS radiocarbon data. Samples in this study processed at NOSAMS
- Determine **model age** by converting actual age in BP to age in radiocarbon years using **MARINE09 calibration curve**.
- Compare **modeled age** of sample to **radiocarbon age** in radiocarbon years.
- The **difference** between **the radiocarbon age and the model age** yields the marine reservoir correction, or **ΔR value** in radiocarbon years

Dated Samples & Results

Spatial distribution of ΔR values



Radiocarbon data and calculated ΔR values

Sample Number	Species	Location	Lat.	Long.	Coll. Year	^{14}C Age	(+/-)	$\delta^{13}C$	Model Age	(+/-)	ΔR	(+/)
ERT-2011-023	*Busycotypus canaliculatus*	Great South Bay, NY	40°40'44.23"N	73° 7'23.50"W	1949	545	25	0.7	469	24	**76**	35
ERT-2011-018	*Mercenaria mercenaria*	Coney Island, NY	40°34'15.90"N	73°59'11.31"W	1936	585	25	0.65	457	23	**128**	34
ERT-2011-019	*Mercenaria mercenaria*	Staten Island, NY	40°32'52.30"N	74° 6'51.09"W	1934	605	25	-0.02	457	23	**148**	34
ERT-2011-027	*Ilyanassa obsoleta*	Barnegat, NJ	39°42'28.40"N	74° 7'48.42"W	1938	515	35	1.43	460	23	**55**	42
ERT-2011-021	*Crassostrea virginica*	Great Egg Harbor, NJ	39°18'12.72"N	74°31'59.04"W	1884	415	25	-0.04	469	24	**-54**	35
ERT-2011-024	*Busycotypus canaliculatus*	Cape May, NJ	38°55'54.86"N	74°54'20.09"W	1892	560	30	0.45	465	23	**95**	38
ERT-2011-022	*Crassostrea virginica*	Bethany Beach, DE	38°32'23.49"N	75° 3'12.89"W	1914	665	30	-2.01	448	23	**217**	38
ERT-2011-025	*Ilyanassa obsoleta*	Ocean City, MD	38°20'11.41"N	75° 5'5.66"W	1945	615	35	1.74	464	23	**151**	42
ERT-2011-026	*Ilyanassa obsoleta*	Chincoteague, VA	37°53'56.20"N	75°24'16.21"W	1932	560	25	2.08	454	23	**106**	34
ERT-2011-020	*Ilyanassa obsoleta*	Hog Island, VA	37°24'46.57"N	75°41'35.87"W	1884	540	35	1.58	469	24	**71**	42
ERT-2011-017	*Mercenaria mercenaria*	Magothy Bay, VA	37° 7'1.50"N	75°54'25.01"W	1916	425	25	0.71	458	23	**-33**	34
ERT-2011-003	*Crassostrea virginica*	Pea Island, NC	35°41'1.78"N	75°28'57.14"W	1938	455	35	-1.9	460	23	**-5**	42
ERT-2011-006	*Mercenaria mercenaria*	Pea Island, NC	35°41'1.78"N	75°28'57.14"W	1938	470	30	0.705	460	23	**10**	38
ERT-2011-009	*Mercenaria mercenaria*	Pea Island, NC	35°41'1.78"N	75°28'57.14"W	1938	495	25	1.27	460	23	**35**	34
ERT-2011-002	*Crassostrea virginica*	Beaufort, NC	34°41'34.40"N	76°38'16.47"W	1884	445	25	0.11	469	24	**-24**	35
ERT-2011-004	*Mercenaria mercenaria*	Beaufort, NC	34°41'34.40"N	76°38'16.47"W	1887	655	35	0.75	469	24	**186**	42
ERT-2011-013	*Busycotypus canaliculatus*	Beaufort, NC	34°41'34.40"N	76°38'16.47"W	1884	440	25	1.44	469	24	**-29**	35
ERT-2011-014	*Busycotypus canaliculatus*	Cape Lookout, NC	34°36'19.09"N	76°32'11.93"W	1939	450	30	0.58	460	23	**-10**	38
ERT-2011-001	*Crassostrea virginica*	Sneads Ferry, NC	34° 31.199'N	77°21'37.25"W	1926	450	25	-1.19	451	23	**-1**	34

Discussion

Potential Sources of Error:

– $\delta^{13}C$

- Offers insight regarding the amount of **freshwater influence** for a sample
- Purely marine samples are assumed to have a value of **zero** (Southon et al. 2002)
- $\delta^{13}C$ was used to aid in interpreting the ΔR values and understanding the **local environmental conditions**

– Species Selection

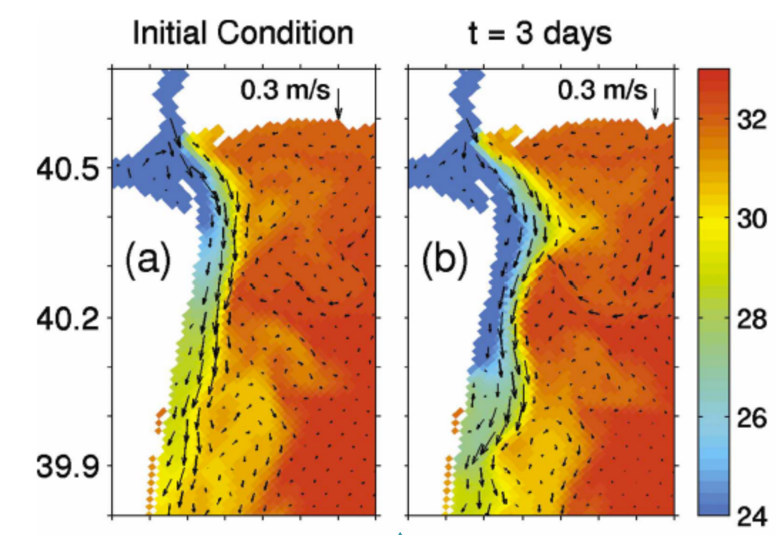
- Ideal species for a true marine reservoir correction are **subtidal filter feeders** such as *Mercenaria mercenaria*
- *Ilyanassa obsoleta* is a mud snail that mostly inhabits **estuaries**. Since it is not a purely marine species, **freshwater influx** may influence ΔR values – however, can provide a correction for estuarine areas

B. canaliculatus *Ilyanassa obsoleta* *Crassostrea virginica* *Mercenaria mercenaria*

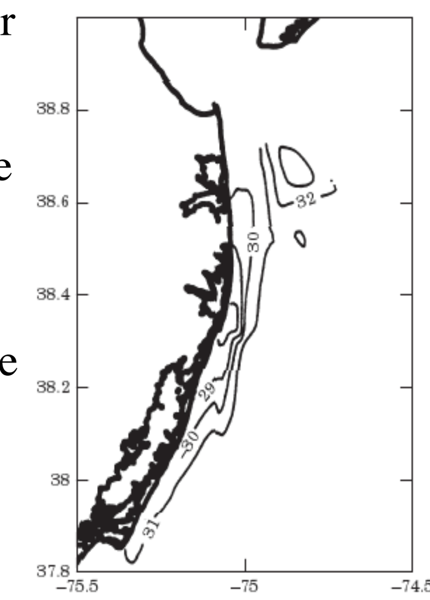
Regional Variation:

We see clear regional variations that can be divided into three sub-regions:

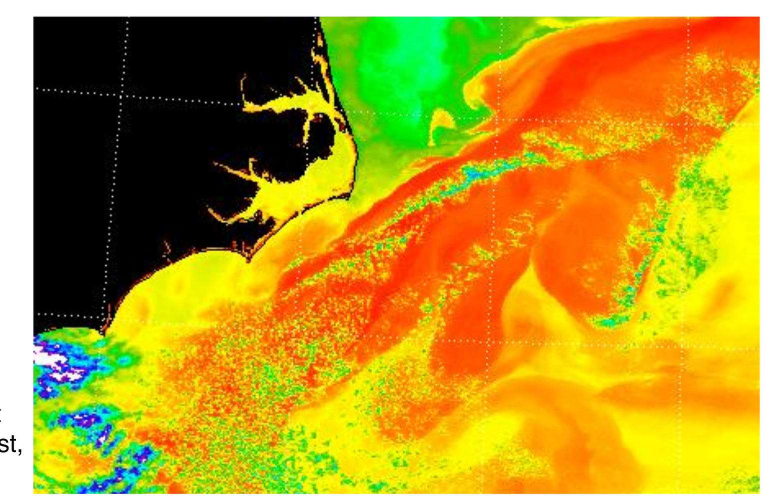
- **New York & New Jersey:** ΔR values are high near the mouth of the Hudson and decline to the south and east. We speculate reflect influx and subsequent mixing and dispersal of freshwater from the Hudson River plume.
- **Delmarva peninsula**: ΔR values are high at the mouth of Delaware Bay and decline along the Delmarva coast, similar to observations along the New Jersey coast. We speculate that the influx of freshwater from the Delaware River introduces ^{14}C-depleted water to the coast as it moves south as a coastally-trapped plume.
- **North Carolina:** Low ΔR values that we speculate reflect influx of relatively ^{14}C-rich surface waters (i.e., close to the ~400 year global average age) from the Gulf Stream.



Above: Model results showing Hudson river outflow behaving as a trapped coastal plume along the New Jersey coast. Our ΔR results appear to track the southward decline in fluvial-sourced carbon as well as the eastward limit of this plume. [Choi and Wilkin, 2007].



Left: Map of surface salinity expression of the Delaware Coastal Current (DCC) along the Delmarva coast during a field survey. Like the Hudson, the DCC is a coastally-trapped coastal plume under common oceanographic conditions. Similar to our ΔR results along the New Jersey coast, our results along the Delmarva coast appear to reflect the southward decline in fluvial-sourced carbon as the plume dissipates. [Epifanio and Garvine, 2001].



Right: Satellite temperature image of the Gulf Stream passing along the coast of North Carolina. Warmer colors correspond to higher water temperature. Our results suggest that the Gulf Stream influences ΔR values along the NC coast, making them similar to the global ocean (i.e., ΔR ~0 yr).

Acknowledgements

We gratefully acknowledge the Greg and Susan Walker Endowment for partial funding of this research. Dr. J. Wehmiller aided in sample preparation. Dr. J. Harasewych provided access to Smithsonian NMNH collections.