Wells (WEL) NERR Nutrient Metadata
January-December 2024
Latest Update: July 11th, 2025

Note: This is a provisional metadata document; it has not been authenticated as of its download date. Contents of this document are subject to change throughout the QAQC process and it should not be considered a final record of data documentation until that process is complete. Contact the CDMO (cdmosupport@baruch.sc.edu) or reserve with any additional questions.

I. Data Set and Research Descriptors

1) Principal investigator(s) and contact persons –

Jason Goldstein – Research Coordinator
Wells National Estuarine Research Reserve
342 Laudholm Farm Road
Wells, Maine 04090
Phone: 207-646-1555 x 136
Email: jgoldstein@wellsnerr.org

Jeremy Miller – SWMP Manager
Wells National Estuarine Research Reserve
342 Laudholm Farm Road
Wells, Maine 04090
Phone: 207-646-1555 x 136
Email: jmiller@wellsnerr.org

2) Research objectives –

a) Monthly Grab Sampling Program-
The monthly grab samples provide data for 5 additional water quality variables to supplement the 15-minute interval data stream from the YSI EXO's. Grabs are collected from a similar depth stratum as the YSI datalogger (within 1 m of the depth of the probes) at each site. These variables (nitrate, nitrate+nitrite, ammonium, orthophosphate, silicate and chlorophyll a), are important indicators of estuarine trophic status and point and non-point sources of nutrient enrichment. Although limited, these data enable estimation of average trophic status, and may demonstrate seasonal patterns. Our datalogger monitoring design allows for gradient analysis from head of tide to inlet in the Webhannet estuary, allowing comparison of the Little River and Webhannet River estuaries at their inlets, where they exchange water directly with the Atlantic Ocean. Monthly grab data provide the basis for investigation of questions regarding watershed and marine inputs of nutrients in Wells NERR estuaries, and nutrient influence on trophic status as indicated by chlorophyll a.

b) Diel Sampling Program-
At the Webhannet Inlet site, the monthly grab samples are augmented with a 24-hour sampling series (at 2 hr 15 min intervals for a total of 12 samples – 1 sample per 2 hr 15 min interval). These data can provide estimates of temporal variation in nutrients and chlorophyll on the scale of hours, providing a context for interpretation of data collected less frequently. This finer scale information will also inform interpretation SWMP grab sample data. These data can be used to investigate the relationship between nutrients, chlorophyll, and dissolved oxygen, an integrator of water column metabolism.

3) Research methods –

a) Monthly Grab Sampling Program
Monthly grab samples are collected at two sites in the Webhannet River Estuary and two sites in the Little River Estuary. These sites coincide with the four datasonde sites: Head of Tide (HT), Skinner Mill (SM), and Inlet (IN) in the Webhannet River; and the Mouth (LM) in the Little River. All grab samples are taken within a 24-hour period, and efforts are made to sample between +/- 3 hours slack low tide. Efforts are

also made to allow for a previous dry period of 72 hours prior to sampling, however this was not always possible due to lengthy periods of inclement weather. Replicate (N=2) 1-liter samples are collected at a depth of 0.5 meters below the water surface at the HT, SM, and LM sites. Replicate (N=2) samples at the IN site are taken by pumping the sample up through the ISCO sampler. All samples are collected in 1-liter wide-mouth amber Nalgene bottles that were previously washed with Fisher brand Versa-Clean and water, acid washed (10% HCl), rinsed (3x) with distilled-deionized water, dried, and rinsed (3x) with ambient water prior to collection of the sample. Samples are immediately placed on ice in a dark cooler, and returned to the laboratory for immediate processing.

b) Diel Sampling Program

Diel samples are collected once a month, during the same 24-hour period as our grab sample collection, at the Webhannet River Inlet (IN) datalogger site. An ISCO 6700 automated sampler is deployed on a floating dock at the Wells Harbor pier. As with the grab samples, efforts are made to begin the automated sampling between +/- 3 hours slack-low tide. Efforts are also made to allow for a previous dry period of 72 hours prior to sampling, however this was not always possible due to lengthy periods of inclement weather. Sampling events are staggered each month at the optimal low tide, given constraints of Reserve personnel scheduling. A 1-liter sample is taken every 2-hours and 15 minutes over the complete tidal cycle (just over 24hrs) for a total of 24 samples. All samples are pumped into ISCO 1-liter polypropylene wedge sample bottles that were previously washed with Fisherbrand Versa-Clean and water, acid washed (10% HCl), rinsed (3x) with distilled-deionized water and dried prior to collection of the sample. The ISCO sampler is filled with ice and/or frozen gel packs prior to deployment, and at the end of the 24-hour period the sample bottles are immediately capped, kept in the dark, and returned to the laboratory for immediate processing.

Once back in the Wells NERR laboratory, samples are shaken and processed for nutrient and Chlorophyll-a analysis. All samples are filtered at the Wells NERR. The Chl-a analysis is completed on-site at the Wells NERR laboratory with a Turner Designs 10-AU field fluorometer, and the nutrient analysis takes place at the Virginia Institute of Marine Science (VIMS).

The nutrient processing methodology includes filtering 50 ml of a sample through 25 mm, 0.45 μm HV Millipore Durapore® membrane filters using a Becton, Dickinson and Co. (BD) 60 ml polyethylene syringe with Luer-Lok® tip locked to a Millipore Swinnex 25 mm polypropylene filter holder. If a sample is particularly turbid, a 25 mm PALL A/E Glass Fiber Filter is used to filter the sample prior to filtering through the 0.45 μm Millipore filter, although this happens very rarely. The liquid volume of the filtered sample is collected into a Fisherbrand 50 ml polypropylene centrifuge tube (after rinsing collection tube (3x) with sample) and placed in the freezer and mailed overnight delivery to VIMS for analysis.

The Chl-a processing methodology here at the Wells NERR Research Laboratory follows the non-acidification method, "A Procedure For Measuring Extracted Chlorophyll a Free From The Errors Associated With Chlorophyll b and Pheopigments", adapted from the EPA Method 445.0: "In Vitro Determination of Chlorophyll a and Pheophytin a in Marine and Freshwater Algae by Fluorescence." This methodology involves filtering 200-1000 ml of a sample through 47 mm Whatman® GF/F filters using a vacuum pump and filter flask apparatus, and to determine the Chl-a concentration we use a Turner Designs 10-AU Field Fluorometer. Chlorophyll filters are held at -20ºC until analysis.

All laboratory glassware, centrifuge tubes, syringes, filter holders, 1-liter graduated cylinders, and forceps were previously washed with Fisherbrand Versa-Clean and water, rinsed (3x) with distilled-deionized water and dried prior to filtration of the sample; and rinsed (3x) between samples with distilled-deionized water to avoid any contamination.

4) Site location and character –

The Wells National Estuarine Research Reserve is located in York County, within the Town of Wells, on the coast of southern Maine and faces the Atlantic Ocean. The Wells NERR is approximately 31 km (20 miles) south of Portland, Maine and 110 km (70 miles) north of Boston, Massachusetts. The Reserve encompasses 1,690 acres along the Gulf of Maine coastline of tidally-flushed wetlands, riparian and transitional upland fields and forests within the Little River Estuary and the larger Webhannet River Estuary. Both estuaries arise in the sandy glacial outwash plain about eight miles inland. Both rivers empty into Wells Bay, a sandy basin stretching for approximately ten miles along the Atlantic coast. Bordering each river's inlet are double spit barrier beaches attached to the mainland. The backbarrier system in the Webhannet River Estuary is approximately 5 sq. km and is composed of large intertidal marshes (predominantly *Spartina patens* and *Spartina alterniflora*), intertidal sand and mud flats, and tidal channels. The watershed for the Webhannet River estuary covers an area of 35 sq. km and has a total of 6 streams, brooks or creeks, which enter the estuary. These tributaries flow across sand and gravel deposits near the headwaters and the impermeable sandy muds of the Presumpscot Formation in the lower reaches.

The watershed for the Little River estuary covers an area of 84 sq. km and has a total of 2 tributaries. The backbarrier system in the Little River Estuary is approximately 2.51 sq. km and is composed of large intertidal marshes (predominantly *S. patens* and *S. alterniflora*), intertidal sand and mud flats, and tidal channels. The Webhannet River is connected to the ocean via Wells Inlet, which has a spring tidal prism of 28,200,000 cubic meters (Ward 1993). The Little River is connected to the ocean by an unstructured, double spit system and is one of the few tidal inlets along the southern Maine coast that is not stabilized by either natural outcrops or artificial jetties. The force and volume of tidal action affect the salinity level of both rivers. In the Wells region, the annual mean wave height is almost 20 inches. These estuarine systems are dominated by semi-diurnal tides having a range of 8.5 to 9.8 feet. The volume of freshwater influx into both estuaries is moderate to low (on the order of 0.5 cubic meters/second), especially in the summer, because of the rivers' relatively small drainage areas and the presence of deep glacial deposits. The relatively low flows from these two rivers taken in with the 20 inch per year average runoff of the area surrounding the estuaries combine to form a fresh water flow, which is dwarfed by tidal flushing. Twelve-foot tides dwarf the freshwater flow into the Webhannet estuary, which has a drainage area of 14.1 square miles. The Merriland River and Branch Brook meet south of Route 9 to form the Little River, which drains an area of 10.75 sq. miles. The Webhannet estuary, fed by both Blacksmith and Depot Brooks, is adjacent to the harbor and greatly developed land. It offers a valuable opportunity for comparison with the relatively pristine Little River estuary. The land use of the Webhannet estuary include a total of 15% for wetland, fresh water, and tidal marsh; a total of 63.7 % for woodland; and a total of 18.6% for developed land compared to a total of 5.7% development in the Little River estuary (WNERR RMA 1996; Holden 1997).

The following information on the general climatology of Maine was taken from the "NOAA National Centers for Environmental Information; State Climate Summaries 2022)
(https://statesummaries.ncics.org/chapter/me/)

Maine is located on the eastern margin of the North American continent. Its northerly latitude and geographic location expose the state to both the moderating and moistening influence of the Atlantic Ocean and the effects of hot and cold air masses from the interior of the continent. Maine is also located within the primary storm track of the mid-latitudes. Maine's climate is characterized by cold, snowy winters and mild summers. Winter average temperatures range from 25°F in the far south to less than 15°F in the northern and interior portions of the state. Summer average temperatures range from near 60°F in the far north to near 70°F in the south. Maine is approximately 90% forested and has more than 3,500 miles of coastline, making forestry, fishery, hunting and fishing, tourism, and ecosystem services all sensitive to a changing climate.

Temperatures in Maine have risen almost 3.5°F since the beginning of the 20th century. Since the mid-1990s, the amount of winter warming has been approximately twice that of summer warming, with

persistently above average temperatures occurring since the 1990s. Winter warming is reflected in the number of very cold nights, which has been below average since the late 1990s. However, the number of hot days has not increased. Winter warming has resulted in earlier lake ice-out dates. On Damariscotta Lake, the average ice-out date during the mid-20th century was mid- to late April; it is now early April. The growing season has also lengthened.

Total annual precipitation in Maine reached a historically high multiyear average during the 2005–2009 period. In the harsh winter months, average accumulated snowfall ranges from 40 to 80 inches across the Southern Interior and Northern Interior climate divisions, with the northern tip of the state receiving up to 100 inches. The annual number of 2-inch extreme precipitation events has varied over the period of record, but the 10-year interval from 2005 to 2014 had a record number (nearly double the long-term average, similar to the rest of the northeastern United States. Maine has also been experiencing more short-term dry periods, with extreme drought occurring in 2002, 2016, and 2020. Drought conditions in 2020 contributed to more than 900 wildfires, the most Maine has seen in a decade.

Heat and cold waves, droughts, severe rainstorms, nor'easters, ice storms, and tornadoes are all part of Maine's normal climate. In general, nor'easters cause more disruption than any other type of extreme weather. Nor'easters are cold-season coastal storms that can generate a tremendous amount of precipitation (in the form of snow, sleet, or freezing rain), strong winds, coastal flooding, and damage to infrastructure. Observed wind speeds from nor'easters are commonly equal to or greater than those from hurricanes that have reached Maine. Nor'easters are prevalent in most years in winter, spring, and fall, while landfalling hurricanes are very rare. Since 1861, only 3 hurricanes have reached Maine with hurricane-force winds, the last being Gloria in 1985. Since 2007, weather-related disasters have been declared in every county in Maine.

There are two sampling sites in the Webhannet River estuary. These are located at the Head of Tide (HT) and at the Webhannet Harbor Inlet (IN). The tidal range at each of these sites is 2.6-2.9 meters.

The Head of Tide site (43 deg 17' 54.05" North, 70 deg 35' 13.54" West) is located 4 miles south of the Wells Reserve, just downstream of the Webhannet Falls (freshwater) and 10 feet east of U.S. Route One. U.S. Route One is used heavily by traffic all year, especially during the summer tourist months. This site has soft mud, sand, and a rocky substrate, and the low and high tide depth is relatively shallow. Depth at mean high water is 1.1 meters. Max and min measured depths are 0.2 to 1.6 meters, giving a max tidal range of 1.4 meters. The salinity range here is 0-31 ppt, with a mean of 3.6 ppt. These headwaters of the Webhannet are relatively undeveloped. This site is located just 10 feet east of the U.S. Route One bridge, and is our roving site.

The Inlet site is located 1.5 miles south of the Wells Reserve, at the Wells Harbor pier (43 deg 19' 12.32" North, and 70 deg 33' 48.39" West). The mouth of the Webhannet estuary forms an extensive wetland/salt marsh area which is surrounded by development. Wells Harbor, which was most recently dredged in 1971, has moorings for approximately 200 commercial fishing and recreational boats. The mouth of the river flows between two jetties to the Atlantic Ocean. This channel was dredged in 1974. This site has a predominately sand substrate and is characterized by strong current during incoming and outgoing tides. Max and min measured depths at the Inlet site are 1.2 to 5.9 meters, giving a max tidal range of 4.7 meters. The maximum depth of the Inlet site is 6.8 meters. The salinity range here is 7-35 ppt, with a mean of 31 ppt. The Inlet site is heavily impacted at the Wells Harbor dock and is our long-term monitoring site.

The Skinner Mill (SM) site is located approximately 100 meters downstream from the intersection of the Merriland River (tributary to Merriland/Branch/Little River estuary) and Skinner Mill Road (at 43 deg 20' 40.96" north and 70 deg 32' 57.18" West). This site is approximately 70 meters downstream from the Watershed Evaluation Team (Educational water quality program at Wells NERR) site L5. Substrate is mud/sand bottom, salinities range from 0 ppt on low or outgoing tides and as high as 27ppt on high tides. Max and min measured depths are 0.1 to 1.9 meters, giving a max tidal range of 1.8 meters. Depth at mean high water is 1.3 meters. Data prior to 5/30/2006 is from the original SM site located approximately 70 meters upstream from the current site, which is approximately 20-30 meters beyond the head of the estuary

where mixing between fresh and marine waters occur. Please see the 2005 Water quality metadata for a better description of the original site.

The Little River Mouth site is located 0.4 miles from the Wells Reserve. Due to problems with heavy sediment movement in the Inlet of the Little River, we were forced to relocate the site (see 2002 metadata). We designated a new location for the 2003 sampling season, and it has remained since then. It is located just off the bank of the marsh, in the main channel of the river (43 deg 20' 24.55" North, and 70 deg 32' 26.17" West). The first location attempted in 2002 (N 43 deg 20.176 Latitude, W 70 deg 32.497 Longitude) was located in the main channel of the river, just inland of a spit, beside a bank. The second location attempted in 2002 (N 43 deg 20.083 Latitude, W 70 deg 32.585 Longitude) was located 1/8 mi. southwest of the first site, within an Inlet, just inland of a spit. The second site was located in an area of much lower current than the first site and often drains completely during low tides. It was also placed within a pool next to incipient low marsh peat that retains calm water during low tides. Max and min measured depths at this site are 0.3 to 2.4 meters, giving a max tidal range of 2.1 meters. The Little River sites exist in a shallow and relatively pristine system with a sandy to mud bottom and a salinity range of 0-32 ppt. There are two major freshwater inputs, the Merriland and Branch Brook Rivers, which converge to form the Little River.

All Wells NERR historical nutrient/pigment monitoring stations:

Station Code	SWMP Status	Station Name	Location	Active Dates	Reason Decommissioned	Notes
welinnut	P	Inlet	Wells Harbor-Mouth of the Webhannet River	05/01/2002 - current	NA	NA
welhtnut	P	Head of Tide	Head of tide of Webhannet River	05/01/2002 - current	NA	NA
wellmnut	P	Little River Mouth	Mouth of the Little River Estuary	05/01/2002 – current	NA	NA
Welsmnut	P	Skinner Mill	Head of Tide of Little River Estuary	01/01/2004 – current	NA	NA
Welmlnut	D	Mile Road	Middle of Webhannet River	01/01/2002 – 12/31/2003	Unknown	none

5) Coded variable definitions –
Reserve code:

wel = Wells NERR

Station codes:
in = Webhannet River Inlet
sm = Skinner Mill (head of tide of Little River.)
ht = Head of Tide at Webhannet R.
lm = Little River Mouth

Program code:
nut = nutrient sampling program

These abbreviations are combined to form the sample name as follows:
welinnut = sample taken from Webhannet River Inlet as part of the Wells NERR nutrient sampling program

6) Data collection period –
Year in which monitoring started at each station:
Welinnut: 2002
welhtnut: 2002
wellmnut: 2002
welsmnut: 2004

Diel Sampling, every 2 hours, 15 minutes as follows: All diel sampling occurs at the welinnut site.

Diel Start	Diel End
1/23/2024 11:00	**1/24/2024 11:45**
2/20/2024 11:00	**2/21/2024 11:45**
3/26/2024 11:00	**3/27/2024 11:45**
4/21/2024 10:00	**4/22/2024 10:45**
5/13/2024 11:15	**5/14/2024 12:00**
6/24/2024 11:00	**6/25/2024 11:45**
7/16/2024 11:00	**7/17/2024 11:45**
8/22/2024 9:30	**8/23/2024 10:15**
9/19/2024 10:45	**9/20/2024 11:30**
10/22/2024 11:30	**10/23/2024 12:15**
11/20/2024 13:00	**11/21/2024 13:45**
12/16/2024 9:30	**12/17/2024 10:15**

Grab Sampling (once monthly):

Site	Date and Time of Grabs	
	Rep 1	Rep 2
welinnut	1/24/2024 12:05	1/24/2024 12:06
welinnut	2/21/2024 12:20	2/21/2024 12:21
welinnut	3/27/2024 12:06	3/27/2024 12:07
welinnut		
welinnut	5/14/2024 12:20	5/14/2024 12:21
welinnut	6/25/2024 12:50	6/25/2024 12:51
welinnut	7/17/2024 11:40	7/17/2024 11:41
welinnut	8/23/2024 10:20	8/23/2024 10:21
welinnut	9/20/2024 10:05	9/20/2024 10:06
welinnut	10/23/2024 12:40	10/23/2024 12:41
welinnut	11/21/2024 14:45	11/21/2024 14:46
welinnut	12/17/2024 11:15	12/17/2024 11:16

Site Date and Time of Grabs

**No grabs from Jan, Feb, Mar, and Dec due to ice conditions, April due to lost samples, and Nov/Dec due to construction at site*

	Rep 1	Rep 2
welhtnut		
welhtnut		
welhtnut		
welhtnut		
welhtnut	5/14/2024 12:22	5/14/2024 12:23
welhtnut	6/25/2024 12:38	6/25/2024 12:39
welhtnut	7/17/2024 10:03	7/17/2024 10:04
welhtnut	8/23/2024 10:03	8/23/2024 10:04
welhtnut	9/20/2024 10:12	9/20/2024 10:13
welhtnut	10/23/2024 12:30	10/23/2024 12:31
welhtnut		
welhtnut		

Site Date and Time of Grabs

**No grabs from Jan, Feb, March, and Dec due to ice conditions and April lost samples*

	Rep 1	Rep 2
wellmnut		
wellmnut		
wellmnut		
wellmnut		
wellmnut	5/14/2024 9:10	5/14/2024 9:11
wellmnut	6/25/2024 9:30	6/25/2024 9:31
wellmnut	7/17/2024 10:00	7/17/2024 10:01
wellmnut	8/23/2024 10:00	8/23/2024 10:01
wellmnut	9/19/2024 8:12	9/19/2024 8:13
wellmnut	10/23/2024 9:45	10/23/2024 9:46
wellmnut	11/21/2024 9:34	11/21/2024 9:35
wellmnut		

Site Date and time of Grabs

**No grabs from Jan-Mar, and Dec due to ice conditions and April lost samples*

	Rep 1	Rep 2
welsmnut		
welsmnut		
welsmnut		
welsmnut		

welsmnut	5/14/2024 10:45	5/14/2024 10:46
welsmnut	6/25/2024 11:30	6/25/2024 11:31
welsmnut	7/17/2024 10:05	7/17/2024 10:06
welsmnut	8/23/2024 11:00	8/23/2024 11:01
welsmnut	9/20/2024 9:40	9/20/2024 9:41
welsmnut	10/23/2024 9:47	10/23/2024 9:48
welsmnut	11/21/2024 10:30	11/21/2024 10:31
welsmnut		

7) Associated researchers and projects–

*__**Please visit our website: www.wellsreserve.org/research.htm for further information on the Wells NERR research program and for specific research projects and reports.**__

The Research Program at the Wells NERR conducts and supports research, monitoring, workshops, and research/resource management planning of relevance at local, regional and national levels. The overall aim of our work is to produce science-based information needed to sustain or restore Gulf of Maine coastal habitats and resources, especially those found in salt marsh estuaries and watersheds. During 2016 many different studies involving scores of scientists, students, staff and volunteers focused on several related themes: 1) the quality of water resources in salt marsh estuaries and watersheds 2) land conservation strategies to protect coastal watersheds 3) factors controlling salt marsh accretion, erosion and plant community vigor 4) the value of salt marsh as habitat for fish, shellfish and birds, 5) restoration of salt marsh habitat degraded through human actions, and 6) understanding the ecology and functions of salt marsh habitat.

NERRS SWMP Program:
As part of the SWMP long-term monitoring program, WEL NERR also monitors meteorological and water quality data which may be correlated with this nutrient dataset. These data are available from the Research Coordinator or online at http://cdmo.baruch.sc.edu/.

__**Salt Marsh Habitats and Communities**__

Factors that control the dynamics and vigor of salt marsh plant communities and marsh peat formation consequently determine the ability of a salt marsh to persist in the face of sea level rise. Through a combination of experimental manipulations and long term monitoring, a number of multi-year studies are currently producing data to answer questions concerning the sustainability of salt marsh habitats in this region. These studies are looking at nutrient-plant relations, plant community responses to physical and hydrologic disturbance, and the relative contribution of short-term natural events (e.g. storms) and human activities (dredging, tidal restriction) on patterns of sediment accretion and erosion. The Reserve's marshes and beaches are already among the best studied sites in the U.S. with regard to long term accretion and erosion (over thousands of years).

__**Monitoring tracks changes in the composition/phenology of larval fishes & invertebrates**__

The Research Associate and SWMP Coordinator will continue to conduct plankton monitoring at Wells Harbor (SWMP station; welinwq) four times monthly to better understand the community composition, diversity, long-term temporal dynamics, and phenology of ichthyoplankton and invertebrate assemblages within the Webhannet River Estuary. The SWMP Coordinator and Research Associate will oversee a core group of interns and volunteers who will help support these efforts by conducting sampling in the field, and sorting samples in the laboratory. We have expanded our laboratory processing to include separation and identification of all crab larvae to 1) inform our existing work investigating decapod ecology in estuarine systems; 2) improve our understanding

of seasonal patterns of crab spawning in Gulf of Maine estuaries; and 3) monitor the arrival of invasive or range expanding species such as the Blue crab (*Callinectes sapidus*).

Related to this, the SWMP Coordinator and Research Director have begun to integrate SWMP data into a community meta-analysis to better understand the impacts of environmental drivers on fish and crab community structure. The Reserve will work with individuals from NOAA's Southwest Fisheries Science Center and Gulf of Maine Research Institute to bring associated monitoring data into the forefront of the peer-reviewed literature and to expand our efforts to understand shifts in larval fish community dynamics in a rapidly warming Gulf of Maine. The Research Director and SWMP Coordinator will continue to pursue the development of a larger manuscript for peer review and publication, describing changes in the phenology and distribution of larval fishes in the Webhannet River Estuary. This continued work will improve upon our techniques for documenting and reporting changes in both fish and invertebrate larval assemblages in our system.

Monitoring the range expansion of blue crabs (*Callinectes sapidus*) into the Gulf of Maine

The blue crab (*Callinectes sapidus*) has been documented in salt marsh pools in the Webhannet and Little River estuaries at the Wells Reserve since 2020, as well as other locations in the northern New England region, indicating a range expansion of this species into the Gulf of Maine. We will monitor seasonal and spatial dynamics of blue crabs (and opportunistically other potential marsh crab species) that includes their spatio-temporal distribution in our estuarine systems by fishing a series of blue crab traps across a gradient of estuarine and salt marsh habitats in the Little River and Webhannet Estuaries. We will engage interns and volunteers to help monitor weekly changes in catch (CPUE), size distribution, sex ratio, and habitat usage over time (April-November). As opportunities arise, and through the facilitation of the newly-formed Gulf of Maine Blue Crab Network (led by Wells NERR), we will collaborate with other researchers in the New England region to catalyze expanded monitoring of this recent range expander and research into its impacts on Gulf of Maine ecosystems. Combined, these efforts will provide valuable information regarding the distribution, population dynamics, and impacts of blue crabs within this new expanded range.

Improving Business Practices to Reduce Mortality in the Lobster Supply Chain:

After being captured, lobsters (*Homarus americanus*) undergo several rounds of handling and processing prior to reaching consumers. Estimates suggest 3-5% of lobsters do not survive this process; this "shrink" in the supply chain results in tens of millions of dollars of lost revenue annually. This project aims to understand where in the supply chain lobster stress and mortality is greatest, as well as identifying specific causal factors (storage in warm water, rough handling, air exposure, etc.) which could be addressed to reduce lobster mortality. To do this, we are building novel sensor packages capable of monitoring the environmental and handling conditions lobsters are exposed to from the trap all the way to the dealer, and simultaneously measuring lobster viability using heart rate dataloggers coupled with lobster health assessments. The University of Maine is the primary recipient of the grant, but other partners include Saint Joseph's College of Maine and several industry partners. PIs: Ben Gutzler & Jason Goldstein. Funding from NOAA Saltonstall-Kennedy Fisheries Program.

Marine Invader Monitoring and Information Collaborative (MIMIC):

Researcher Associate at the Wells NERR act as State Coordinator for groups of citizen scientist who monitor 12 sites in coastal southern Maine for marine invasive species. Data has been being collected on the presence and absence, and general abundance of 23 priority species as identified by the Massachusetts Office of Coastal Zone Management and MIT SeaGrant.

In addition to the Reserve-sponsored projects outlined above, numerous visiting investigators will be involved in on-site research. Topics include: the effects of land use, sea level, and climate on estuarine productivity; the relationship between soil nutrients and plant community patterns; the influence of soil salinity on plant community interactions; the effect of tidal restriction on marsh peat accretion; the comparative ecology of fringe marshes and back barrier marshes; habitat use by upland birds, impacts of the invasive green Crab on salt marsh communities, and the ecology of lyme disease.

8) Distribution –

NOAA retains the right to analyze, synthesize and publish summaries of the NERRS System-wide Monitoring Program data. The NERRS retains the right to be fully credited for having collected and processed the data. Following academic courtesy standards, the NERR site where the data were collected should be contacted and fully acknowledged in any subsequent publications in which any part of the data are used. The data set enclosed within this package/transmission is only as good as the quality assurance and quality control procedures outlined by the enclosed metadata reporting statement. The user bears all responsibility for its subsequent use/misuse in any further analyses or comparisons. The Federal government does not assume liability to the Recipient or third persons, nor will the Federal government reimburse or indemnify the Recipient for its liability due to any losses resulting in any way from the use of this data.

Requested citation format:
NOAA National Estuarine Research Reserve System (NERRS). System-wide Monitoring Program. Data accessed from the NOAA NERRS Centralized Data Management Office website: www.nerrsdata.org; *accessed* 12 October 2024.

NERR nutrient data and metadata can be obtained from the Research Coordinator at the individual NERR site (please see Principal investigators and contact persons), from the Data Manager at the Centralized Data Management Office (please see personnel directory under the general information link on the CDMO home page) and online at the CDMO home page www.nerrsdata.org. Data are available in comma separated version format.

II. Physical Structure Descriptors

9) Entry verification –
[Instructions/Remove: This section explains how data acquisition, data entry, and data verification (QAQC) were performed before data were sent to the CDMO to be archived into the permanent database. Describe how your reserve receives data from the analytical laboratory, how it is entered into Excel, and how it is verified. If your reserve converts nutrient values to attain the required units of measurement, note that here and detail your process. List who was responsible for these tasks and include the following statement.]

Nutrient data are entered into a Microsoft Excel worksheet and processed using the NutrientQAQC Excel macro. The NutrientQAQC macro sets up the data worksheet, metadata worksheets, and MDL worksheet; adds chosen parameters and facilitates data entry; allows the user to set the number of significant figures to be reported for each parameter and rounds using banker's rounding rules; allows the user to input MDL values and then automatically flags/codes measured values below MDL and inserts the MDL; calculates parameters chosen by the user and automatically flags/codes for component values below MDL, negative calculated values, and missing data; allows the user to apply QAQC flags and codes to the data; produces summary statistics; graphs selected parameters for review; and exports the resulting data file to the CDMO for tertiary QAQC and assimilation into the CDMO's authoritative online database.

10) Parameter titles and variable names by category –

Required NOAA NERRS System-wide Monitoring Program nutrient parameters are denoted by an asterisk "*".

Required NOAA/NERRS System-wide Monitoring Program nutrient parameters are denoted by an asterisks "*".

Data Category	Parameter	Variable Name	Units of Measure

Phosphorus and Nitrogen:			
	*Orthophosphate	PO4F	mg/L as P
	*Ammonium, Filtered	NH4F	mg/L as N
	*Nitrite + Nitrate, Filtered	NO23F	mg/L as N
	Dissolved Inorganic Nitrogen	DIN	mg/L as N
Plant Pigments:			
	*Chlorophyll a	CHLA_N	µg/L
Other Lab Parameters:			
	Silicate, Filtered	SiO4F	mg/L as SI

Notes:
1. Time is coded based on a 2400 clock and is referenced to Standard Time.
2. Reserves have the option of measuring either NO2 and NO3 or they may substitute NO23 for individual analyses if they can show that NO2 is a minor component relative to NO3. WELLS NERR has shown NO2 to be a minor component.

11) Measured or calculated laboratory parameters –

a) **Parameters measured directly**

Nitrogen species:	NH4F, NO23F
Phosphorus species:	PO4F
Other:	CHLA_N, SiO4F

b) **Calculated parameters**

DIN	NO23F+NH4F

12) Limits of detection –

Method Detection Limits (MDL), the lowest concentration of a parameter that an analytical procedure can reliably detect, have been established by the VIMS Nutrient Analytical Laboratory. The MDL is determined as 3 times the standard deviation of a minimum of 7 replicates of a single low concentration sample. These values are reviewed and revised periodically.

Table 1. MDLs for reported parameters

Parameter	Start Date	End Date	MDL	Revisited
CHLA_N	01/01/24	06/24/2024	0.11*	Mar 2023
CHLA_N	06/24/24	12/31/2024	0.11	June 2024
PO4F	01/01/24	12/31/24	0.0016	Jan 2023
NH4F	01/01/24	12/31/24	0.0062	Jan 2023
NO23F	01/01/24	12/31/24	0.0055	Jan 2023
SiO4F	01/01/24	12/31/24	0.0062	Jan 2023

**NOTE* regarding Chlorophyll *a* limits of measurement:
The following article describes the method used:
"Method 445.0 *In Vitro* Determination of Chlorophyll *a* and Pheophytin *a* in Marine and Freshwater Algae by Fluorescence"
Elizabeth J. Arar and Gary B. Collins
Revision 1.2, September 1997
National Exposure Research Laboratory, Office of Research and Development, USEPA, Cincinnati, OH 45268

The above article states in section 1.2:
"Instrument detection limits of 0.05 µg chl *a*/L and 0.06 µg pheo *a*/L in a solution of 90% acetone were determined by this laboratory. Method detection limits (MDL) using mixed assemblages of algae provide little information because the fluorescence of other pigments interferes in the fluorescence of chlorophyll *a* and pheophytin *a*. A

single lab estimated detection limit for chlorophyll *a* was determined to be 0.11 µg/L in 10 ml of final extraction solution. The upper limit of the linear dynamic range for the instrumentation used in this method evaluation was 250 µg chl *a*/L."

The Reserve began to verify this MDL annually starting in March of 2023 when the MDL was found to be 0.11 mg/l.

13) Laboratory methods –
part I: Analysis conducted at Virginia Institute of Marine Science (VIMS) Once filtered, nutrient samples are frozen at -80°C then shipped overnight to VIMS where they are held at -20°C until analyzed.

Parameter: Orthophosphate (PO4F)
Method References: Virginia Institute of Marine Science Analytical Service Center.
SKALAR Method: O-Phosphate / Total Phosphate Catnr. 503-365.1, issue 042993/MH/93-Demo1. Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chim. Acta 27:31-36. EPA 600/R-97/072 Method 365.5 Determination of Orthophosphate in Estuarine and Coastal Waters by Automated Colorimetric Analysis. IN: Methods for the Determination of Chemical Substances in Marine and Estuarine Environmental Matrices - 2nd Edition. National Exposure Research Laboratory, Office of Research and Development. U.S. EPA, Cincinnati, Ohio 45268.

Method Descriptor: Instrumentation: SKALAR San-Plus continuous flow autoanalyzer. Ammonium molybdate and antimony potassium tartrate react in a sulfuric acid environment to form an antimony-phospho-molybdo complex, which is reduced to a blue colored complex by ascorbic acid. Reaction is heat catalyzed at 40°C and measured colorimetrically at 880nm. The range is 1-50 ppb. Preservation Method: 100 ml of a sample is filtered through 0.45 µm Millipore filters using a vacuum-pump and a filtering flask apparatus. If samples are extremely dirty a 47 mm GF/C filter may be used to filter the sample prior to filtering through the 0.45 µm Millipore filter. The liquid volume of the filtered sample is collected into a Nalgene bottle and placed in the freezer until shipment time arrives the following day.

Parameter: Nitrate + Nitrite (NO23F)
Method References: Virginia Institute of Marine Science Analytical Service Center.
SKALAR Method: Nitrate + Nitrite/ Total Dissolved Nitrogen Catnr. 461-353.2 issue 120293/MH/93128060.
U.S. EPA. 1974 Methods for Chemical Analysis of Water and Wastes, pp. 207-212. Wood, E.D., F.A.G. Armstrong and F.A. Richards. 1967. Determination of nitrate in seawater by cadmium-copper reduction to nitrite. J. Mar. Biol. Assoc. U.K. 47: 23. Grasshoff, K., M. Ehrhardt and K. Kremling. 1983. Methods of Seawater Analysis. Verlag Chemie, Federal Republic of Germany. 419 pp. EPA 600/R-97/072 Method 353.4 Determination of Nitrate and Nitrite in Estuarine and Coastal Waters by Gas Segmented Flow Colorimetric Analysis. IN: Methods for the Determination of Chemical Substances in Marine and Estuarine Environmental Matrices - 2nd Edition. National Exposure Research Laboratory, Office of Research and Development U.S. EPA, Cincinnati, Ohio 45268.

Method Descriptor: Instrumentation: SKALAR San-Plus continuous flow autoanalyzer. Nitrate is reduced to nitrite by a copper/cadmium reductor column. The nitrite ion then reacts with sulfanilimide to form a diazo compound. This compound then couples with n-1-napthylenediamine dihydrochloride to form a reddish/purple azo dye and is read colorimetrical at 540 nm. Nitrate concentration is obtained by subtracting the corresponding nitrite value from the NO3- + NO2- concentration. The color development chemistry is the same as that used in Nitrite. Range is 0-1.2 mg/L.

Preservation Method: 100 ml of a sample is filtered through 0.45 µm Millipore filters using a vacuum-pump and a filtering flask apparatus. If samples are extremely dirty a 47 mm GF/C filter may be used to filter the sample prior to filtering through the 0.45 µm Millipore filter. The liquid volume of the filtered sample is collected into a Nalgene bottle and placed in the freezer until shipment time arrives the following day.

Parameter: Ammonia (NH4F)
Method References: Virginia Institute of Marine Science Analytical Service Center. U.S. EPA. 1974. Methods for Chemical Analysis of Water and Wastes, pp. 168-174. Standard Methods for the Examination of Water and Wastewater, 14th edition. p 410. Method 418A and 418B (1975). Annual Book of ASTM Standards, Part 31. "Water", Standard 1426-74, Method A, p 237 (1976). EPA 600/R-97/072 Method 349.0. Determination of Ammonia in Estuarine and Coastal Waters by Gas Segmented Continuous Flow Colorimetric Analysis. IN: Methods for the Determination of Chemical Substances in Marine and Estuarine Environmental Matrices - 2nd Edition. National Exposure Research Laboratory, Office of Research and Development U.S. EPA, Cincinnati, Ohio 45268.

Method Descriptor: Instrument is SKALAR San-Plus continuous flow autoanalyzer. Alkaline phenol and hypochlorite react with ammonia to form indophenol blue that is proportional to the ammonia concentration. The blue color formed is intensified with sodium nitroprusside. Reaction is heat catalyzed at 37°C and is measured colorimetrically at 660 nm. The range is 0.01-2.0 mg/L.

Preservation Method: 100 ml of a sample is filtered through 0.45 μm Millipore filters using a vacuum-pump and a filtering flask apparatus. If samples are extremely dirty a 47 mm GF/C filter may be used to filter the sample prior to filtering through the 0.45 μm Millipore filter. The liquid volume of the filtered sample is collected into a Nalgene bottle and placed in the freezer until shipment time arrives the following day.

Parameter: Silicate (SiO4F)

Method References:
Virginia Institute of Marine Science Analytical Service Center. Technicon Industrial Systems Method: Silica. 1973. Technicon Auto-analyzer II Industrial Method No. 186-72W, Silicates in Water and Seawater.
U.S. EPA. 1982. Methods for Chemical Analysis of Water and Wastewater, 18th edition. Method 4500-Si F. Automated Method for Molybdate-Reactive Silica. pp. 4-122 through 4-123.
Grasshoff, K., M. Ehrhardt and K. Kremling. 1983. Methods of Seawater Analysis. Verlag Chemie, Federal Republic of Germany. pp. 175-180.

Method Descriptor:
Instrumentation: SKALAR San-Plus continuous flow autoanalyzer.
The determination of soluble silica is based on the reduction of silicomolybdate in acidic solution to "molybdenum blue" by ascorbic acid. Oxalic acid is added to eliminate interference from phosphates. The silicomolybdate complex is measured colorimetrically at 660 nm using the Auto-Analyzer II.

Preservation Method:
100 ml of a sample is filtered through 0.45 μm Millipore filters using a vacuum-pump and a filtering flask apparatus. If samples are extremely dirty a 47 mm GF/C filter may be used to filter the sample prior to filtering through the 0.45 μm Millipore filter. The liquid volume of the filtered sample is collected into a Nalgene bottle and placed in the freezer until shipment time arrives the following day. Samples may be kept up to 28 days.

Section 13, part II: Analysis conducted at Wells NERR.

Parameter: Chlorophyll a (CHLA_N)
Method References:
Wells National Estuarine Research Reserve Coastal Ecology Center Laboratory
Strickland, J.D.H., and Parson, T.R. 1972. A Practical Handbook of Seawater Analysis. Fish. Res. Bd. Canada 167:310.
TD-10-AU-005-CE Field Fluorometer Operating Manual. Version 1.4. April 1999. Turner Designs, 845 West Maude Avenue, Sunnyvale, CA 94086.
EPA - Method 445.0. In Vitro Determination of Chlorophyll a and Pheophytin a in Marine and Freshwater Algae by Fluorescence.

Using the Turner Designs Model 10 Analog, The 10AU Digital, Or the TD-700 Fluorometer with EPA Method 445.0. January 19, 1999. Turner Designs, 845 West Maude Avenue, Sunnyvale, CA 94086.
A Procedure For Measuring Extracted Chlorophyll a Free From The Errors Associated With Chlorophyll b and Pheopigments. Turner Designs, 845 West Maude Avenue, Sunnyvale, CA 94086. This method was developed by Dr. Nicholas A. Welschmeyer of Moss Landing Marine Laboratories, Moss Landing, CA. A paper by Dr. Welschmeyer, Fluorometric Analysis of Chlorophyll a in the presence of Chlorophyll b and Pheopigments, which details his research, appears in Limnology and Oceanography (June 1994).

Method Description:
Instrumentation: Turner Designs 10-AU-005-CE Field fluorometer.
The Chl-a processing methodology here at the Wells NERR Research Laboratory follows the non-acidification method, "A Procedure For Measuring Extracted Chlorophyll a Free From The Errors Associated With Chlorophyll b and Pheopigments", adapted from the EPA Method 445.0: "In Vitro Determination of Chlorophyll a and Pheophytin a in Marine and Freshwater Algae by Fluorescence." The method used requires filtering a known quantity of water through a glass fiber filter (47 mm GF/F). The sample is steeped in 90% acetone at least 2 hours and not exceeding 24 hours at 4°C, in the dark. The samples are centrifuged and read on the fluorometer. If the samples cannot be read within that time period, they are stored in the research freezer at -20ºC.

Preservation Method:
This methodology includes filtering 500 ml of a sample through 47 mm Whatman® GF/F filters using a vacuum pump and filter flask apparatus. The Whatman type GF/F filter is either folded immediately after sample filtering, enclosed in a waxed paper envelope, placed in a petri dish, wrapped with aluminum foil, placed in a sealed freezer bag, and placed in the freezer until analysis. The final concentration of Chl-a = (F x v)/V; where F = the direct fluorescence reading, v = volume of the extract, and V = volume of sample filtered.

14) Field and Laboratory QAQC programs –

a) **Precision**
   i) **Field variability** – True field replicates are taken at each site during grab sampling. Both replicate grabs are taken one immediately after the other.

   ii) **Laboratory variability** – See laboratory SOP from VIMS
   .
   iii) **Inter-organizational splits** – same samples were not split or analyzed by two different labs

b) **Accuracy**
   i) **Sample spikes** – none
   ii) **Standard reference material analysis –** See lab SOP above
   iii) **Cross calibration exercises** – The Wells NERR did not participate in any cross lab comparisons.

15) QAQC flag definitions –

QAQC flags provide documentation of the data and are applied to individual data points by insertion into the parameter's associated flag column (header preceded by an F_). QAQC flags are applied to the nutrient data during secondary QAQC to indicate data that are out of sensor range low (-4), rejected due to QAQC checks (-3), missing (-2), optional and were not collected (-1), suspect (1), and that have been corrected (5). All remaining data are flagged as having passed initial QAQC checks (0) when the data are uploaded and assimilated into the CDMO ODIS as provisional plus data. The historical data flag (4) is used to indicate data that were submitted to the CDMO prior to the initiation of secondary QAQC flags and codes (and the use of the automated primary QAQC system for WQ and MET data). This flag is only present in historical data that are exported from the CDMO ODIS.

-4 Outside Low Sensor Range
-3 Data Rejected due to QAQC
-2 Missing Data
-1 Optional SWMP Supported Parameter
0 Data Passed Initial QAQC Checks
1 Suspect Data
4 Historical Data: Pre-Auto QAQC
5 Corrected Data

16) QAQC code definitions –

QAQC codes are used in conjunction with QAQC flags to provide further documentation of the data and are also applied by insertion into the associated flag column. There are three (3) different code categories, general, sensor, and comment. General errors document general problems with the sample or sample collection, sensor errors document common sensor or parameter specific problems, and comment codes are used to further document conditions or a problem with the data. Only one general or sensor error and one comment code can be applied to a particular data point. However, a record flag column (F_Record) in the nutrient data allows multiple comment codes to be applied to the entire data record.

General errors

GCM	Calculated value could not be determined due to missing data
GCR	Calculated value could not be determined due to rejected data
GDM	Data missing or sample never collected
GQD	Data rejected due to QA/QC checks
GQS	Data suspect due to QA/QC checks
GSM	See metadata

Sensor errors

SBL	Value below minimum limit of method detection
SCB	Calculated value could not be determined due to a below MDL component
SCC	Calculation with this component resulted in a negative value
SNV	Calculated value is negative
SRD	Replicate values differ substantially
SUL	Value above upper limit of method detection

Parameter Comments

CAB	Algal bloom
CDR	Sample diluted and rerun
CHB	Sample held beyond specified holding time
CIP	Ice present in sample vicinity
CIF	Flotsam present in sample vicinity
CLE	Sample collected later/earlier than scheduled
CRE	Significant rain event
CSM	See metadata
CUS	Lab analysis from unpreserved sample

Record comments

CAB	Algal bloom
CHB	Sample held beyond specified holding time
CIP	Ice present in sample vicinity
CIF	Flotsam present in sample vicinity
CLE	Sample collected later/earlier than scheduled
CRE	Significant rain event

CSM	See metadata
CUS	Lab analysis from unpreserved sample
Cloud cover	
CCL	clear (0-10%)
CSP	scattered to partly cloudy (10-50%)
CPB	partly to broken (50-90%)
COC	overcast (>90%)
CFY	foggy
CHY	hazy
CCC	cloud (no percentage)
Precipitation	
PNP	none
PDR	drizzle
PLR	light rain
PHR	heavy rain
PSQ	squally
PFQ	frozen precipitation (sleet/snow/freezing rain)
PSR	mixed rain and snow
Tide stage	
TSE	ebb tide
TSF	flood tide
TSH	high tide
TSL	low tide
Wave height	
WH0	0 to <0.1 meters
WH1	0.1 to 0.3 meters
WH2	0.3 to 0.6 meters
WH3	0.6 to > 1.0 meters
WH4	1.0 to 1.3 meters
WH5	1.3 or greater meters
Wind direction	
N	from the north
NNE	from the north northeast
NE	from the northeast
ENE	from the east northeast
E	from the east
ESE	from the east southeast
SE	from the southeast
SSE	from the south southeast
S	from the south
SSW	from the south southwest
SW	from the southwest
WSW	from the west southwest
W	from the west
WNW	from the west northwest
NW	from the northwest
NNW	from the north northwest
Wind speed	
WS0	0 to 1 knot
WS1	> 1 to 10 knots
WS2	> 10 to 20 knots
WS3	> 20 to 30 knots
WS4	> 30 to 40 knots
WS5	> 40 knots

17) Other remarks/notes –

Data may be missing due to problems with sample collection or processing. Laboratories in the NERR System submit data that are censored at a lower detection rate limit, called the Method Detection Limit or MDL. MDLs for specific parameters are listed in the Laboratory Methods and Detection Limits Section (Section II, Part 12) of this document. Concentrations that are less than this limit are censored with the use of a QAQC flag and code, and the reported value is the method detection limit itself rather than a measured value. For example, if the measured concentration of NO23F was 0.0005 mg/l as N (MDL=0.0008), the reported value would be 0.0008 and would be flagged as out of sensor range low (-4) and coded SBL. In addition, if any of the components used to calculate a variable are below the MDL, the calculated variable is removed and flagged/coded -4 SCB. If a calculated value is negative, it is rejected and all measured components are marked suspect. If additional information on MDL's or missing, suspect, or rejected data is needed, contact the Research Coordinator at the reserve submitting the data.

Note: The way below MDL values are handled in the NERRS SWMP dataset was changed in November of 2011. Previously, below MDL data from 2007-2010 were also flagged/coded, but either reported as the measured value or a blank cell. Any 2007-2011 nutrient/pigment data downloaded from the CDMO prior to November of 2011 will reflect this difference.

Sample hold times for 2024: Samples are held at -20°C. NERRS SOP allows nutrient samples to be held for up to 28 days (CHLA for 30) at -20°C, plus allows for up to 5 days for collecting, processing, and shipping samples. Samples held beyond that time period are flagged suspect <1>and coded (CHB). If measured values were below MDL, this resulted in <-4> [SBL] (CHB) flagging/coding.

Date Samples Collected	**Date analysis conducted**	
Sample Collection (both diel and grabs)	**PO4F. NH4F, NO23F, and SiO4F**	**Chla**
1/24/2024 12:05	2/9/2024	2/25/2024
2/21/2024 12:20	3/22/2024	3/15/2024
3/27/2024 12:06	4/19/2024	4/25/2024
April 2024	N/A	N/A
5/14/2024 12:20	6/2/2024	6/24/2024
6/25/2024 12:50	7/12/2024	7/13/2024
7/17/2024 11:40	8/2/2024	9/20/2024
8/23/2024 10:20	9/4/2024	9/24/2024
9/20/2024 10:05	10/10/2024	9/24/2024
10/23/2024 12:40	11/22/2024	12/18/2024
11/22/2023 10:45	*1/3/2024 (samples held by VIMS for month…)	12/18/2024
12/21/2023 12:15	*1/17/2025 (samples held by VIMS for month…)	01/6/2025

References

Holden, W.F. 1997. Fresh water suspended sediments and nutrient influx into the Little River and Webhannet River estuaries, Wells, ME. Dissertation, Boston University, Boston, MA. 279 pp.

Mariano, C.G. and FitzGerald, D.M. 1989. Sediment transport patterns and hydraulics at Wells inlet, Maine. Boston University, Boston, MA. 143 pp.

Ward, L.G. 1993. Precipitation, streamflow, and water characteristics of the Webhannet River Estuary, Wells, Maine. Jackson Estuarine Research Lab, University of New Hampshire department of Earth Sciences, Durham, NH. 101 pp.

Wells National Estuarine Research Reserve. 1996. Reserve Management Plan. Reserve Management Authority, Wells, Me. 241 pp.