chapter eight

SALINITY

There are many types of water chemistry studies, including investigations of **ambient water quality** trends that typically involve several **parameters**, or specific investigations of suspected sources of pollution or parameters of interest. Ambient water quality sampling is usually conducted concurrently with the aquatic **invertebrate** and fish **monitoring** methods described in this handbook, and the parameters of interest include salinity, dissolved oxygen, pH, and temperature. Researchers usually collect measurements for a range of parameters with an automated water chemistry multimeter, which can be cumbersome to calibrate and prohibitively expensive for most volunteer monitoring groups. This chapter describes methods for a more specific investigation of one parameter — salinity — that is considered the most important chemical parameter in salt marshes and does not require the purchase of an expensive multimeter.

Tidal inundation controls **salinity regimes** in **salt marshes**. Salinity is highest in areas of estuaries closest to the ocean and in pools or pannes within salt marshes, and gradually declines in a landward direction as the effects of tidal inundation diminish. Perhaps the most recognizable consequence of salinity regimes in salt marshes is the vegetation **zonation** patterns (see Chapter Two). Some dominant salt marsh plants are **specialists** that require specific salinity ranges and cannot tolerate fresh water (i.e. *Spartina alterniflora* [smooth cordgrass]), whereas other plants can tolerate high salinity levels, but do not necessarily require it (i.e. *Spartina patens* [salt hay grass]). Some plant species are **generalists** because they can exist in a wide range of salinities. *Phragmites australis* (common reed) is an invasive species that is widespread in New England because it can tolerate saline, brackish, and freshwater conditions. Alterations to natural salinity regimes often result in the loss of specialist species and the spread of generalist or invasive species, which in turn affects plant and animal communities and the overall structure and function of salt marsh ecosystems.

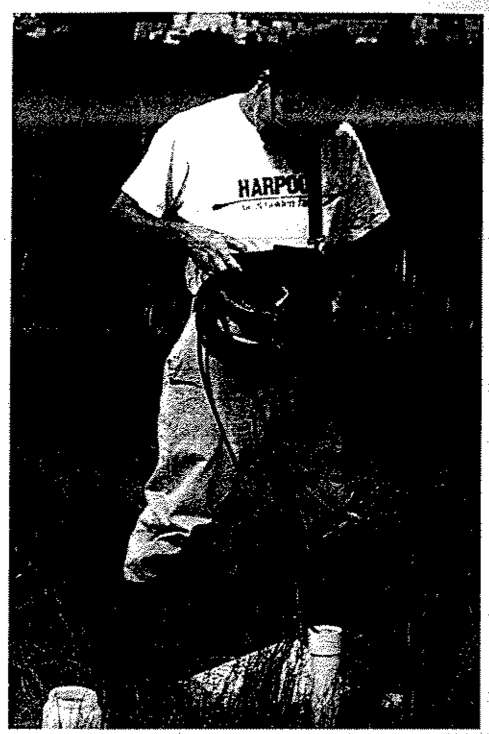
Measurements of salinity can help to explain the **diversity**, distribution, and **abundance** of plants and animals in a salt marsh. Salinity is also a critical parameter to measure when investigating any type of tide restriction or tide restoration project. Salinity measurements often provide a clear understanding of the effect of a tidal restriction, and careful measurements before and after the removal of a tide restriction can provide an excellent indication of the success of restoration efforts. The primary goals of programs that seek to restore tidal flow are the reestablishment of natural salinity regimes and restoration of biological communities.

EQUIPMENT

Table 1 lists the equipment needed for a salinity monitoring project. Water salinity is a relatively inexpensive parameter to incorporate into a monitoring program. A group that needs to buy all new equipment can expect to spend roughly $450. However, many of the more expensive pieces of equipment are also required for other parameters listed in this manual. For example, volunteers will need a measuring tape for vegetation, fish, macroinvertebrate, and tidal influence monitoring and will need an auger to collect invertebrates. It can be time consuming to assemble **groundwater** wells. Two people that are adept with power tools can build wells in an afternoon.

TABLE 1. EQUIPMENT FOR SALINITY MONITORING

EQUIPMENT
8 groundwater wells, constructed from the following materials:
3" plastic PVC pipe
PVC caps for pipe
Power drill to drill holes in PVC pipe
3/16, 1/4, or 3/8-inch drill bit
Permeable black garden mulching fabric
Duct tape
Water pump: Beckson Model #9A
Bailer: Forestry Suppliers, Inc., dimensions: 1.66"O.D., 36"L
Refractometer: VISTA Series Instruments Portable Refractometer (Model Number A366ATC (0-10% Sal.))
Measuring tape
Auger
Disposable paper cups
Plastic pipette
Dipper with long-handled stick
Tap water (in large container)
Deionized water
Field data sheets
Pencils



Measuring salinity with a digital multimeter.
Photo: Vivian Kooken

Volunteers can construct groundwater wells from materials that are available at hardware or garden supply stores. Investigators have developed a variety of groundwater well designs to suit specific conditions and data needs. For instance, some researchers install wells at different soil depths to obtain precise information about the vertical gradient of salinity in the **pore water**. This manual provides instructions for wells that integrate approximately 16 inches of subsurface soil, which represents the rooting zone for most salt marsh plants. Assembly and installation instructions are as follows:

Well Assembly (all measurements given are approximate and serve as guidance only!) (see Figure 1)

1. Cut a 3-foot section of 3-inch PVC pipe.
2. Drill 3/16 to 3/8-inch holes into the lower third of the pipe at a frequency of one hole per square inch.
3. Wrap the lower end of the pipe, including the opening and all of the drill holes, with garden mulching fabric and secure the fabric with duct tape.
4. Drill one 3/16 to 3/8-inch vent hole four inches from the top of the pipe.
5. Fit a screw top or cap (male and female adapters can be purchased to fit the pipe) over the top opening of the pipe, being careful not to cover the vent hole.

Well Installation

1. Using an auger, extract a 1-2 foot core of marsh sediment.
2. Gently push the lower end of the pipe (the end covered with fabric) into the hole, and make sure that the perforated section of the pipe is completely submerged into the ground.
3. To secure the well, pack the sediment extracted with the auger around the edge of the pipe.

SAMPLING METHODS

Deciding where to locate salinity **sample stations** can be subjective and should be done by an individual with some background knowledge in salt marsh vegetation. However, once the wells are in place, salinity sampling becomes a simple and straightforward exercise. As in all fieldwork, safety is the top priority. Work in teams and avoid entering the salt marsh alone.

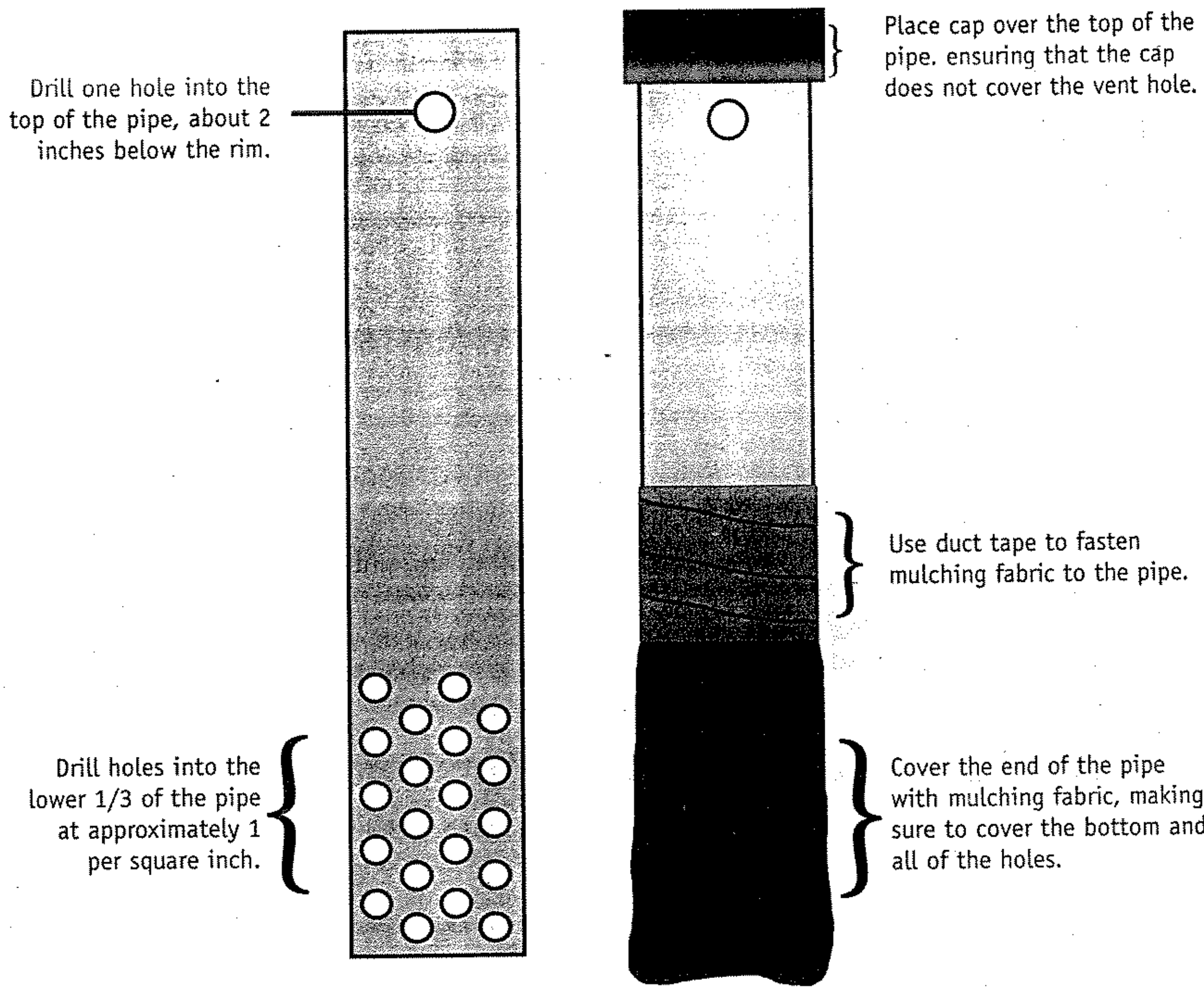


FIGURE 1. GROUNDWATER WELL ASSEMBLY See text for details.

Sampling Location

The number of sampling stations depends on the specific objectives of the study design. Obviously, increasing the number of sampling stations will increase your understanding of salinity regimes, but also requires more time, effort, and equipment. Investigators need to find a balance between data quantity and available resources (time and money). The protocols in this manual call for a minimum of six sampling stations per site, which includes three sampling stations located along two **transects** that bisect the **wetland evaluation area.** The textbox on the following page provides an example of the types of questions investigators should consider when establishing sampling locations.

Specific Guidelines for Transect & Sampling Locations

1. At each site, establish two transects perpendicular to the tidal creek or shoreline from the bank to the upland edge of the salt marsh. Transects should originate 150 feet and 300 feet from the tide restriction along the salt marsh creek (Figure 2). If you are studying a marsh that borders open water (not a tide restriction study), then establish two transects at opposite ends of the wetland evaluation area.
2. Install two groundwater wells along each transect, one closer to the bank (Well A) and the second near the upland edge of the salt marsh (Well B).
3. Collect surface water samples where each transect meets the creek channel, ditch, bay, or pond.

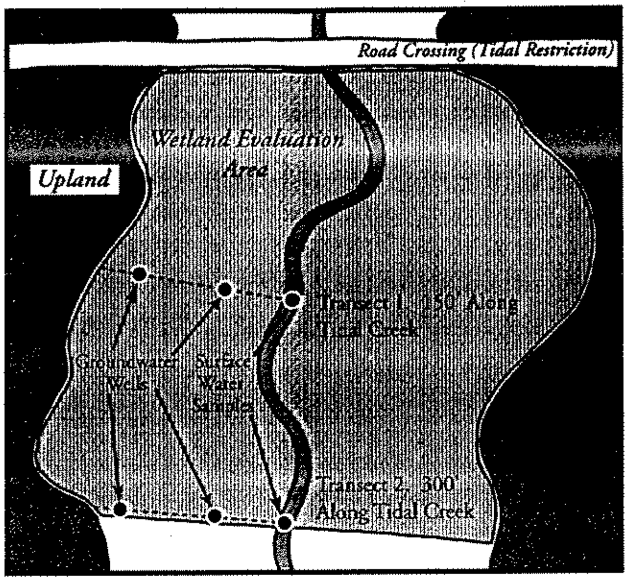


FIGURE 2. SAMPLE LOCATIONS
This figure shows transects and sample locations for one side of a tide restriction study. See text for details.

Data Collection

A **refractometer** is used to measure salinity. There are several different types of refractometers and users should be familiar with the specific instructions for their instrument. It is important that the refractometer have internal temperature compensation, otherwise the readings will have to be adjusted. Users must calibrate the refractometer before each sampling run, and rinse and dry the sensor (prism) with deionized water between readings.

At the minimum, collect samples monthly from July through September. Volunteer groups may want to collect samples more frequently, but as stated previously, investigators need to find a balance between data quantity and available resources. Volunteers should collect salinity measurements at low, late ebbing, or early flowing tides, as long as there is no surface water on the marsh near the wells. If there is surface water on the marsh, you should return later when the tide is low.

Specific Procedures for Collecting Samples

1. Use a hand-held pump to remove standing water from the groundwater well and wait for a few minutes until the well refills with pore water. This ensures that the water sample consists of pore water and not rain or surface water.
2. To be time efficient, pump out all wells within the marsh first, and then revisit them to obtain salinity readings.
3. Once a sufficient amount of water has recharged the well, extract a water sample using a **bailer**. Rinse the bailer with tap water before collecting water samples.
4. Pour the water sample from the bailer into a clean, dry Dixie® cup.
5. Use a plastic pipette (rinsed with deionized water between samples) to transfer sample water from the Dixie® cup to the sensor on the refractometer.
6. Read water salinity according to specific instructions for your refractometer.
7. Record the salinity measurement on the field data sheet.

To collect water from the creek channel, ditch, bay, or pond, use a Dixie® cup, bailer, or a cup on a pole depending on how easy it is to reach the water. If using either the bailer or a pole, be sure to rinse those pieces of equipment with tap water prior to use.

PLACEMENT OF GROUNDWATER WELLS

Where on your transect do you place Well A and Well B? Well A is installed closer to the salt marsh creek than Well B, which is located near the upland edge of the marsh. Vegetation patterns within the marsh may influence your decision on where to place the wells. Here is an example of this thought process:

You are standing on a transect in a marsh study site and just placed Well A in a *high marsh* community dominated by *Spartina patens* and *Distichlis spicata*. While determining where to install Well B, you notice a stand of *Scirpus robustus* (Salt marsh bulrush) near the upland edge of the salt marsh you are studying. Your research indicates that this plant species enjoys more brackish conditions. Is there a fresh groundwater seep in your salt marsh? Does this area of marsh receive an abundance of freshwater runoff? You decide to place Well B within that stand of *Scirpus robustus* to better understand the salinity patterns at work there.

Volunteers being trained to monitor salinity. **Photo: Vivian Kooken**

DATA ENTRY

Volunteers should use one field data sheet for both the study site and **reference sites**. A blank standard field data sheet is provided in Appendix 1 of this chapter. Project leaders can modify field data sheets according to specific objectives of the study. For example, studies that examine additional study and reference sites, transects, or ground-water wells will need to adjust field data sheets accordingly.

Data entry occurs both in the field and in the office. Users should carefully record all of the information requested on the field data sheet, and make sure that site-specific information is recorded in the proper location. The standard field data sheet is organized to clearly distinguish study sites, transects, and sampling stations. Investigators should fill out field forms neatly and thoroughly to ensure that no critical information is omitted. It is frustrating to return to the office or laboratory after a long day in the field and realize that you forgot to record important information!

In the office, investigators should transfer data into a computer spreadsheet such as Microsoft Excel. On the computer spreadsheet, create clearly-marked columns for site name, date, transect number, station, time of high tide, time sampling began, and salinity. Tables 2 and 3 show example data for a study site and reference marsh in Gloucester, Massachusetts; only data for transect #1 is shown and it is intended for illustrative purposes only. Table 2 has row (1-13) and column (A-G) identifiers that are used to identify individual cells, similar to how a computer spreadsheet is organized.

Looking through a refractometer. **Photo: Vivian Kooken**

TABLE 2. EXAMPLE DATA ENTRY SPREADSHEET

	A	B	C	D	E	F	G
1	**SITE**	**DATE**	**TRANSECT**	**STATION**	**TIME OF HIGH TIDE**	**TIME BEGIN SAMPLING**	**SALINITY (PPT)**
2	Gloucester-Study	7/13/00	1	Channel	10:31	16:00	25.0
3	Gloucester-Study	7/13/00	1	Well A	10:31	16:00	18.0
4	Gloucester-Study	7/13/00	1	Well B	10:31	16:00	11.0
5	Gloucester-Ref	7/13/00	1	Channel	10:31	16:00	26.0
6	Gloucester-Ref	7/13/00	1	Well A	10:31	16:00	20.0
7	Gloucester-Ref	7/13/00	1	Well B	10:31	16:00	15.0
8	Gloucester-Study	8/2/00	1	Channel	23:09	11:30	7.0
9	Gloucester-Study	8/2/00	1	Well A	23:09	11:30	8.0
10	Gloucester-Study	8/2/00	1	Well B	23:09	11:30	5.0
11	Gloucester-Ref	8/2/00	1	Channel	23:09	11:30	12.0
12	Gloucester-Ref	8/2/00	1	Well A	23:09	11:30	20.0
13	Gloucester-Ref	8/2/00	1	Well B	23:09	11:30	7.0

TABLE 3. EXAMPLE AVERAGE SALINITY DATA

SITE	**TRANSECT**	**STATION**	**SALINITY (PPT)**	**FORMULA** (from Table 2)
Gloucester - Study	1	Channel	16.0	=average(G2,G8)
Gloucester - Study	1	Well A	13.0	=average(G3,G9)
Gloucester - Study	1	Well B	8.0	=average(G4,G10)
Gloucester - Study	1	Combined	12.3	=average(G2:G4,G8:G10)
Gloucester - Reference	1	Channel	19.0	=average(G5,G11)
Gloucester - Reference	1	Well A	20.0	=average(G6,G12)
Gloucester - Reference	1	Well B	11.0	=average(G7,G13)
Gloucester - Reference	1	Combined	16.7	=average(G5:G7,G11:G13)

Once you have entered all of your data (2 sites x 2 transects per site x 3 stations per transect x 3 sample dates = 36 salinity measurements), create a second table to compute average values for different combinations of sample date, site location, transect, and station location; specific combinations will depend on the scope of your salinity study. You may customize the spreadsheet to calculate average salinity for each station using formulas shown in Table 3.

DATA ANALYSIS AND COMPARISON

Once investigators complete data entry and compute average salinity, they can graph average salinity to provide a visual representation of salinity differences between the study site and reference site (Figure 3).

Volunteers can review data sets in the field after completing salinity sampling to get a sense of the salinity regimes within the salt marsh. However, one day's worth of salinity measurements gives only a snapshot of the salinity levels within a marsh. Volunteers can get a much better understanding of salinity regimes by taking multiple measurements over time, averaging these measurements, and comparing averages between wells, transects, or sites.

Two common comparisons are:

- Compare salinities at different sampling stations within a marsh. This may provide insight on the spatial extent of seawater inundation and influence within a marsh, and can help explain distribution patterns of plants and animals.

- Compare salinities at different marshes, such as the study site and reference site. This may provide insight about the effect of a tidal restriction on salinity regimes, and/or help explain why the plant and animal communities differ between two marshes.

Comparing average salinity data is subjective. It is important to note the error of the refractometer used to measure salinity, which may be as much as 1.0 ppt. Only salinity differences that exceed the error of the refractometer are considered significant. At what point is the difference in salinity between two marshes large enough to warrant closer examination? This is a difficult question to answer, and is usually left to the project leader. If volunteers detect a large difference in the salinity regime of two marshes, they should carefully examine all potential causes and the consequences for the marsh **community**. In many instances, salinity regimes differ because of natural phenomena, and investigators should not necessarily presume that humans are responsible.

	Salinity (ppt)	
Station	**Study Site**	**Reference Site**
Channel	27.5	30.7
Well A	28.9	31.3
Well B	27.5	28.7
Combined	28.0	30.2

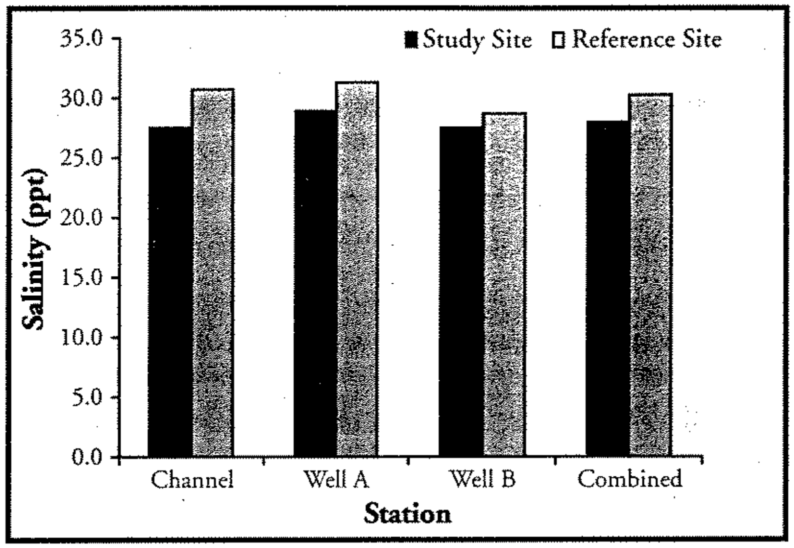


FIGURE 3. DISPLAYING AVERAGE SALINITY

References and Other Suggested Reading

Brown, M.T., K. Brandt, and P. Adamus. 1990. Indicator fact sheets for wetlands. In: *Ecological Indicators for the Environmental Monitoring and Assessment Program* (Hunsaker and Carpenter, eds.). US EPA, Office of Research and Development. EPA 600/3-90/060.

Carlisle, B.K., A.L. Hicks, J.P. Smith, S.R. Garcia, and B.G. Largay. 1998. *Wetland Ecological Integrity: An Assessment Approach: The Coastal Wetlands Ecosystem Protection Project.* MCZM, Boston, MA.

Hemmond, H.F. and J. Benoit. 1988. Cumulative impacts on water quality functions of wetlands. *Environmental Management* 12(5):6639-6653.

Leibowitz, N.C. and M.T. Brown. 1990. Indicator strategy for wetlands. In: *Ecological Indicators for the Environmental Monitoring and Assessment Program.* Hunsaker and Carpenter (Eds.) US EPA, Office of Research and Development. EPA 600/3-90/060.