chapter six

FISHES AND CRABS

Salt marshes support diverse and abundant **populations** of creatures that swim; these organisms are collectively called **nekton** and include fishes and many types of **invertebrates**. This chapter focuses on fishes and crabs that occupy estuarine **wetlands**. Salt marshes support most life stages of fishes and crabs, which are essential components of the **food web** and represent a large proportion of the total animal biomass and biological **diversity** in a marsh. Some **species** spend only a small portion of their lives in salt marshes, whereas others rarely ever leave. Mummichogs and fourspine sticklebacks are two species that reside in marshes throughout their lives and contribute to the environmental condition of near shore environments. Transient species use salt marshes during critical development periods such as **spawning** or juvenile rearing and are important seasonal components of salt marsh condition. Transients include forage species such as the Atlantic silverside, and commercial and sport species such as winter flounder and blue crab.

It is challenging to sample nektonic organisms because their distribution and **abundance** varies greatly throughout the marsh and over time. The use of salt marshes by fishes and crabs can vary from tide to tide, marsh to marsh, species to species, and year to year. Even meteorological events such as a full moon or new moon will influence what you are likely to find in a salt marsh. Unlike plants or benthic invertebrates, nektonic animals are highly mobile and difficult to capture. Despite these challenges, fishes and crabs are fun to study and learn about, can be important **indicators** of salt marsh condition, and in many cases are the impetus for marsh restoration (Burdick et al. 1999).

Scientists do not fully understand the influence of marsh degradation on fishes and crabs, though they continue to investigate this important topic. Tide restrictions may alter fish and crab communities by reducing **habitat** availability, accessibility, and quality on the restricted side. Many species are **sensitive** to changes in dissolved oxygen, salinity, and nutrient levels that result from pollution and surface runoff. Changes to salt marsh vegetation resulting from upland **human disturbance**, alterations to natural **hydrology**, or invasive species may affect fishes or crabs that require native or natural plant communities.

This chapter provides volunteer monitors with the tools and instructions necessary to monitor the presence and relative abundance of fishes and crabs in submerged salt marsh habitats, and investigate differences between different sites. Submerged salt marsh habitats include tidal creeks, channels, near shore embayments, and salt ponds that are completely underwater during all tidal cycles (or during the majority of low tide). This chapter does not provide instructions for **monitoring** high marsh habitats, which requires different methods and equipment.

EQUIPMENT

There are a variety of equipment and methods used to collect salt marsh fishes and crabs, each suitable for different conditions, habitats, and target organisms. This chapter describes the equipment and methods required to use minnow traps and bag seines. Table 1 lists the equipment

TABLE 1. EQUIPMENT FOR NEKTON SAMPLING

ITEM	PURPOSE	DESCRIPTION
6 Minnow Traps	Collect creatures	Wire mesh traps
Two Seines Bag seine Stop Net	Bag seine catches fishes and crabs Stop net hinders fishes and crabs from escaping in front of seine	Bag seine: 4' (height) x 6' (width) Stop Net: 4'(height) x 4' (width)
Picking Nets (fine net)	Sub-sample and weigh fish	Standard aquarium net
Fish Measuring Board	Measure fish and crabs (length)	Metric ruler on board (millimeters)
Scale	Measure fish and crabs (weight)	Spring-loaded scale (grams)
3 five gallon buckets	Store and process samples	
Water quality instrument	Measure water quality parameters (temperature, salinity, and dissolved oxygen)	Example: YSI multi-parameter instrument (expensive; efficient) or chemical water test kits (inexpensive; time consuming)
Ethyl alcohol solution 70%	Preserve specimens	
Polypropylene bottle	Container for preserved creatures	Jar with water-tight lid
Chest waders and/or Neoprene boots	Walking through the marsh	
Clipboard, data sheets, pencil	Organize and collect field data	
Fish identification guides	Identify creatures in the field	Example: Peterson's Field Guide to Atlantic Coast Fishes

you will need for both methods and general equipment that you will need regardless of the method you use. The following section, "Sampling Methods," describes and compares different methodology for collecting fishes and crabs in estuarine wetlands.

SAMPLING METHODS

The goals and objectives of your study should dictate your sampling methods. Project leaders should examine a variety of methods that will effectively achieve monitoring objectives. One method will not characterize the entire fish and crab **community** or populations, rather a combination of methods are used to sample particular marsh habitats. Initially, monitoring efforts will usually attempt to gather baseline information on species presence and relative abundance to evaluate potential differences between reference and study sites and allow evaluation of monitoring techniques. Volunteers can easily obtain **qualitative** information about common marsh species (Burdick et al. 1999). **Quantitative** estimates are possible as volunteers gain experience with salt marsh sampling. Innovative ideas for sampling fishes and crabs are encouraged because of the variety of organisms that are encountered and the variety of environmental conditions that exist within and between evaluation areas.

Caution!

Salt marshes can present a variety of challenges that affect seine efficiency. It is difficult to seine creeks that are deep or have a strong current, and can be dangerous for volunteers. In potentially dangerous situations, samples should be collected when conditions are less severe, or not at all.

Table 2 lists the advantages and disadvantages of different types of equipment and methods. Equipment and sampling methods will influence the amount of area that can be sampled, the ease of taking multiple samples at different locations or dates, **catch efficiency** (the success of collecting species in an area), and **catch stability** (the success of collecting species at different locations or times). Rozas and Minello (1997) present a discussion of the relative merits of different sampling gear.

This manual recommends the use of minnow traps and haul seines. Minnow traps and haul seines are effective for collecting fishes and crabs and are widely used in marsh monitoring because they are easy to deploy and retrieve,

TABLE 2. ADVANTAGES AND DISADVANTAGES OF DIFFERENT SAMPLING METHODS

GEAR TYPE	ADVANTAGE	DISADVANTAGE
Enclosures Throw Traps Lift Nets	Collect from known area Can yield quantitative data Can be used in a variety of habitats Will collect many species	Variable catch efficiency Awkward to throw Difficult sampling fishes in trap High initial construction time High maintenance
Passive Traps Minnow Traps Breder Traps	Will collect common marsh species Easy to deploy and retrieve Easy to collect multiple samples Only need two people Inexpensive	Collect from unknown area Only yields qualitative data Will not collect all species CPUE highly variable with minnow traps
Towed Nets Bag Seine Otter Trawl	Collect from known area Can yield quantitative data Will collect many species	Variable catch efficiency High initial cost High maintenance and labor intensive

sampling is repeatable, and start-up cost is relatively low. Minnow traps are easy to use, and catch efficiency can be stable if traps are placed in appropriate locations. Minnow traps will effectively catch killifishes (such as mummichogs) and lower numbers of other resident and transient species (such as sticklebacks and American eel). Catch stability is low with seines, but seines can capture a variety of fish and crab species in a sample area. Both techniques are easy to learn, and as volunteers become more familiar with the gear, catch efficiency and stability will increase.

Fishes and crabs can be sampled year-round, but this manual recommends June to September. Greater collection frequency improves the rigor of the data. Tidal stage and water level influence catch efficiency and species presence, so all sampling should occur at similar tidal stages or tidal cycles. Once you select **sample stations**, you should mark their locations with stakes or flagging, or record their position using high-accuracy **GPS** receivers (such as differential GPS). Use the same sample stations for the duration of the study to reduce variability in fish and crab communities caused by small-scale variability of habitat conditions. The following section describes the steps in collecting minnow trap samples and haul seine samples.

Collecting Minnow Trap Samples

1. You will need a total of six minnow traps for each sampling date — three for the study site and three for the reference site.
2. Place three minnow traps in the study and reference area (six total traps). The traps are equally spaced along the study and reference gradient; that is, for a 100 meter stretch, traps are located at 0m, 50m, and 100m.
3. Position the traps at the edge of the tidal creek, and be sure that they are completely submerged at low tide.
4. Place weight (rocks work well) in the traps so they will sink and remain on the bottom.
5. Deploy minnow traps for a specific tidal cycle (i.e., low tide to high tide or low tide to low tide). The soak time (hours in the water) corresponds to the tidal cycle and standardizes catches to time. Do not leave traps in the water if water subsides below trap at low tide.
6. Retrieve the traps and empty individual traps into individual buckets of water.
7. Process the sample (see below).
8. Take water quality readings at deployment and retrieval (see below).

Collecting Bag Seine Samples

1. You will collect six seine samples for each sampling date — three for the study site and three for the reference site.
2. Seine stations are equally spaced along the reference and study tidal creek. Identify the stretch of creek to survey and fix study and reference stations. Do not overlap stations.
3. Collect seine samples at the same tidal stage. Take samples during a moving tide (i.e., flood or ebb). This reduces the effects of tide on the composition and relative abundance of fishes and stabilizes seine efficiency.

4. Seining requires a minimum of three people. One person handles the stop net and two people handle the seine.
5. Make sure that sufficient weights are attached to the bottom of the seine so that the net drags along the bottom.
6. Place the stop net at the upstream end of your sample location.
7. Begin seining 10 meters downstream from the stop net and pull the seine upstream toward the stop net.
8. Haul the seine onto the marsh surface (out of the creek). Grab the bottom line to prevent creatures from escaping under the net as you pull the net out of the creek.
9. Place fishes and crabs from the bag seine into a bucket of water.
10. Process the sample (see below).
11. Take water quality readings prior to each seine (see below).

Sample Processing & Water Quality Measurements

Follow these steps for both the minnow trap samples and bag seine samples. However, if you collect large numbers (>40) of particular species you should also follow the sub-sampling procedure outlined below.

1. For each sample, identify all fishes and crabs to species and count the numbers of each species.
2. Measure length of each organism to the nearest millimeter. You should measure standard length (SL) of fish and carapace length of crabs (CL) (Figure 1).
3. Weigh each species to nearest gram. For example, if you have 10 blue crabs then you would weigh all 10 together to determine the **aggregate weight**.
4. Note any external abnormalities, such as **skin lesions** or **parasites**.
5. Return creatures to the water as soon as possible to limit mortality.

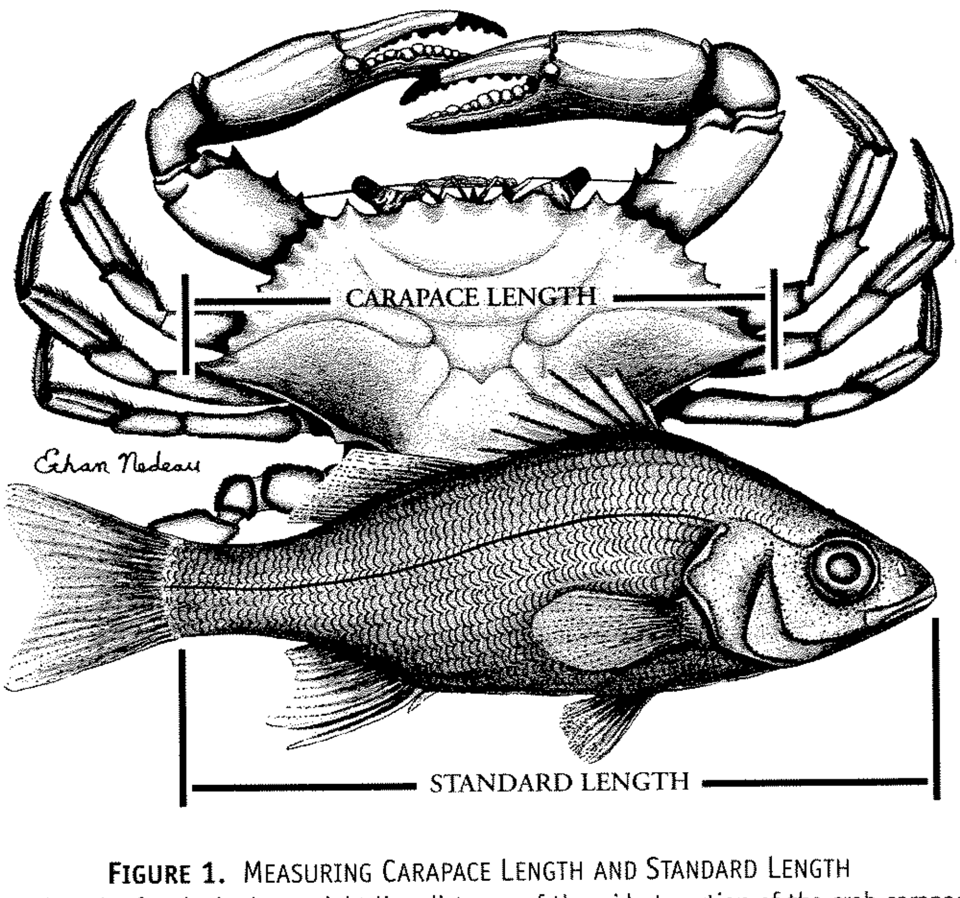


FIGURE 1. MEASURING CARAPACE LENGTH AND STANDARD LENGTH
Carapace length of crabs is the straight line distance of the widest portion of the crab carapace, as shown. Standard length of fish is the straight line distance from the tip of the snout to the posterior end of the vertebral column, as shown.

6. Collect water quality information (i.e., water temperature, salinity, and dissolved oxygen) at deployment and retrieval of traps and prior to seine samples.
7. If you have the equipment and resources, you may decide to collect additional water quality **parameters** such as pH and turbidity.

Sub-Sampling Procedure

Use this procedure if you collect greater than 40 individuals of any particular species. **Sub-samples** are a small but representative number of individuals randomly selected from a larger sample. It is important that the sub-sample is representative of the entire sample; that is, the length range of the species is represented in the sub-sample. Sub-sampling reduces processing time of large catches.

1. Separate the entire sample by species. Put species collected in large numbers in separate buckets.
2. Use the net to randomly capture 40 fish from the bucket containing the entire individual species catch.
3. You need to measure at least 40 individuals of any species that you sub-sample.
4. Weigh the entire sample of a particular species (not the sub-sample), and weigh the sub-sample. Note the sub-sample weight on the data sheet.
5. The proportion of sub-sample weight to total weight is used as an expansion factor. The expansion factor is the calculation derived from the sub-sample to the entire sample (i.e., a sub-sample of 40 fish weighs 10g; entire sample weighs 20 g; 10g to 20g is an expansion factor of 2; length measurements and relative abundance is doubled from the sub-sample).

Identification & Taxonomy

Excellent identification references include Bigelow and Schroeder 1953, Robins and Ray 1986, Weiss 1995, Murdy et al. 1997, and Pollock 1998. The volunteer coordinator should be familiar with common species to demonstrate distinguishing characteristics to volunteers. Table 3 lists fish and crab species commonly encountered in New England salt marshes, and provides information about habitat use and environmental preferences. Figure 2 shows important morphological characteristics that you will need to identify fish.

DATA ENTRY

Investigators should use a separate field data sheet for each sample. If groups use both minnow traps and bag seines, they will need 12 field data sheets per sample date (2 methods x 3 samples per method x 2 evaluation areas). The standard field data sheet is organized to clearly distinguish study sites, sampling stations, and individual samples. A blank

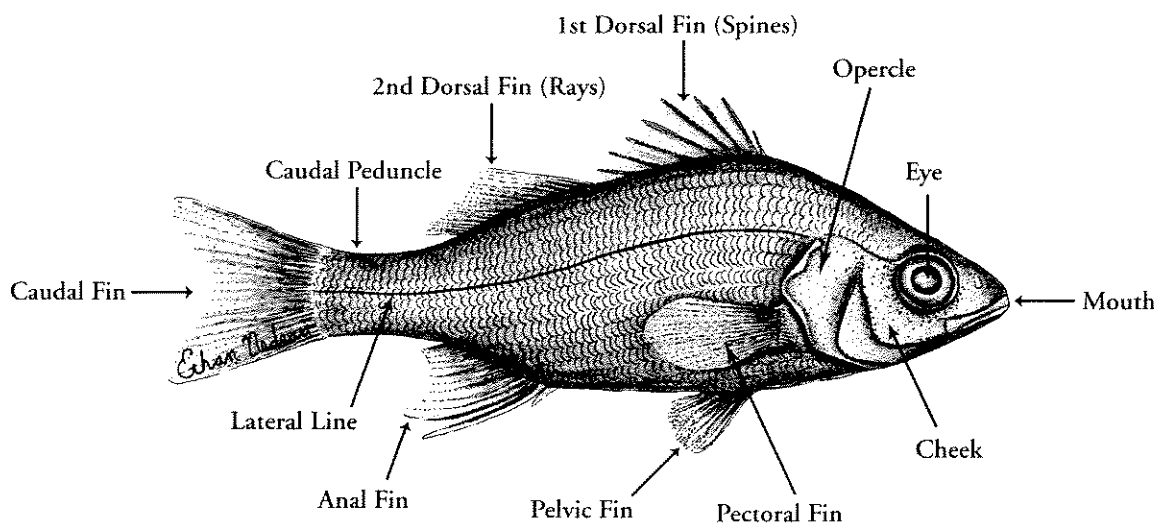


FIGURE 2. IMPORTANT MORPHOLOGICAL CHARACTERISTICS USED TO IDENTIFY FISH

TABLE 3. COMMON SALT MARSH FISHES AND CRABS AND IMPORTANT TRAITS
Abbreviations: RES = Resident, TRA = Transient, FRE = Freshwater, BRA = Brackish, MAR = Marine, ANA = Anadromous, CAT = Catadromous.

		Species Traits						
Common Name	**Scientific Name**	**RES**	**TRA**	**FRE**	**BRA**	**MAR**	**ANA**	**CAT**
Alewife	*Alosa pseudoharengus*		X	X	X	X	X	
American eel	*Anguilla rostrata*		X	X	X	X		X
American shad	*Alosa sapidisssima*		X	X	X	X	X	
Atlantic herring	*Clupea harengus*		X	X	X	X		
Atlantic silverside	*Menidia menidia*		X			X		
Atlantic tomcod	*Microgadus tomcod*		X	X	X	X		X
Blackspotted stickleback	*Gasterosteus wheatlandii*		X		X	X		
Blue crab	*Callinectes sapidus*		X		X	X		
Blueback herring	*Alosa aestivalis*		X	X	X	X	X	
Fourspine stickleback	*Apeltes quadracus*	X		X	X	X		
Green crab	*Carcinus maenas*	X			X	X		
Mummichog	*Fundulus heteroclitus*	X		X	X	X		
Ninespine stickleback	*Pungitius pungitius*		X		X	X		
Northern pipefish	*Syngnathus fuscus*		X		X	X		
Rainbow smelt	*Osmerus mordax*		X	X	X	X	X	
Rainwater killifish	*Luciana parva*	X		X	X			
Rock gunnel	*Pholis gunnelus*		X			X		
Sheepshead minnow	*Cyprinodon variegatus*	X		X	X	X		
Striped killifish	*Fundulus majalis*	X		X	X	X		
Sunfishes	*Lepomis spp.*		X	X				
Threespine stickleback	*Gasterosteus aculeatus*		X	X	X	X		
White mullet	*Mugil curema*		X	X	X			
White perch	*Morone americanus*		X	X	X		X	
Winter flounder	*Pseudopleuronectes americanus*		X		X	X		

standard field data sheet is provided in Appendix 1 of this chapter. Volunteers should follow the format provided in this manual, though project leaders can modify data sheets according to their specific needs.

On every field sheet it is extremely important to record exactly where, how, and when the samples were collected. The field sheet also contains all field measurements and site-specific environmental conditions. Investigators should neatly and thoroughly fill out field forms to ensure that no critical information is omitted. It is always 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 information on field data sheets into a computer spreadsheet such as Microsoft Excel. An example of a typical spreadsheet is provided in Table 4. As with the field data sheets, you can customize the spreadsheet according to the specific requirements of your project.

TABLE 4. EXAMPLE DATA ENTRY SPREADSHEET

The top portion is for site data, physical data, and chemical data. The bottom portion is for biological data. This table only shows biological data for Station 0 at the reference site, and a complete spreadsheet would be longer to include both trap and seine samples from three stations at the study site and reference site.

Date	Site	Area	Station	Time	Tide	Temp (C)	Sal (ppt)	DO (mg/l)	pH	Depth (m)	Substrate
6-Jul-00	FH	Ref	0	1030	1	24	28	6.8	7.4	1.4	Soft Mud
6-Jul-00	FH	Ref	50	1040	1	24	27	6.8	7	1.1	Soft Mud
6-Jul-00	FH	Ref	100	1050	1	24	28	6.8	7.4	0.8	Soft Mud
6-Jul-00	FH	Study	0	1100	1	25	24	4.5	6.8	1.2	Soft Mud
6-Jul-00	FH	Study	50	1110	1	24	20	3.8	6.7	1	Soft Mud
6-Jul-00	FH	Study	100	1120	1	26	22	4.4	6.7	1.3	Soft Mud

							Species Traits						
Area	Station	Sample	Species	SL (mm)	Weight (g)	Abnormality	RES	TRA	FRE	BRA	MAR	ANA	CAT
Ref	0	Trap	Threespine Stickleback				0	1	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Trap	Mummichog				1	0	1	1	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Atlantic Silverside				0	1	0	0	1	0	0
Ref	0	Seine	Blueback Herring				0	1	1	1	1	1	0

Data Analysis and Comparison

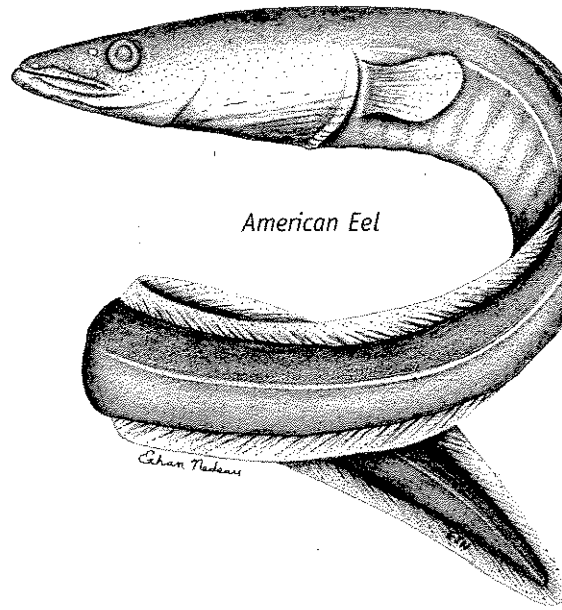
Relative abundance, biomass, species composition, species richness, life history characteristics, and fish condition are **variables** that describe the composition and quality of fish and crab communities. A short description of each variable along with instructions on how to compute these variables from your data is provided below. These variables can be important indicators of wetland condition, but generally only if the data is collected using a rigorous sample design that includes multiple samples taken over space (replicate samples within a marsh or across several marshes) and time (replicate samples at different seasons and years). This chapter provides the means to describe fish and crab communities, identify communities that are potentially impaired, and compare study sites and reference sites.

The methods described in this chapter will not allow investigators to estimate population size, or completely characterize a fish or crab community. This is because environmental conditions vary tremendously over time and space, and in order to completely quantify and characterize the biological community you would have to collect a large number of samples using several different methods during several consecutive years. Although the goal of most monitoring projects is to understand the effects of human influence on salt marshes, volunteers should understand that it is difficult — but not impossible — to collect rigorous and meaningful data on fish and crab communities. Pay attention to sampling details, such as trap location and tidal stage, and monitoring data will improve the description of the salt marsh community and provide the means to evaluate human impacts.

Relative Abundance

Relative abundance is used to compare **catch per unit effort** (CPUE) between sites. CPUE is a standardized catch (number or weight of organisms) for a sample. Since the number of organisms captured will depend on seine haul length or minnow trap soak time, volunteers must standardize catches so that different samples are comparable. One way to standardize samples is to define start/end points of seine samples and deployment/retrieval times of minnow traps.

- Bag Seine CPUE: # Organisms per 10-Meter Haul



- Minnow trap CPUE: #Organisms per Trap (given equal soak time)

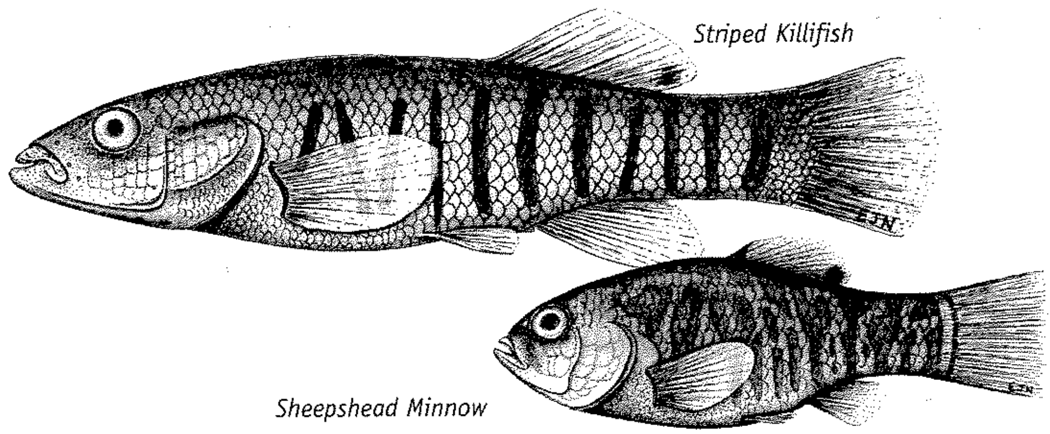
Relative abundance is the average CPUE in a sample area, which is either the study site or the reference site. The average (or mean) is the sum of all organisms in a sample divided by the sum of the number of samples. Volunteers can use relative abundance to make a variety of comparisons, including:

- Total number of fishes for study site and reference site samples.
- Total crabs for marsh, study, and reference samples.
- Species of interest for marsh, study, and reference samples.

In addition to computing average values, it may be useful to examine data variability within each site. For instance, in Table 5 the average relative abundance of

Table 5. Relative Abundance Example

	Study Site		Reference Site	
Station	**Seine**	**Trap**	**Seine**	**Trap**
0	34.0	12.0	256.0	11.0
50	68.0	3.0	61.0	17.0
100	41.0	34.0	44.0	23.0
Total	143.0	49.0	361.0	51.0
Average	47.7	16.3	120.3	17.0



organisms caught using bag seines is almost 2.5X higher in the reference site than the study site, yet the large number of organisms caught in Sample 1 accounts for virtually all of this difference. Sample 1 may contain a large number of schooling fish (e.g., blueback herring). The schooling fish may be collected in one sample or quickly move out of the sample area after the first sample. Volunteers should note the large difference between the study site and reference site and attempt to explain the difference. Overall, higher relative abundance usually indicates favorable conditions. Volunteers should also look at the relative abundance of **taxa** that are reliable indicators of environmental conditions, invasive species, or other taxa of interest.

Biomass

Biomass is the combined weight of all creatures or weight of a species in a sample. The justification, computation, and analysis for biomass are identical to that for relative abundance. The reason that scientists compute both relative abundance and biomass is because organisms and life history stages have vastly different biomass, and the number of individuals may not reflect the overall importance of a species in a community. Consider this example: you collect 1000 juvenile Atlantic silversides in a sample and the aggregate weight is eight grams. In the same sample, you collect 10 American eel with an aggregate weight of 80 grams. If you only computed relative abundance, you would conclude that Atlantic silverside are extremely important because they are 100X more abundant than American eel. However, the eel biomass is 10X greater than silverside biomass in the sample. Collectively, relative abundance and biomass provide a good overall indication of the size and composition of a community.

Species Richness

Species richness is the number of species collected in a sample area. Calculate species richness for the salt marsh, study, and reference area. Salt marsh quality may be related to species richness. High species richness may indicate a diversity of habitat features and valuable habitat quality.

Community Composition

It is important to know what species comprise a community because the environmental tolerance, life history traits, and ecology of different species provide clues about salt marsh condition. The list of common salt marsh fishes and crabs in Table 3 lists some important traits of each taxa that volunteers can use to determine community composition. Table 6 provides an example of how to display community composition data. The percent composition of different groups or species in a sample is computed using the following formula:

% Composition of Species A =
(# of Species A in Sample / # of Individuals in Entire Sample) x 100

Volunteer groups may be interested in determining the percent composition of several different species or species groups. Some useful species groups are defined by their environmental tolerance, such as freshwater species,

TABLE 6. COMMUNITY COMPOSITION EXAMPLE
Abbreviations for the column "Residency" are: RES = Resident and TRA = Transient. Abbreviations for the column "Tolerance" are: F = Freshwater, B = Brackish, M = Marine, C = Catadromous, A = Anadromous.

			Study Site		Reference Site	
Species	**Residency**	**Tolerance**	**Number**	**Percent**	**Number**	**Percent**
Mummichog	RES	F, B, M	170	88.5	224	54.4
Atlantic silverside	TRA	M	5	2.6	115	27.9
American eel	TRA	C	6	3.1	15	3.6
Threespine stickleback	RES	F, B, M	11	5.7	30	7.3
Blueback herring	TRA	A	0	0.0	28	6.8
		Total	192	100	412	100

brackish species, or marine species. A change in the percent composition of these groups may provide clues about tidal restrictions, altered salinity regimes, or freshwater intrusion. Other species groups include marsh residents or transient species. In addition, project leaders may examine the percent composition of other species or groups according to the particular needs of their study.

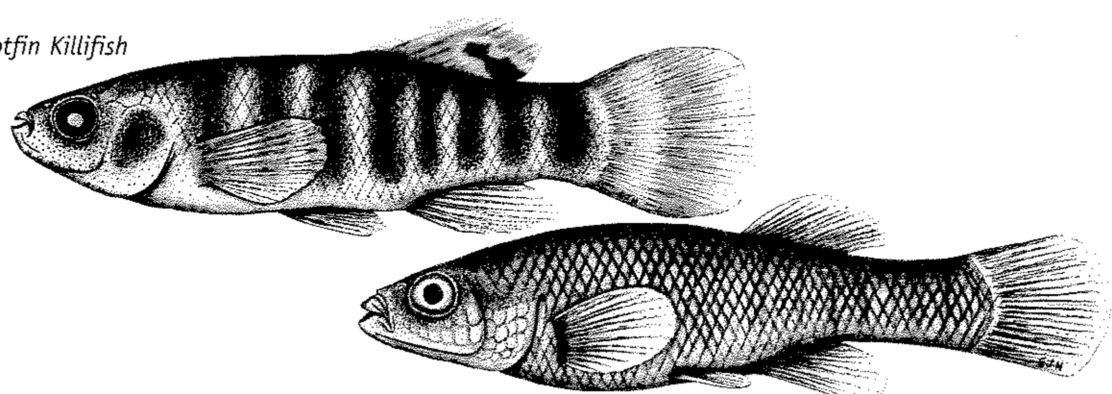
Life History Characteristics

Fish and crab size (i.e., SL and CL) indicates how different life stages use salt marshes. Certain fish species inhabit marshes during juvenile, adult, or spawning stages. The presence of juvenile fishes, for example, indicates that a marsh is functioning as a nursery. A large size range of a particular species usually indicates that the species exists in the marsh for its entire life cycle, whereas a narrow size range usually indicates that the species only uses the marsh for a portion of its life cycle. Marshes that support the development of a species from egg to spawning adult are usually considered healthy and productive.

TABLE 7. LIFE STAGE (STANDARD LENGTH) EXAMPLE

	SL Average (mm)		SL Range (mm)	
Species	**Study**	**Ref**	**Study**	**Ref**
Atlantic silverside	56.7	58.0	15 - 76	20 - 76
Striped killifish	44.2	45.2	13 - 55	15 - 62
Mummichog	39.2	45.6	25 - 47	9.0 - 65
American eel	85.5	95.8	70 - 96	68 - 110
Blue crab (CL)	59.8	75.8	13 - 125	65 - 80
Green crab (CL)	49.8	50.4	14 - 68	14 - 72

Spotfin Killifish



Mummichog

LENGTH CLASS (mm)	STUDY	REFERENCE
10 to 40	10	5
41 to 70	50	20
71 to 100	45	25
101 to 130	5	1

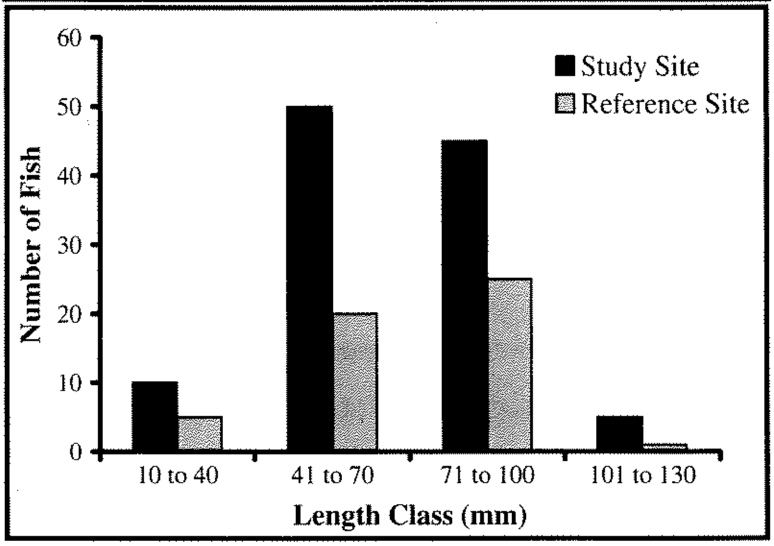


FIGURE 3. LENGTH FREQUENCY EXAMPLE

Volunteers should compute the average, range, and frequency distribution of SL (fish) and CL (crabs) to represent life history characteristics of the community. Volunteers should compute statistics for individual species (not the entire sample) and should first combine the data into two groups: the reference site and study site. Table 7 shows example data for SL averages and ranges, and Figure 3 shows a table and bar graph of frequency distribution.

Fish Condition

The presence of abnormalities, such as parasites, skin lesions, **fin rot**, and **mutation**, may indicate degraded environmental conditions. Volunteers should record the presence and type of abnormality on each species and include this information with their report. A simple table resembling Table 8 is suitable for this purpose.

TABLE 8. FISH CONDITION EXAMPLE

SPECIES	TYPE OF ABNORMALITY	% INDIVIDUALS WITH ABNORMALITY	% SPECIES WITH ABNORMALITY
Striped killifish	Fin Rot	6	6.5
	Lesions	13	14.0
Mummichog	Lesions	4	8.9
Sheepshead minnow	Lesions	7	29.2
Total Number of Fish with Abnormalities: 30			
Percent of Fish Community with Abnormalities: 7%			

REFERENCES

Bigelow, H.B. and W.C. Schroeder. 1953. *Fishes of the Gulf of Maine.* U.S. Fish and Wildlife Service, Fishery Bulletin 53(74).

Burdick, D., R. Buchsbaum, C. Cornelisen, and T. Diers. 1999. *Monitoring Restored and Created Salt Marshes in the Gulf of Maine: Framework and Data Collection Methods to Guide Monitoring Programs that Involve Volunteers.* Based on: Salt Marsh Monitoring Workshop, June 2, 1998, Castle Hill, Ipswich, Massachusetts. Sponsored by: Massachusetts Audubon Society and Gulf of Maine Council on the Marine Environment.

Carlisle, B.K., A.L. Hicks, J.P. Smith, S.R. Garcia, and B.G. Largay. 1999. Plants and aquatic vertebrates as indicators of wetland biological integrity in Waquoit Bay watershed, Cape Cod. *Environment Cape Cod* 2(2): 30-60.

Day, J.W., C.A.S. Hall, W.M. Kemp, and A. Yanez-Arancibia. 1989. *Estuarine Ecology.* John Wiley & Sons, Inc.

Dionne, M., F.T. Short, and D.M. Burdick. 1999. Fish utilization of restored, created, and reference salt-marsh habitat in the Gulf of Maine. Pages 384-404 in L. Benaka, editor. *Fish Habitat: Essential Fish Habitat and Rehabilitation.* American Fisheries Society, Symposium 22, Bethesda, MD.

Murdy, E.O., R.S. Birdsong, and J.A. Musick. 1997. *Fishes of Chesapeake Bay.* Smithsonian Institute.

Pollock, L.W. 1998. *A Practical Guide to the Marine Animals of Northeastern North America.* Rutgers University Press. 367 pp.

Robins, C.R. and G.C. Ray. 1986. *A Field Guide to Atlantic Coast Fishes (North America).* The Peterson Field Guide Series. Houghton Mifflin Company, Boston. MA.

Rozas, L.P. and T.J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: A review of sampling design with focus on gear selection. *Estuaries* 20(1): 199-213.

Schreck, C.B. and P.B. Moyle. 1990. *Methods for Fish Biology.* American Fisheries Society, Bethesda, Maryland.

Waters, W.E. and D.C. Erman. 1990. Research methods: Concept and design. Pages 1-34 *in*: C.B. Schreck and P.B. Moyle, eds. *Methods for Fish Biology.* American Fisheries Society, Bethesda, Maryland.

Weiss, H.M. 1995. *Marine Animals of Southern New England and New York: Identification keys to common nearshore and shallow water macrofauna.* State Geological and Natural History Survey of Connecticut, Bulletin 115.