SEASCAPES: Getting to Know the Sea Around Us

A Guide to Characterizing Marine and Coastal Areas

Section 3: Components of a Marine Area Characterization

QUEBEC-LABRADOR FOUNDATION
Atlantic Center for the Environment

Acknowledgments

Project Manager	Jennifer Atkinson, Quebec-Labrador Foundation/Atlantic Center for the Environment
Working Group Coordinator	Tracy Hart, Maine Sea Grant
Project Working Group	William Ambrose, Heather Deese, Michele Dionne, Molly Docherty, Lee Doggett, Stewart Fefer, Jill Fegley, Edward Hawes, Anne Hayden, Elizabeth Hertz, Carol Janzen, John Lichter, Linda Mercer, Slade Moore, Joe Payne, Neal Pettigrew, Linda Rowe, John Sowles, Andrew Thomas, Sean Todd, Barbara Vickery, Richard Wahle, Huijie Xue, Steve Zeeman
Text Reviewers	Barbara Arter, Jay Astle, Seth Barker, Deborah Chapman, Charles Curtin, Heather Deese, Michele Dionne, Tracy Hart, Edward Hawes, Anne Hayden, Kathleen Leyden, Linda Mercer, Slade Moore, Joe Payne, Craig Pendleton, Kristen Puryear, Laura Singer, Barbara Vickery, Steve Walker
Writer	Peter H. Taylor, Waterview Consulting
Designer	Kathlyn Tenga-González, Maine Sea Grant
Research Assistant	Elizabeth Stephenson
Cover Photo	Michael Rickard, Shutterstock

Produced by the Quebec-Labrador Foundation, Inc. with funding in part from the Gulf of Maine Council on the Marine Environment, National Oceanic and Atmospheric Administration Award No. NA04OAR4600075 and NA05OAR46011152, and the generous support of the Davis Conservation Foundation, Maine Sea Grant, Maine Coastal Program, Surdna Foundation, and Wallis Foundation.

Please cite this document as:
Taylor, Peter H. and Jennifer Atkinson. 2008. *Seascapes: Getting to Know the Sea Around Us. A Guide to Characterizing Marine and Coastal Areas*. Quebec-Labrador Foundation, Inc. *www.qlf.org*. 80 pp.

Note: This document incorporates Section 3 only.
Other sections are available for download.

Table of Contents

Section 3 Components of a Marine Area Characterization

Overview

A marine area characterization is all about information. But exactly what information is needed to characterize a marine area? How should it be obtained?

During production of this guide, numerous specialists—biologists, ecologists, oceanographers, historians, social scientists, resource managers, and others (see page 2) — worked together to develop and hone recommendations through a series of workshops, group discussions and follow-up interviews. Few full-scale marine area characterizations have been conducted as of this writing, so precedents and best practices have not been established. In addition, scientists usually focus their research to answer specific questions about aspects of the marine ecosystem, not to broadly "characterize" a place. Therefore, the experts who developed the recommendations below started out by discussing what it means to characterize a marine area. Based on their own expertise and reports from existing characterizations, they considered and debated the kinds of information that would be needed for a thorough study. Ultimately, the experts' conclusions evolved into the types of information described in this section. They identified three broad categories of information needed to characterize a marine area: oceanographic/physiographic, biological, and human dimensions.

This section explains each component of a marine area characterization, why it is valuable, and how to get and use the information. Compiling these components for a particular bay, harbor, or other marine area can generate a body of scientifically meaningful information that facilitates resource management and future research.

This guide presents some methods for getting the information that are considered good and reliable, but they are not the only ones. More or less sophisticated methods might work just as well for the purposes of a particular characterization project. Some components and information-gathering methods need to be done

Oceanographic and Physiographic Components

- O1 Marine Area Boundaries, Major Geographic Features, and Habitats
- O2 Substrate Types
- O3 Seafloor Depth, Slope, Topography (Bathymetry)
- O4 Circulation and Currents
- O5 Tides, Tidal Currents
- O6 Winds
- O7 Sea Level
- O8 Vertical Profiles of Temperature, Salinity, and Density

Biological Components

- B1 Historical Perspective on Ecological Changes
- B2 Habitats
- B3 Plants and Animals
  - B3.1 Phytoplankton
  - B3.2 Macrophytes
  - B3.3 Invertebrates
  - B3.4 Fish
  - B3.5 Marine Birds
  - B3.6 Marine Mammals
  - B3.7 Sea Turtles

Human Dimensions Components

- H1 Human Population
- H2 Community Economic Profile
- H3 Land Ownership
- H4 Land Use and Land Cover
- H5 Fisheries and Fishing Industries (Commercial, Recreational, Aquaculture)
- H6 Maritime Transport and Navigation
- H7 Marine Research and Education Sites
- H8 Transportation Infrastructure
- H9 Manufacturing Sites
- H10 Natural Resource Use
- H11 Residential Development
- H12 Recreation (Individual, Commercial)
- H13 Public and Private Waterfront Use and Access
- H14 Protected/Conserved/High-value Natural Areas
- H15 Filled Areas and Reclaimed Land
- H16 Tidal Restrictions and Barriers to Fish Passage
- H17 Riparian Buffers
- H18 Habitat Restoration Project Sites
- H19 Significant Cultural Sites (Prehistoric, Historical, Current)
- H20 Point Source Pollution (Known or Potential)
- H21 Resource Management Framework for Shore and Water
- H22 Regulatory Framework for Shore and Water

by trained professionals, such as academic scientists or environmental consultants, while others are appropriate for non-experts such as community volunteers.

The information described in this section might seem daunting, but it represents the ideal for a thorough characterization. Many characterizations do not include all the components due to budgets, schedules, skills, and interests of the groups conducting the characterization. The comprehensive list presented here enables people to understand the framework for a full characterization and to make educated choices about which components they will pursue. A complete characterization could be pursued all at once or in phases over many years, as circumstances allow. Regardless, the framework outlined in this guide helps to ensure that the characterization will withstand scientific scrutiny and provide value for resource management.

Information Provided in This Section about Each Component

Why: Why is the component important? What can it tell you?

What: What information, data, maps, or other materials may be produced?

Sources of information: Where can one look for existing information?

Research and monitoring recommendations: What scientific fieldwork can be done to provide the information?

Community involvement: How can community volunteers and other non-experts go about collecting the information?

OCEANOGRAPHIC AND PHYSIOGRAPHIC COMPONENTS

O1 Marine Area Boundaries, Major Geographic Features, and Habitats

Why: The boundaries specify exactly the area under consideration, where data are needed during the characterization process, and where the findings apply when the characterization is complete. A description of the area's major geographic features and habitats provides context for all findings of the characterization. It offers a glimpse into what might be expected for the area in terms of ecological, physiographic, oceanographic, and human characteristics.

What: Boundaries of the marine area may be defined using many types of natural and political features, such as watersheds, headlands, or town borders (see Section 2). A description of major geographic features and habitats may address such questions as:

- Is the area along the coast? Does it include offshore waters? Or both?
- Are the waters estuarine, marine, or some of each?
- Does the area include only subtidal areas or intertidal acreage as well?
- Are intertidal areas rocky coast, sandy beach, or mudflat?
- Is the coastline relatively straight, or does it have bays, coves, or islands?
- If the area is coastal, how big is the adjoining watershed?
- Are cities, small towns, or rural areas along the coast?

Sources of information: See Appendix A, page 47.

Research and monitoring recommendations: New research or monitoring usually is not necessary because the information can be obtained from maps and other sources.

Community involvement: Community members can gather information. With some training, they can categorize the major habitats, if this work has not been done already in the past.

O2 Substrate Types (see also B2 Habitats)

Why: The types of sediment or rocks on the shoreline and seabed help determine the animals and plants that can live there. "Substrates" is a general term for sediments and rocks. Knowing the types of substrates and where they are located is important for classifying habitats. Information about substrates can be highly relevant for commercial activities and resource management. For example, young lobsters and urchins often hide in cobble-covered areas of seabed, and some commercially important fish species often are associated with particular substrates. Substrates influence where pipelines, cables, and other marine structures are installed. In addition, substrates differ in their vulnerability to human activities.


Natalie Springuel

What: Mud, sand, cobble, boulder, and other loose substrates are classified primarily based on grain size. Solid rock substrates can be characterized based on rock type, surface roughness, slope, orientation, and relief.

Sources of information: See Appendix A, page 47.

Research and monitoring recommendations: Analyze sediments for grain size, using grab samples, sieves, or other widely available methods. Underwater video, remotely operated vehicles, and sidescan or multibeam sonar can be used to identify and map substrate types and other geological characteristics of the seabed.

Community involvement: With training, community members can assist in this work.

O3 Seafloor Depth, Slope, Topography (Bathymetry)

Why: The depth and shape of the seabed strongly influence the way that water circulates. For example, water tends to circulate differently in a shallow, long bay than in a deep, broad bay. Accurate depth data are essential for oceanographic models of water circulation. In most coastal areas, existing depth data may be adequate for navigational charts, but not for modeling circulation. For example, a team of oceanographers at the University of Maine once created a circulation model based on chart data. When they later measured the depths themselves from boats, they found places where the chart was off by 30 meters (98 feet), rendering the oceanographic model extremely inaccurate. Depth is a factor in the presence, absence, and growth of kelp and other seaweeds because the amount of available sunlight decreases with depth. Pressure, temperature, and concentrations of dissolved oxygen, carbon dioxide, and particulate organic carbon also vary with depth. Areas of seabed that are smooth (low relief) have less variety of habitats than areas of underwater hills, mountains, cliffs, and crevices (high relief). Sediments are more likely to move on steeply sloped areas of the seabed than on flat areas. “Bathymetry” is the scientific term for seafloor topography, or the shape of the ocean bottom.

What: Oceanographers need accurate, high-resolution data on water depths to model the circulation of water. Measurements of the surface area and approximate volume of water in a bay are important parameters for oceanographic modeling. Depth data provide information about seabed relief and slope.

Sources of information: See Appendix A, page 49.

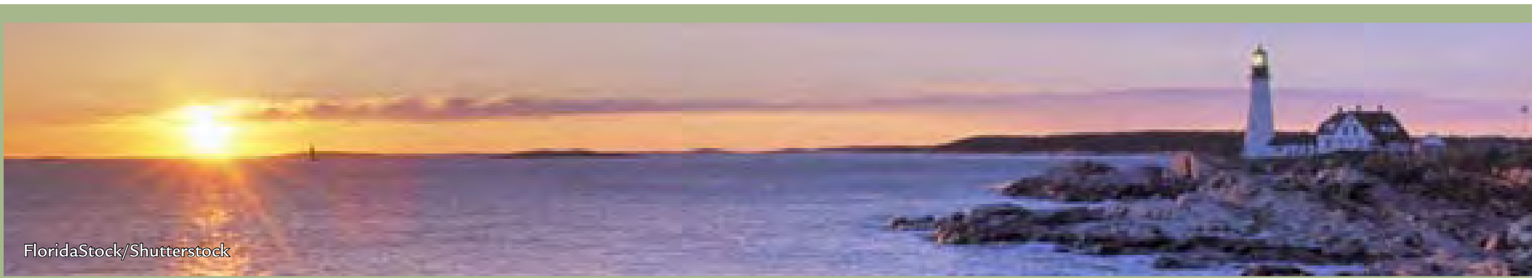
Research and monitoring recommendations: For many places, existing data on water depths is insufficient, and new bathymetric surveys will be needed as part of a complete marine area characterization. Ways of collecting the data range from old-fashioned soundings to electronic depth sounders to sophisticated sonar equipment.

Community involvement: Boaters with GPS and depth sounders can do a high-quality job of measuring water depths, if they plan and carry out their surveys carefully with advice from oceanographers or other scientists with relevant expertise. In Maine, a local, all-volunteer group did a hydrographic survey of a section of the Georges River estuary using this method, with a professional study design from a hired consultant.

O4 Circulation and Currents

Why: Circulation is the geography of the ocean. Just as mountains, rivers, and plains define a landscape, circulation patterns, such as currents, fronts, and upwelling of nutrient-rich water, define a marine area. Understanding circulation is critical because it influences nearly every aspect of a marine area. The movements of water affect temperature, species living there, nutrient levels, red tide, number of young lobsters and other animals joining their adult populations, and more. Without understanding circulation, it is impossible to understand a marine area.

What: An ideal outcome would be an accurate diagram—perhaps even an animated video—showing how water circulates in the marine area. It would show both the horizontal and vertical movements



of water, and changes that occur over the tidal cycle and seasons. Because the data or funding may not be available, however, a rough sketch or brief description might be the best practical outcome.

Sources of information: See Appendix A, page 49.

Research and monitoring recommendations: Because it is very complex, circulation can be very difficult and expensive to measure accurately. Oceanographers use tools such as drifters, moored sensors, satellite imagery, and mathematical models to understand circulation. Well-qualified physical oceanographers should be engaged in the characterization of circulation patterns to ensure accurate results.

Community involvement: Fishermen can help scientists deploy drifters and other oceanographic gear. Community members can conduct informal studies with less sophisticated gear—such as tracking oranges as they drift. While the results are not likely to be very accurate or useful in a scientific sense, they might provide some interesting clues and raise people's interest in the marine area.

Ocean Circulation

Most people who live and work along the coast know that seawater moves due to the tides, which rise and fall twice daily in the Gulf of Maine. They may not know that tidal flow is just one factor in ocean circulation. Some other factors that drive the strength and direction of circulation are (1) winds blowing across the ocean surface, (2) differences in density of water masses due to water temperature and salinity, and (3) shape of the seabed and coast. The combined effect is that ocean water moves in complex ways both horizontally and vertically offshore and along the coast. While tidal currents are often the most familiar and visible, other factors may have at least as big an effect on determining where and how fast ocean water moves. Oceanographers create complex computer models that show the movements of ocean circulation in a given area.

O5 Tides, Tidal Currents

Why: Tides are a major influence on circulation and biology along the coast. They are less important offshore. Tides help determine where species can live because low tides expose areas of the shoreline and seabed; animals and plants living there must tolerate extremes in temperatures and dryness. Tides affect the salinity and temperature of coastal waters, which in turn affect species living there.

What: Tidal range (height difference between high and low tide). Measurements and maps of tidal currents. Maps and/or aerial photography showing area at high and low tides.

Sources of information: See Appendix A, page 51.

Research and monitoring recommendations: Use tide gauges to measure tidal heights and current meters to measure tidal current speeds. Measure for a minimum of 28 days to cover a complete monthly cycle.

Community involvement: With training, community members could assist with tide measurements.

O6 Winds

Why: Wind is a driving force behind ocean circulation and surface waves. Winds blowing across the water cause horizontal and vertical water movement. Wind and the resulting waves can mix the water and can affect the seafloor, causing sand waves or scouring an area of sediment. Oceanographers need local measurements of wind speed and direction to create models of circulation. Along the coast, winds can vary greatly because of blockage or funneling of wind by hills and other land features. Although wind data is available from sources such as airports and the National Weather Service, those data are not localized enough to be useful for circulation models (unless the airport or weather station is located at the marine area).

What: Measurements of wind speed and direction.

Sources of information: See Appendix A, page 52.

Research and monitoring recommendations: Wind measurements are some of the easiest data to collect. Automated wind sensors should be placed in multiple locations within the marine area. They should be located on docks or buoys, not on land, because the goal is to measure the winds blowing across the water surface. They should not be located on shore next to hills, valleys, or other features that block or funnel the winds hitting the sensor. Characterize the orientation of the bay or other marine area in relation to wind directions.

Community involvement: Community members, such as coastal property owners with docks, could set up and maintain wind sensors.

Natalie Springuel

O7 Sea Level

Why: Although people generally think of sea level as being constant from place to place, it actually varies due to factors such as wind forcing and circulation patterns. For example, sea level can vary imperceptibly even between one end of a bay and the other or between inside and outside the bay. These tiny differences in sea level provide major clues to oceanographers about circulation patterns. Sea level is also expected to rise significantly over the next century. Taking measurements now provides a baseline for observing the change.

What: Measurements of sea level at multiple places in the marine area.

Sources of information: See Appendix A, page 52. Local data are not likely to be available unless the area has been studied by meteorologists or physical oceanographers.

Research and monitoring recommendations: Qualified scientists should measure sea level at multiple places in the marine area. If the area is a bay or other coastal indent, measurements should be taken in the main channel and at the head of the bay, not along the shore or in small coves.

Community involvement: Because fine-scale sea-level measurements are technically challenging and require specialized equipment, community members are not generally able to perform them.

O8 Vertical Profiles of Temperature, Salinity, and Density

Why: Measurements of temperature, salinity, and density of seawater are critical parameters for understanding the oceanography and biology of a marine area. At any given place in the ocean, these parameters vary with depth, and they vary horizontally from place to place. The variations may seem extremely slight on the scale of a bay or gulf, but they are important to marine life and actually help to drive the movement of ocean circulation. Temperature and salinity affect the density of seawater, such that cold, saline water is denser than warmer, less saline water, and it naturally wants to sink beneath it. This explains why scuba divers often notice that the water suddenly gets colder at a particular depth; the warmer, less dense water is on top of the colder, denser water. Similarly, freshwater flowing out of a river mouth often “floats” on top of saltier water in an estuary because it is less dense.

What: Measurements of water temperature, salinity, and density at multiple depths at multiple sites within the study area.

Sources of information: See Appendix A, page 52. Local data are not likely to be available unless the area has been studied by physical oceanographers.

Research and monitoring recommendations: Taking measurements from boats along the same transects at regular time periods is preferable to sampling at random sites and times. Consistency of sampling locations and time of day is one of the most important considerations.

Community involvement: With guidance and a sampling plan provided by qualified scientists, volunteer boaters can assist with taking the measurements. Volunteers can also sample temperature from docks, preferably at a designated time of day.

BIOLOGICAL COMPONENTS

B1 Historical Perspective on Ecological Changes

Why: An overview of past conditions and changes can provide insight into present-day circumstances. Having a timeline also provides context for the “snapshot” provided by new biological surveys. Many ecological changes occur over hours, days, months, years, or centuries. Although historical conditions could be described for each component, an integrated overview of all components may provide a better sense of a place’s history and factors that shape its ecology.

What: Key elements of an area’s ecological history are losses or declines of species (such as urchins, salmon, puffins); frequency of harmful algal blooms (red tide); habitat changes and degradation, such as loss of salt marsh and eelgrass beds; invasions by non-native species; and eutrophication events (large algal blooms leading to severe declines in dissolved oxygen in the water).

Sources of information: See Appendix A, page 53. Integrate historical information obtained for other biological components.

Research and monitoring recommendations: Interviews with local residents or others with firsthand knowledge about the area can provide useful anecdotes about past conditions. It is best to interview more than one person about the same event and then, where possible, to collect additional information from written accounts, documents, photos, maps, or other illustrations. In this way the key elements of the event become evident.

Community involvement: Citizens can find specimen collections, documents, images, maps, and data at government agencies, universities, libraries, and research field stations.

B2 Habitats

Why: Information about habitats is essential for characterizing a marine area because habitats help to determine which species and ecological processes occur in the area. On a practical level, understanding the types, extent, and locations of habitats can help to guide many other aspects of a characterization project. For example, habitat maps can indicate which methods for counting animal and plant species would be most appropriate and how much effort will be needed for sampling different ecological communities. Habitat maps also make it possible to identify changes over time, such as shifts in the size and locations of seagrass beds, when compared to earlier or subsequent maps.

Examples of Habitat Types in the Gulf of Maine

- Salt marsh
- Seagrass bed
- Kelp and rockweed bed
- Shellfish bed
- Muddy bottom
- Sandy bottom
- Rocky bottom
- Water column

Consult the *Gulf of Maine Marine Habitat Primer*, published by the Gulf of Maine Council on the Marine Environment *(www.gulfofmaine.org/habitatprimer)*, for more information.

What: Ideally, the product should be a map of habitats on the seabed and shoreline of the marine area. The habitat types should be defined as sandy, muddy, and rocky, and finer distinctions can be made based on sediment grain size or rock type (e.g., gravel, cobble, boulder, outcrop). In addition, the habitat maps should show the size and density of seagrass, kelp, rockweed, mussel, and oyster beds and salt marshes because these features provide habitat for many fish and other species. Another key habitat factor, especially along the shoreline, is exposure or shelter from waves because this determines the plants and animals that can live at the site. For example, sheltered rocky shores often host huge beds of rockweed, but mussels dominate on exposed rocky shores. Along with categorizing seabed and shoreline habitats, areas of water can be categorized into different habitats based on salinity, temperature, nutrients, depth, and other factors that affect sea life.

Sources of information: See Appendix A, page 55.

Research and monitoring recommendations: To map shoreline (intertidal) habitats, researchers use rapid surveys, spot checks, and aerial imagery. For seabed (subtidal) habitats, they lower devices from boats to grab samples of sediment from the seabed or to bring up sediment cores, much like using an apple corer. When they take the samples, they mark the site using a global positioning system (GPS) so that they can later show on a map what sediment types can be found at each collection site. Placed together on a map, these samples provide a picture of the sea bottom's composition. Researchers also use aerial photographs (primarily in shallow water) and equipment using sound waves (acoustic technologies such as multibeam, sidescan, and single-beam sonar) to produce visual images showing where different substrates or habitat types are located. Scuba diving, underwater video, and sediment samples are used with these photographic and acoustic techniques to "ground-truth" the images. These techniques enable researchers to identify, classify, and map the habitat types.

Community involvement: Citizens can acquire data from NOAA or state agencies. They can also participate in field research under the guidance of scientists.

B3 Plants and Animals

This information component is made up of seven subcomponents.

B3.1 Phytoplankton Microscopic organisms that drift in the water and live off photosynthesis.

B3.2 Macrophytes Includes seaweeds (e.g., kelp, rockweed, Irish moss) and aquatic flowering plants (e.g., seagrasses, salt marsh grasses).

B3.3 Invertebrates Includes a wide range of species from crabs, lobsters, clams, urchins, and mussels to tiny zooplankton and jellies that drift in the water.

B3.4 Fish

B3.5 Marine birds

B3.6 Marine mammals

B3.7 Sea turtles

Baseline Information

For each subcomponent of B3 Plants and Animals, the following baseline information should be collected.

- How many species are there and what are they (*species composition*)?
- How many animals or plants are there of each species? This can be expressed as the number of individuals of each species (*species abundance*). However, often it is more useful to express it as the number of individuals in a given area (*species density*), such as clams per square meter. For species that live attached to rocks or sediment but are difficult to count because they are so numerous, such as barnacles, mussels, seaweeds, and salt marsh plants, scientists often measure abundance as *percent cover*, instead of counting individuals. For example, mussels might cover 15 percent of a rocky shore, barnacles 20 percent, and rockweed 40 percent.
- What is the relative abundance of each species compared to other species (*species proportional abundance*)?
- Are *indicator species* present? These are particular species that reflect noteworthy ecological conditions. For example, if certain plants are present in a salt marsh, it indicates that the site is transforming to a freshwater marsh, perhaps due to restricted tidal flooding from undersized culverts under road crossings.

Identifying the species of some plants and animals is extraordinarily difficult, especially for groups of species that look very similar. If lack of expertise, time, or resources makes species identification impractical, an alternative is to identify the plants and animals to the lowest taxonomic level that is reasonable such as class, order, or genus.

At first, getting a handle on species abundance might seem relatively easy—just go out and count the birds, plants, or shellfish. However, animals and plants can vary greatly in their numbers over time and space. One month, barnacles might be scarce on the rocky shore; then a huge influx of young barnacles might settle on the rocks; and a few months later half of the young barnacles might have been eaten by whelks. Similarly, one rocky headland might be totally covered in barnacles, while a nearby cove has few barnacles. For fish, birds, lobsters, and other mobile creatures, numbers can vary in a given place with their daily travels or seasonal migrations. As any birdwatcher knows, the number and species of birds at a salt marsh varies tremendously with time of day, tides, seasons, weather, and other factors.

For all of these reasons, accurately determining the abundance of any species in a marine area is more complicated than it might seem, even if the goal is just to get a baseline snapshot and not long-term trends. As a result, the sampling program should be designed by trained scientists and followed carefully, if the goal is to produce scientifically defensible, meaningful estimates of species abundance. A good sampling program will take into account the variability over time and space in order to produce a good count of individuals.

Are crabs becoming more or less abundant? Is the diversity of seaweeds changing? Is an invasive plant or invertebrate gradually taking over the seabed—or is it staying at harmless levels? Understanding long-term trends like these is even more challenging than getting a snapshot in time. One or two years of data collection is not enough to understand such trends. A marine area characterization project is likely to be a relatively short-term effort, spanning months or a couple of years, making it appropriate for getting a snapshot but not for characterizing long-term trends. However, comparison with historical data (if available) or re-sampling periodically after the initial characterization can help to identify trends.

B3.1 ***Phytoplankton***

Why: Phytoplankton are microscopic organisms that drift in the water and live off photosynthesis. They are eaten by many animals and form the basis of the marine food web. Abundance of this important food source helps to determine the number of fish, shellfish, and other animals. Because phytoplankton have short life spans, they can serve as a useful indicator of shifts in the ecosystem. "Red tide" and other harmful algal blooms are caused by toxic species of phytoplankton, making phytoplankton an important consideration for human health. Phytoplankton can become overwhelmingly abundant in waters that suffer from over-productivity, or eutrophication, due to excessive nutrients from such sources as sewage effluent, lawn fertilizers, manure washed from fields, and other land-based sources. Decomposition of the abundant phytoplankton can lead to shortages of dissolved oxygen in the water, leading to fish kills and dead zones.

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topics for phytoplankton.

1. *Pigment measurements.* The amount of chlorophyll *a* or certain other pigments in seawater provides a measure of how much phytoplankton is present. Repeated, ongoing monitoring can show how the amount changes between sites, seasons, and oceanographic conditions.

2. *Eutrophication events.* How often does eutrophication occur in the marine area? What are the ecological impacts of those events?

3. *Harmful algal blooms.* Is the area a hotspot for red tide? Are cysts of *Alexandrium* phytoplankton, which cause red tide, present on the seabed?

Sources of information: See Appendix A, page 59.

Research and monitoring recommendations: The following are some recommended methods for collecting new data.

- Measuring the amount of chlorophyll *a* in water samples provides information on total density of phytoplankton.
- Phytoplankton can be collected with fine nets and then identified and counted. The size of the net's mesh and the number of samples taken over time must be determined based on what scientific questions are being asked and the person's expertise.
- Plankton tows can reveal where phytoplankton species live in relation to different habitats. The surveys must be designed appropriately to take into account ocean currents, temperature gradients, and water masses.

Community involvement: Some government programs, such as the Maine Phytoplankton Monitoring Program, offer training for people who want to collect phytoplankton samples. Analysis of the samples needs to be done by experts. Citizens can gather historical data and information on phytoplankton in the marine area.

B3.2 ***Macrophytes***

Why: Kelp, eelgrass, rockweed, and salt marsh grasses are examples of macrophytes, which translates roughly as "large plants" and includes all ocean-dwelling plants and algae larger than phytoplankton. Macrophytes live primarily in coastal waters that are shallow enough to allow sunlight to reach them on the seabed. The plants and algae may live entirely underwater, like kelp, or partially exposed, like salt marsh grasses at low tide. Certain species, such as Irish moss and rockweed, are harvested commercially. Because they are large and often grow in beds that resemble underwater forests, macrophytes form vital habitats where other animals and plants live and take cover from predators. Many animals eat macrophytes, making them an important food source. Therefore, increases or decreases in macrophytes can affect other species. Macrophytes are sensitive to environmental changes, so they can signal the overall condition of the ecosystem. For example, a big patch of *Enteromorpha* seaweed indicates that nutrient levels in the water are high. Macrophytes can signal ecological impacts from climate shifts, pollution, coastal development, ice scouring, harvesting, and other human and natural causes. In addition, they indicate changes in the animals that are associated with macrophyte habitats. For example, when sea urchins become numerous, they often obliterate kelp beds, eating the kelp like lawn mowers. The loss of kelp causes animals dependent on kelp beds to become less numerous.

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topics.

- *Invasive species.* Presence or absence of non-native, invasive macrophyte species such as *Codium fragile*. Invaders can quickly take over an area, harming native macrophytes, fish, and shellfish.
- *Changes in dominance.* Monitoring changes in macrophyte dominance can reveal important changes, such as increases in sediments that block the light or waterborne nutrients coming from land-based activities.

Sources of information: See Appendix A, page 60.

Research and monitoring recommendations: Recommended methods for a baseline characterization include:

- analysis of aerial imagery (e.g., aerial photos of eelgrass and seaweed beds),
- on-the-ground mapping of where macrophyte species live in the marine area,
- surveys of macrophyte abundance using transects (lines across parts of the marine area) and quadrats (squares, often one square meter), and
- photographs showing changes in macrophytes over time.

Using these methods may involve scuba diving, remote sensing from satellites, underwater video, intertidal surveys, and other techniques in subtidal and intertidal areas. It may be possible to use existing protocols that have been developed and refined by the Boston Harbor Islands Intertidal Inventory, Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), and other groups.

B3.3 *Invertebrates*


Capt. Albert E. Theberge/NOAA Corps

Why: Lobsters, crabs, clams, urchins, and mussels often dominate in habitats of the Gulf of Maine and play key roles in the ecosystem. Some invertebrates live for many years in the same place. These qualities make them potentially useful as indicators of changes in the marine ecosystem. Declines or increases in these indicator species may reflect the overall condition of the ecological community, localized changes in climate, and habitat changes, such as warming waters or toxic contaminants. The high commercial value of species such as lobsters, crabs, and clams is another reason why they are essential to include in a marine area characterization. At the same time, non-native (or invasive) invertebrates present a grave threat because they can quickly invade and dramatically alter habitats and ecosystems. Many non-native invertebrates already are present in the Gulf of Maine, such as the European green crab, shipworms, Asian shore crab, and many tunicate species.

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topic.

- *Vertical zonation.* Different species of barnacles, mussels, other invertebrates, and algae live at particular heights on rocky shores. Certain species tend to dominate at each height. The result is vertical zonation of species on the rocky shore. Although the same species live along much of the Gulf of Maine coast, the heights and widths of the species bands or zones on the rocks vary from place to place depending on tidal range, exposure to waves, and other factors. Mapping the heights where different species live on the rocky shore is useful information to collect as part of a marine area characterization.

Sources of information: See Appendix A, page 61.

Research and monitoring recommendations: For data collection, techniques differ between the intertidal (between the high and low tide marks) and subtidal (below low tide mark) zones.

Methods for the intertidal zone:

- Obtain any available information from previous research about rare species, invasive species, abundant and dominant species, and other species of management interest. Consider doing new sampling in the same locations in order to see changes that may have occurred.
- Devices called grabs and cores can be used to obtain samples of sand or mud for counting the invertebrates that live in the sediment. Sampling at several times throughout the year reveals seasonal shifts.
- On rocky shores, scientists commonly use quadrats or transects for surveying invertebrates. A quadrat is a square, often made from pieces of rigid plastic pipe, that is placed on the rocks. Scientists count the species living within the square or estimate the percentage of the square covered by each species. Transects are lines laid out along the rocks, and the scientists count species along the line. Some invertebrates, especially smaller species, may need to be collected and taken to a laboratory for identification. Quadrats and transects can be photographed and species coverage measured from the photographs.

Methods for the subtidal zone:

- Conduct surveys in shallow and deep waters. Methods will vary with depth.
- In addition to grabs and cores (see above) lowered from a boat, subtidal surveys can use video, photography, scuba diving, and remotely operated vehicles.
- For crabs, lobsters, and other small, mobile invertebrates, scientists sometimes use suction devices that suck up the animals for counting.

Methods for invertebrates living in the water:

- Tow nets to collect zooplankton.

Community involvement: Community involvement is more feasible for intertidal (shoreline) surveys than for subtidal (underwater) surveys because of the special skills needed for surveying the underwater environment. Local marine resource committees and shellfish harvesters are invaluable sources of information. With training, citizens can identify a few key species as part of a survey, although experts are needed for a complete survey.

B3.4 Fish

Why: Many people are interested in fish—fishermen, seafood lovers, naturalists, and just about anyone with an interest in the sea—and fish are widely viewed as important inhabitants of the ocean. Fish are well known and understood, and the public is more likely to be engaged in information about fish than about the many obscure creatures that live in the sea. Fish serve as indicators of water pollution, habitat loss and degradation, and climate change. Information about commercially and recreationally harvested species is important from a socioeconomic perspective, and it also provides an indicator of human impacts on the ecosystem.

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topics.

- *Descriptive list.* Compile a descriptive list of fish species found in each habitat of the marine area, such as sandy, muddy, or cobble bottom. Indicate which species are full-time residents or seasonal visitors. Highlight rare species, any species that are commercially or recreationally harvested, diadromous species (salmon, eels, smelt), and species that serve as important forage fish for other species (such as menhaden, alewives, herring).
- *Fish abundance.* Use towed nets, seines, hook and line, and other methods to determine abundance of fish. Scientists often discuss fish abundance in terms of how many fish were caught using a particular method during a given period of time, which is called catch per unit effort. Record length, weight, and age class of the fish, along with general health such as presence of lesions or malformities that could indicate water pollution. Keep track of which habitat the fish were in.

Repeat fish sampling at various times during the year to see seasonal shifts.

- *Nurseries and spawning areas.* Some fish species tend to spend their early lives in particular habitats, such as eelgrass beds, and adult fish may congregate year after year in certain places to mate. Identify and map any nursery habitats and spawning areas in the marine area that is being characterized.

Sources of information: See Appendix A, page 63.

Research and monitoring recommendations: Sampling throughout the seasons can provide key information about fish species and abundance.

Methods:

- Snorkeling or scuba diving, trapping, and hook and line are used to survey intertidal and subtidal habitats ranging from mud and sand to cobble and rocky outcrop.
- At beaches and marshes, seines can be useful.
- For subtidal surveys, beam trawls, otter trawls, gill nets, video, and remotely operated vehicles are other possible methods.
- In intertidal and shallow subtidal areas, fish sampling typically begins in late April or May and continues through November, although year-round sampling may be possible. Deeper, ice-free areas can be surveyed in the colder months.

Community involvement: With training, it may be possible for community members to participate in fish surveys under the supervision of a professional scientist. Fishermen routinely contribute to and participate in fisheries research conducted by state and federal agencies, universities, and private research organizations, such as the Gulf of Maine Research Institute.

B3.5 Marine Birds

Why: Some marine and estuarine areas provide critical habitat for birds. Salt marshes and mudflats along shorebird migration routes can serve as vital feeding and resting places for long-distance migrants. Imperiled species such as piping plovers may feed along beaches or other habitats in the marine area being characterized. Some birds can have a big impact on the ecology of a marine area by feeding on mudflat invertebrates or other creatures, which makes it important to document the birds' presence and abundance. Marine birds can serve as indicators of ecosystem health by signaling changes in prey availability, levels of environmental toxins, and other habitat impacts.


Chris Bartlett

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topics.

- *Breeding birds.* Note presence or absence.
- *Migratory birds.* Note usage as a feeding or resting stop for migratory birds.
- *Rare species.* Presence or absence. Existing information is often available.
- *Restored populations.* Were birds such as puffins brought back to the site after disappearing in the past?
- *Critical bird habitats.* Do birds use the area for feeding, nesting, aggregation, or rookeries?
- *Toxin levels.* Measuring toxin levels in bird tissues can indicate the presence of contaminants in the environment. Because some birds are predators at the top of the food web, they tend to accumulate toxins.

Sources of information: Much information is readily available. See Appendix A, page 65.

Research and monitoring recommendations: Scientists use many different methods to count birds in estuarine and marine habitats. Using standardized methods allows accurate comparisons over time and among different places. For example, they may count the birds seen in a given area of salt marsh in a half-hour period. They sometimes use nets to capture and count groups of shorebirds, which then are released. They use call-and-response methods to count hard-to-see species, such as rails and bitterns. For offshore birds, scientists conduct surveys from boats.

Schedule bird counts to occur at seasonal times of the greatest numbers of birds and best visibility. The seasonal timing depends on whether the birds are breeding, migrating, or wintering in the habitat.

Community involvement: Many amateur birdwatchers are highly skilled at identifying coastal and marine birds. When trained in scientific survey methods, they can play a major role in surveying bird populations as part of a marine area characterization.

B3.6 Marine Mammals

Why: Marine mammals in the Gulf of Maine include seals, whales, dolphins, and porpoises. Some species have favorite places for feeding, breeding, or resting. They can strongly affect the abundance of their prey. At large geographic scales, marine mammals can serve as indicators of ecosystem health by signaling changes in prey availability, levels of environmental toxins, and other habitat impacts in the ocean.

What: In addition to the baseline information listed above under B3 Plants and Animals, characterization studies should consider the following topics.

- Seasonal presence and absence of species.
- Important habitats such as seal haul-outs, feeding, and breeding areas.

Sources of information: Much information is readily available. See Appendix A, page 66.

Research and monitoring recommendations: Scientists conduct marine mammal surveys from aircraft and boats. They also count seals at rookery sites.

Community involvement: Community members can provide information about seal haul-outs and rookeries. With training, they can participate in surveys under the direction of professional scientists by counting, monitoring, and identifying species.

B3.7 Sea Turtles

Why: Sea turtles are not common in the Gulf of Maine, but many laypeople and scientists are interested in them. They are long-lived, poorly understood, and charismatic animals. Regular use of an area by sea turtles would be especially noteworthy.

What: Presence/absence over time, including when and where animals have been seen, their species, size, and other identifying features.

Sources of information: See Appendix A, page 66.

Research and monitoring recommendations: Because sea turtles are so rare in the Gulf of Maine, it is not recommended that sea turtle research be conducted as part of a marine area characterization. Existing information about sightings should be used instead.

Community involvement: Community members could gather existing information about sea turtle sightings, such as by talking with local fishermen and contacting sea turtle rescue organizations.

HUMAN DIMENSIONS COMPONENTS

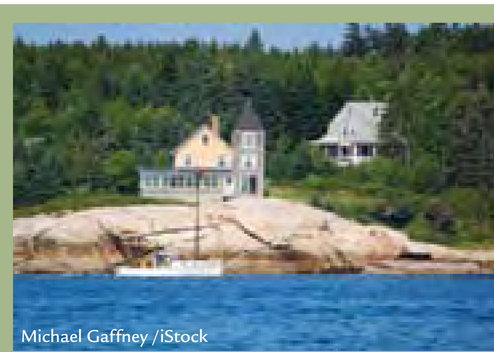
Why: The components in this section describe human uses and activities. Together, the components characterize the types, extent, and degree of impact people may be having on a marine area. The components also highlight the ways in which resource managers try to limit negative effects of human use. These components provide insight into the causes of certain past, present, and even future environmental conditions.

Much of the information about these components is easily obtained, but the question of how the information should be used to characterize a marine area is an active area of research. Increasingly, it is being realized that social sciences should play a bigger role in coastal and marine management. Experts at the National Oceanic and Atmospheric Administration (NOAA), other state and federal agencies, non-government organizations, and academic institutions are working to identify ways of using socioeconomic data and other information from the social sciences to understand the human dimensions of the ocean and coast. This field is relatively new, the practices for characterizing human dimensions are evolving rapidly, and the methods of analysis are not yet firmly established like the methods for characterizing biological and oceanographic components. Therefore, this guide presents only a brief listing of human dimensions components that specialists recommended should be considered as part of a marine area characterization. This guide does not attempt to define specific methods for studying these components. Future editions of the guide will seek to provide updated and more extensive information about how to characterize human dimensions of a marine area, including the latest recommendations from specialists in the field.

Some of the human dimensions, such as fishing and boating, are associated directly with the marine environment. Other components, such as residential development and land conservation, are not directly associated but are important because of the many linkages between land and sea. For example, freshwater that flows from land into the sea may contain contaminants. The amount of contamination is affected by land development and agriculture in the watershed. Fertilizers, pesticides, petroleum products, industrial waste, and other contaminants are common in developed areas. These substances are carried into the ocean by runoff of fresh water from the land. The amount of runoff increases in paved, developed, and disturbed areas of land.

Not all of the human dimensions listed in this section are relevant to every marine area. A particular human use or activity, such as port facilities or seabed mining, may not occur in the study area. A characterization of a deep, offshore area would not include the components related to land-based human activities.

What: Information for these components might be presented best as a set of maps, descriptions, illustrations, and data tables. Collecting information for Human Dimensions tends to be more straightforward than for Biological Components or Oceanographic and Physiographic Components, requiring little or no scientific expertise. For example, knowing how many birds live in a given salt marsh requires a field study using scientifically valid methods. But knowing how many people live in the adjacent town only requires looking at a government census, which is readily available. Similarly, mapping the topography and habitats of the seabed is usually a scientific and technical challenge, but one can obtain information about roads, fish landings, aquaculture leases, and other human dimensions without conducting any scientific studies. Accurate or defensible interpretation of the data, however, requires input from various experts—economists, historians, anthropologists, sociologists, community development professionals, and others.


Michael Gaffney /iStock

Sources of information: Appendix A provides sources of information for each component. Most of the information for Human Dimensions can be obtained from existing sources.

Community involvement: Often laypeople can obtain this information readily. Experts should be consulted about appropriate use and interpretation of the information. For example, correlations that one discovers between human activities and changes observed in the marine environment do not necessarily mean that the human activities caused the marine changes.

H1 Human Population

Describe the number of people living along the coast next to the marine area, the people per square mile or town, demographics, and notable trends in population and demographics over time (seasonal and long-term).

H2 Community Economic Profile

Describe the types of businesses, industries, incomes, and occupations present in the area. Note relative composition, as well as current or anticipated changes.

H3 Land Ownership

Describe who owns or controls land parcels on the mainland and islands around the marine area. Include publicly owned lands, as well as private residential, commercial, nonproft, or industrial ownership.

H4 Land Use and Land Cover

Describe how land around the marine area is used. What kinds of vegetated or unvegetated areas cover the landscape and in what patterns or proportions, e.g., urban areas, residential or commercial development, working forests, blueberry barrens, hayfields, pavement.

H5 Fisheries and Fishing Industries (Commercial, Recreational, Aquaculture)

Describe the species harvested from the area, the amount caught and/or landed in the area, the location and type of fish buyers, dealers, services, and suppliers. What harbors are most active and which have transitioned away from fishing? Where are the major fishing grounds for different species and what gear is used to catch fish in these areas? What offshore grounds do local fishermen frequent? How have the local fisheries declined or grown over the years? Are there closures that prevent fishing in certain areas? How are shellfish harvests affected by pollution closures? Where are the aquaculture lease sites, and which are temporary and which are longstanding? Where are the passages or harvest stations for migratory fishes? Have some fisheries been lost or abandoned due to changes in practices, significant events, or regulations?

H6 Maritime Transport and Navigation

Describe the types and locations of facilities, routes, and activities that support travel by sea. What port facilities, channels, navigational aids, ferry terminals, shipbuilding and servicing operations, dredging, ferry, or deep-draft vessel routes exist in the marine area?

H7 Marine Research and Education Sites

Describe the scientific and educational activities that occur in the area. Are there ongoing or longterm studies, periodic surveys, monitoring stations, laboratories, or other notable sites? Are there summer camps, outdoor expedition routes, nature interpretation centers? What features or functions of the marine area are being studied or used in learning, e.g., lobsters, fishes, seabirds, tide pools, beaches, horseshoe crabs, coastal forests, red tide, phytoplankton, water quality, urchins, climate, island use.

H8 Transportation Infrastructure

Describe the features that support travel across land in the coastal portion of the marine area. Include features such as roads, railways, airstrips, commuter lots, bridges, causeways, dams, dredged channels, culverts, and catch basins.

H9 Manufacturing Sites

Describe the location and type of facilities currently or historically engaged in the manufacturing of raw or processed goods, such as metalworking, furniture, textiles, toys, paper, paint, shoes, electronics, food processors, fish processing plants, and boatbuilding.

H10 Natural Resource Use

Describe the location, intensity, and types of commercial and/or recreational resource use, other than fishing (see H5 on page 45) that occur on land, on the water, or on the seabed in the marine area. Include activities such as hunting, trapping, snowmobiling, logging, agriculture (plant and/or animal), mining, hydropower dams, cell towers, wind farms (on shore or offshore), cables and pipelines (on land or seabed).

H11 Residential Development

In addition to land cover, describe in greater detail the type of development, acreage, distribution, and percentage of land covered with pavement and other impervious surfaces associated with residential life in the marine area. (Determining impervious surface requires expert analysis.) Describe trends in and patterns of development in the area or specific portions of it.

H12 Recreation (Individual, Commercial)

Describe locations commonly used for, or which support, leisurely pursuits such as swimming, sailing, kayaking, canoeing, nature watching, hiking, and swimming. Include areas for individual recreation, as well as those used for organized or commercial activities, such as whale watches, boat cruises, historic tours, and races.


Jeff Schultes/Shutterstock

H13 Public and Private Waterfront Use and Access

Describe the location, use, and ownership of sites and facilities that enable residents and visitors to access the water for recreational and commercial pursuits. Include public and privately owned, commercial, and noncommercial boat launches, ramps, landings, footpaths, moorings, docks, landings, piers, breakwaters, wharves, and marinas. Note limitations in use due to ownership, parking restrictions, tides, safety, and fees.

H14 Protected/Conserved/High-value Natural Areas

Describe the location and nature of marine and terrestrial places which are legally protected from certain types of human use or development. Include local, state or federal parks, reserves, and sanctuaries, as well as lands under conservation easements. Note their level of protection and management, as well as which areas are available for public use and which are not.

H15 Filled Areas and Reclaimed Land

Describe the location and nature of any places in the marine area which have been converted to enable new kinds of uses, such as former salt marsh areas converted to upland, land areas created by filling shallow coastal waters, dredged channels, and armored beaches.

H16 Tidal Restrictions and Barriers to Fish Passage

Describe the location, size, type, and impact (if known) of any man-made or natural structures that impede the natural flow of water or the migration of fishes between marine and freshwater areas. Include features such as road culverts, dams, bridges, berms, causeways, and dikes.

H17 Riparian Buffers

Describe the locations, species composition, and widths of vegetated areas along the shore or the marine area and its estuaries.

H18 Habitat Restoration Project Sites

Describe and locate areas that are the subject of habitat restoration efforts, such as removal of dams and tidal restrictions, replanting of eelgrass beds and salt marshes, removal of fill, and planting or enhancement of riparian buffers.

H19 Significant Cultural Sites (Prehistoric, Historical, Current)

Describe and locate known sites used by Native Americans, early European settlers, recent immigrants, or other distinct populations. Include sites listed on the National Register of Historic Places, local cemeteries, distinct neighborhoods or villages, state historic parks, and other recognized or managed cultural sites. Also include museums, historic societies, granges, lodges, community clubs, and other gathering places. Note churches, schools, and government buildings central to daily life.

H20 Point Source Pollution (Known or Potential)

Describe and locate sites and sources of toxic spills, threats, remediation sites, storage tanks, air emission facilities, thermal discharges, water discharges, sewage treatment facilities, overboard discharge sites, and pump-out stations.

H21 Resource Management Framework for Shore and Water

Other than protected areas (H14), describe the ways and locate the places where local, state, and federal authorities manage human uses. Include techniques and approaches applied on land or water such as zoning, closed areas, input or output controls, gear or equipment restrictions, harvest limits, closed seasons, and wildlife designations.

H22 Regulatory Framework for Shore and Water

Describe the specific federal, state, and local laws, rules, executive orders, ordinances, and regulations that govern human use of the natural environment in the study area. Note the government bodies responsible for administering the laws and rules.

Quebec-Labrador Foundation/Atlantic Center for the Environment
55 South Main Street • Ipswich • Massachusetts • 01938 • USA
QLF Marine Program • 28 Martin Point Road • Friendship • Maine • 04547 • USA
www.QLF.org

MSG-E-08-03