4-1-1991

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Wetlands Program

April 1991 No. 91-4

Technical Report

College of William and Mary
Virginia Institute of Marine Science
School of Marine Science
Wetlands Program
Gloucester Point, Virginia 23062

Dr. Carl Hershner, Program Director
Kirk J. Havens, Editor
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Commonwealth's Declared Policy:

"to preserve the wetlands and to prevent their despoliation and destruction. . ."

This report was funded, in part, by the Virginia Council on the Environment's Coastal Resources Management Program through grant # NA89AA-D-CZ134 of the National Oceanic and Atmospheric Administration.

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Primary Producers and Decomposers of Intertidal Flats

Maryann Wohlgemuth

Intertidal flats are those coastal wetlands characterized by unconsolidated sediments located between mean high water and mean low water. The sediments may be composed of sand, mud, organic substrates, gravel, or shell. Mud and sand flats are often perceived as unproductive and unimportant areas adjacent to vegetated marshes. These areas may appear to be nonvegetated because of the absence of the more conspicuous marsh grasses or other emergent plants. However, tidal flats are vegetated with numerous species of algae, both large (macroalgae) and small (microalgae). Intertidal mudflats may be recognized at low tide as those mucky areas, difficult to walk through and smelling like rotten eggs. Sandflats are generally easier to walk across, and may be good areas to collect clams, oysters, crabs, or worms for fishing.

The organisms and processes that occur on intertidal flats provide an essential component in the balance of the estuarine ecosystem. The next few pages present a sketch of some of the complex processes and fascinating organisms that occur on intertidal flats.

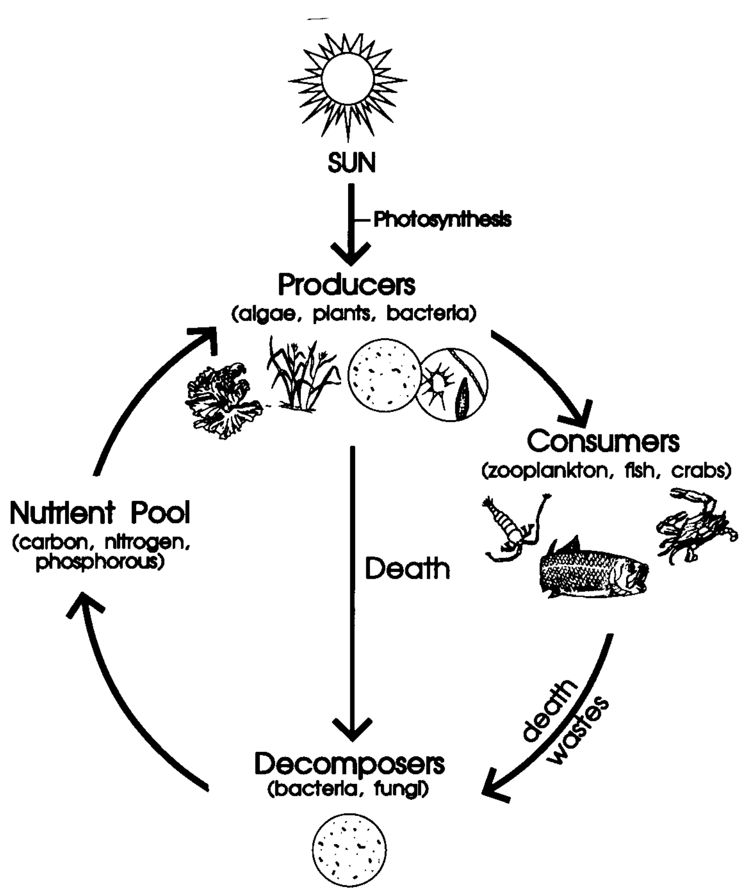
General Ecological Concepts

Energy from the sun provides the initial power source that fuels ecosystem growth processes. Through the process of photosynthesis, plants utilize the sun's energy to convert atmospheric carbon dioxide and water to oxygen and organic matter in the form of plant tissue. As a result of this process, plants such as algae, grass, and trees are recognized as the primary producers of ecosystems. They produce the initial form of edible organic material upon which all living things depend. Many types of bacteria are also primary producers. Some are photosynthetic, using the energy from the sun to make organic matter, while others are chemosynthetic, using energy from chemical compounds.

(continued)

Basic food and energy processes cycle nutrients and energy through producers, consumers and decomposers. Primary consumers (herbivores), such as crabs or fish consume the producers (plants). Secondary consumers, including larger fish, birds, or people feed upon the primary consumers. Decomposers, the bacteria and fungi, obtain their nutrition from degrading dead plant and animal biomass. As they break down organic matter they remineralize constituent nutrients including, carbon, nitrogen, and phosphorous. Remineralization is the process of breaking up the organic biomass into the components from which it was synthesized, the simple minerals (inorganic). These become the raw materials or nutrient pool available to green plants for reuse in primary production of food. Decomposers are therefore an essential link in the recycling of nutrients in all ecosystems (Figure 1). "Life on earth would die out far faster if bacteria became extinct than if the animals, plants, and fungi disappeared" (Margulis, 1982).

Figure 1. Food and energy cycling in an ecosystem.



Primary Producers of Intertidal Flats

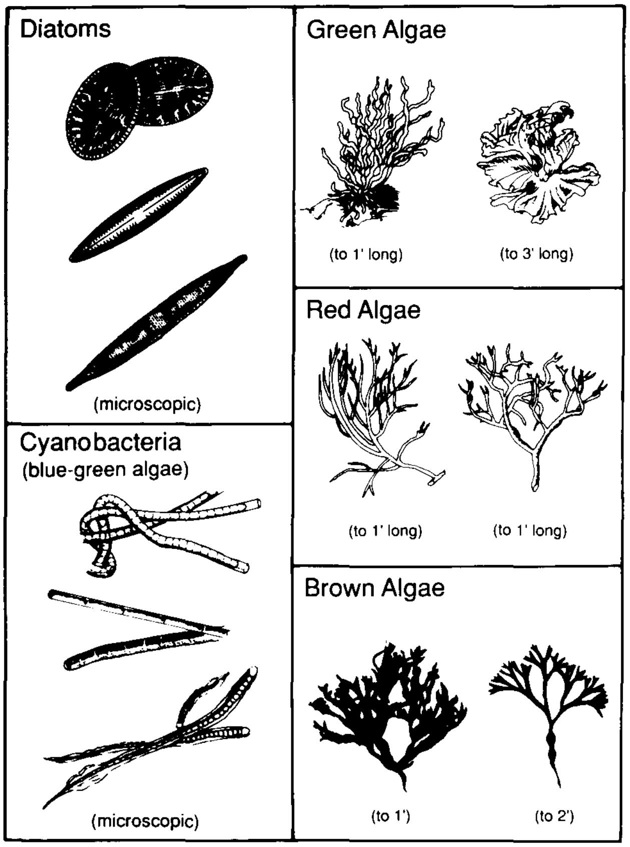
The primary producers on the mud and sand flats include: microalgae such as diatoms, cyanobacteria (blue-green algae), bacteria, and macroalgae (Figure 2). Algae found living on mud and sand flats are referred to as benthic algae to describe their mode of living on the bottom. Though these plants may not be as conspicuous as the easily observed marsh grasses, they are important to the aquatic system for several reasons. They produce an invaluable food source, play an essential role in nutrient cycling, and provide oxygen to the water column.

The organic material produced by benthic algae remains within the aquatic system where it can be utilized as a food source. Similarly, the oxygen produced by benthic algae stays within the aquatic environment. Whereas emergent marsh plants may be utilized as a food source in terrestrial systems; and the oxygen they produce is released to the atmosphere. The organic material produced by algae supplies food for many animals including snails, crabs, clams, and a variety of fish (Figure 3). Microalgae and cyanobacteria are especially important in nutrient cycling because of their fast turnover rate and because they are productive throughout the year. Annual turnover rate is the number of times an organism replaces or reproduces itself in a year.

Microalgae

The microalgae community of intertidal flats is generally dominated by diatoms. Diatoms are single cell organisms that are often observed in dense colonies. Other microalgae observed seasonally include single cell phytoplankton (free-floating plants), such as green algae, dinoflagellates,

Figure 2. Primary producers of intertidal flats.



and other planktonic flagellates (Lippson et al., 1979; Pomeroy, 1959).

Microalgae range from unicellular forms to larger colonial or filamentous forms. Diatoms may be found as solitary cells or attached together in dense colonies. Diatom densities may be up to 40 million per square centimeter (about the size of a postage stamp) (Valiela, 1984). At low tide, microalgae communities growing on tidal flats appear as a discoloration on the sediment surface. Diatoms may appear as a brownish film or gelatinous skin.

Microalgae are valuable to the estuarine ecosystem because they have a high annual productivity, fast turnover, provide a readily utilizable food source and oxygenate the water column (Diaz et al., 1982). Annual productivity of microalgae in a Delaware salt marsh was reported to be approximately a third of the salt marsh production (Gallagher and Daiber, 1974). Unlike emergent marsh plants, microalgae grow in winter as well as summer providing an important winter food source when other plants are dormant.

Diatoms have optimal reproduction rates in the range of 0.5 to 6 doublings per day (Eppley, 1977) resulting in annual turnovers of 182 - 2190 times. Optimal rates may occur when nutrients, light, temperature or other environmental parameters are not limiting. These reproduction rates are appreciable considering that vascular marsh plants, like saltmarsh cordgrass, may only turn over 1 - 2 times per year. This high turnover rate contributes to the high production rate of microalgae. Even though microalgae are small, their annual production may be significant because they reproduce many times during the year. To estimate annual production, biomass from each turnover is summed. The rapid turnover rate of algae also utilizes and recycles nutrients at a high rate.

Microalgae are composed of relatively simple structural materials which provide a readily utilizable food source. Unlike most marsh plants that die and decay before being consumed, microalgae can be consumed directly. Algae are also valued in their ability to oxygenate the water column. Photosynthesis by benthic algae releases oxygen directly into the overlying water, which can result in a significant contribution to dissolved oxygen concentrations. Patrick (1976) reports that unicellular algae are much more efficient oxygenators of water than the more complex emergent marsh plants.

Cyanobacteria

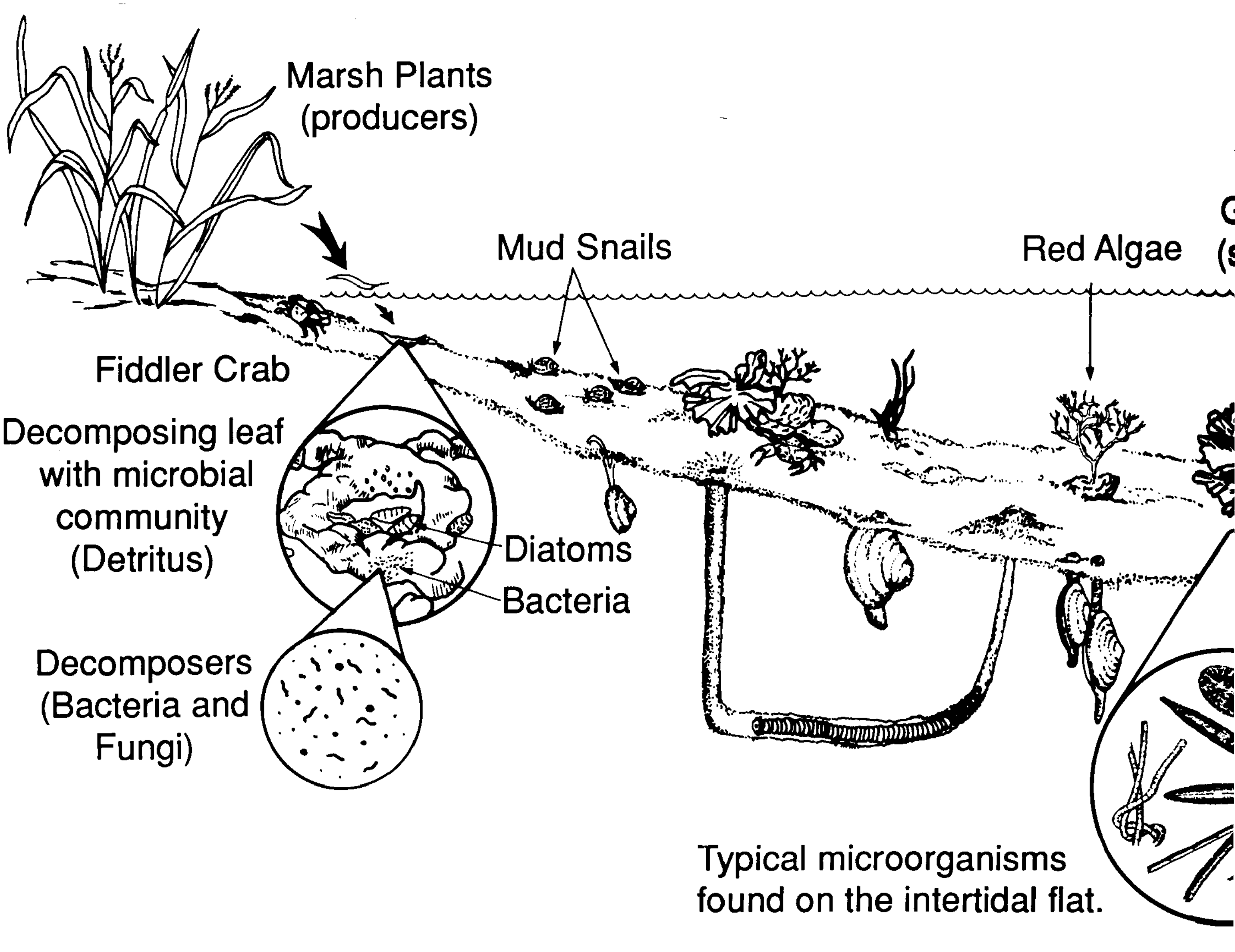
The resemblance of blue-green algae to photosynthetic bacteria resulted in the name change to cyanobacteria (Margulis, 1982). Similar to the microalgae, cyanobacteria are valued for their high annual productivity, rapid turnover rate, readily utilizable food source, and oxygen production. The structure of cyanobacteria is typically a filament or chain of cells. Dense assemblages of filaments appear on intertidal flats as a greenish tinge or thick gelatinous mass. Margulis (1982) reports that cyanobacteria are credited with providing primordial earth with the necessary oxygen concentrations for the evolution of animals and plants. Approximately two billion years ago cyanobacteria increased the atmospheric oxygen concentration from less than 1 percent to about 20 percent (Margulis, 1982).

Macroalgae

Common benthic macroalgae found in Virginia include the green algae (Chlorophyta), red algae (Rhodophyta), and brown algae (Phaeophyta) (Humm, 1979). Macroalgae are commonly referred to as seaweed, and may be found washed up on sandy beaches. A common green algae is sea lettuce which looks similar to the leaves of lettuce. Other examples of structural forms are shown in Figure 2. Macroalgae are most common on intertidal sand flats or attached to rocks, shell, or logs on sand or mud flats. Macroalgae can be distinguished from submerged aquatic plants or other plants by the absence of vascular tissue. Vascular tissue is the circulatory system of plants, transporting water, food, and wastes.

Bacteria

Chemosynthetic and photosynthetic bacteria are also primary producers, using chemical energy or the suns energy to produce organic material. These bacteria are very important in anaerobic (without oxygen) environments such as mudflats. High rates of production by chemosynthetic and photosynthetic bacteria occur in the anoxic zone of the sediment in the intertidal flats (Valiela, 1984). Here they recycle the energy and nutrients that are tied up in organic matter buried in sediments. Margulis (1982) states that bacterial photosynthesis and



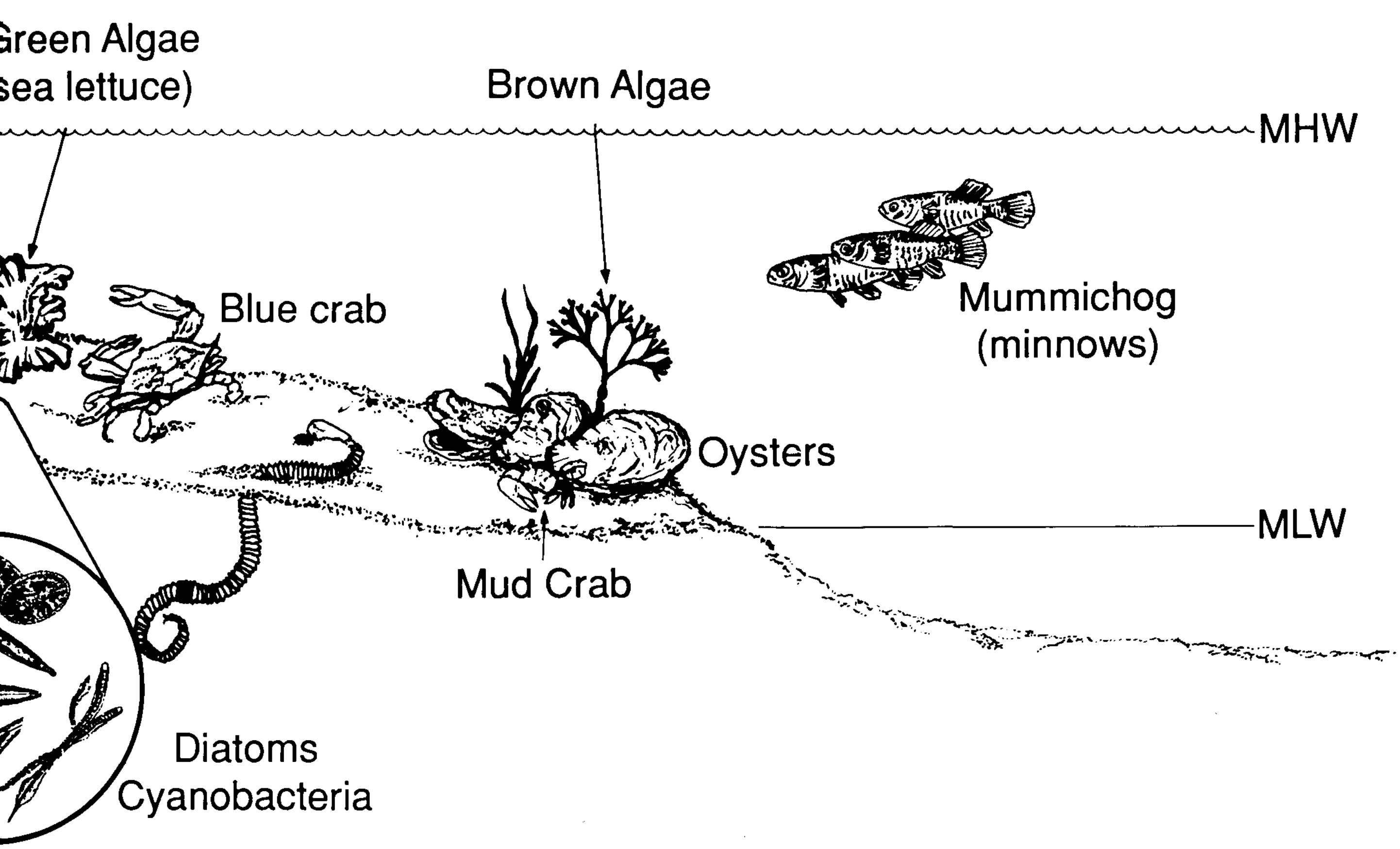
chemosynthesis are essential for cycling the elements and compounds which are fundamental to the survival of the entire biosphere and ourselves. Bacteria are fed upon by microscopic animals which are fed upon by larger animals, thus providing the base of a food web. Larger animals also feed on bacteria by straining them out of the water column or scraping them from sediment or detrital particles.

Decomposers

Tidal flat sediments are important sites for converting complex plant and animal tissue into more utilizable food sources and for remineralizing nutrients. The organisms responsible for decomposition are the bacteria and fungi. The density of bacterial cells is often so great they may form a bacterial film which can be observed as a green or purple tinge on the sediment surface. Decomposers obtain their nutrition by breaking down dead plant and animal matter. Plant and animal tissues in various stages of decay are referred to as detritus, which is a valuable food source for many marine organisms.

Vegetated wetlands, such as the familiar saltmarsh cordgrass wetlands, would be of far less value without the action of decomposers. Only minimal amounts of marsh vegetation are directly grazed upon by herbivores. The majority, 95 percent, of the organic material produced in marshes is consumed as detritus (Patrick, 1976). The action of decomposers allows the large amounts of organic tissue produced in marshes to be degraded into a usable food source which would otherwise be useless to the aquatic food web. Furthermore, the nutrients bound in organic matter would be lost

Figure 3. Mudflat composed of detritus and fine sediments covered with a film of diatoms and bacteria, supports detrital food web.



from the ecosystem and not recycled without bacterial decomposition (Theberge and Boesch, 1978).

Intertidal flats provide an environment for decomposers to degrade organic material produced in adjacent vegetated wetlands into detritus. The microbial community on the intertidal flats play an important role in transferring the plant material produced in vegetated wetlands to a variety of estuarine consumers. As the microbes break down organic matter into detritus and colonize it, they provide a food web base for the estuarine ecosystem. The food source and nutrients made available by the decomposers provide a stable and constant supply throughout the year, which may be especially important when plants are dormant and nutrient levels low.

Remineralization of nutrients by bacteria is a critical pathway in recycling nutrients in all ecosystems. As organic tissues are degraded, remineralized nutrients such as carbon, nitrogen, phosphorous, and sulphur are released. Bacterial decomposition releases sulphur as hydrogen sulphide gas which gives off the rotten egg smell in salt marshes. The benthic microbial community decomposes the available organic matter resulting in a continuous recycling of nutrients between the bottom and the overlying water. The cycling of elements within detritus, sediments and the water column are due largely to the metabolic activities of bacteria (Parsons et al., 1984). Nutrient fluxes across the sediment water interface are important to the primary producers in summer when water column nutrients are low (Nixon et al., 1976).

Bacterial cells have a fast turnover rate similar to the microalgae. They may undergo cell division every 20 minutes under the most optimum conditions and their biomass may increase 5 - 6 times in 24 hours (Zhukova, 1963). Some bacteria are adapted to live below the surface of the sediments where oxygen is absent. Much of the decomposition, production, and nutrient recycling by bacteria is accomplished in the oxygen poor environment below surface sediments.

Detritus

Detritus is a simple word for a complex of decaying organic material and a dense community of microscopic organisms. One gram of detritus may contain up to 5 billion cells of bacteria (Zhukova, 1963). As plant or animal tissue is broken down by bacteria the fragmented parts are readily colonized by microorganisms such as diatoms, bacteria, fungi, ciliates, and flagellates. These organisms are single cell or colonial in structure and provide a protein rich food source for detrital feeding organisms (detritivores) (Bott, 1976). The ciliates and flagellates graze on the bacteria and fungi while this entire microbial community is grazed upon by larger animals. These feeding pathways are part of the detrital food web. The detritivores actually feed on the microorganisms skimmed from the nonliving organic debris (Levinton, 1982). The term 'gardening' has been used to describe this feeding process (Parsons et al., 1984). As the detrital particles pass through the gut of a detritus feeder, microbes are digested while the majority of the plant tissues pass through the gut without being assimilated. The microbe-rich organic matter passing through the gut is further fragmented. The higher surface area to volume ratio of the fragmented particles can then support a larger microbial community. Detrital particles can be seen as a reusable carrier of food as well as a food source.

Detritivores may be either deposit feeders or filter feeders. Deposit feeders ingest sedimentary deposits and assimilate the microbes, composed of bacteria, microalgae, and fungi. Filter feeders consume particles suspended in the water column using a variety of sievelike devices. Examples of filter feeders are clams and barnacles; while worms, fish, and crabs that consume benthic detritus are considered deposit feeders.

In summary, decomposers unlock the organic food source found in dead plants and animals by breaking them down into detritus, a readily utilizable food source. By colonizing the dead material they also provide an additional highly nutritious food source. Microbes create detritus and provide an integral detrital food component as well. They further provide a critical link in nutrient cycling through remineralization of organic material.

Regulation of Intertidal Flats

In 1982 the Virginia General Assembly amended the Wetlands Act of 1972 to include regulation of the intertidal mud and sand flats, or nonvegetated wetlands. These areas are defined as those coastal environments that occur between mean low water and mean high water. The Virginia Marine Resources Commission (VMRC) was given the responsibility as lead state agency. Under the Act's local option alternative most localities have adopted the model ordinance and administer wetlands management through local wetlands boards and ordinances. Federal wetland regulation under the Clean Water Act is administered by the U.S. Army Corps of Engineers (Corps) and overseen by the U.S. Environmental Protection Agency (EPA). The Corps and the VMRC have developed a joint permit application that is used by the local, state, and federal regulatory authorities to streamline the permit process. The Commonwealth has compiled a set of Wetland Guidelines which describe tidal wetland types, their values, and methods of coastal construction that minimize wetland impacts. These guidelines can be used to assist applicants when filling out the joint permit application. Other state and federal agencies that may comment on tidal wetland applications during the joint permit review include: the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Environmental Protection Agency, Council on the Environment, the State Department of Health, State Water Control Board, Shoreline Erosion Advisory Service, and Virginia Department of Game and Inland Fisheries.

Intertidal flats are still being lost at a significant rate. The majority of tidal wetlands permitted to be impacted in Virginia have been intertidal flats; 79 percent in 1988 and 73 percent in 1989 (Havens, personal communication).

Concerned citizens can assist in wetland protection through various activities by: attending Wetlands Board public hearings, locating and monitoring wetlands in their area, supporting wetland legislation, informing neighbors and developers of the values of intertidal flats, and encouraging them to minimize their impact on wetlands.

Suggested Reading

For a description of the types of animals that feed on the algae and bacteria of intertidal mud and sand flats see the Wetlands Program Technical Report No. 90-1.

The *Marine Algae of Virginia*, by H. J. Humm, presents a description of the cyanobacteria and the macroalgae identified in Virginia.

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