SECTION 2: SOURCES OF WATER POLLUTION FROM MARINAS AND RECREATIONAL BOATING

Section 2 Contents

Marinas are not reported by states, territories, or tribes to be a major source of nonpoint pollutants that contribute to poor water quality, as are sources such as agriculture and urban areas, though the location of marinas at the water's edge can lead to their being affected by other pollutant sources. Pollutants from upstream point and nonpoint sources in a watershed might flow to a marina's waters, adding to any nonpoint pollutants released at the marina itself. Water quality in a marina, therefore, is often a reflection of not only nonpoint source pollutants generated at the marina but also a cumulative load of pollutants from several watershed sources. Awareness of the potential for the generation of nonpoint source pollution at a marina and of how to use management measures and site-specific BMPs to reduce nonpoint source pollution is important to ensuring the best possible water quality in a marina basin. This section of the guidance describes the pollutants that can be generated at a marina and their potential effects on water quality and aquatic life.

The construction of a marina can create a condition of reduced water circulation. Installing structures such as bulkheads and jetties, which are necessary to ensure the safety of vessels, docks, and shoreside structures, can cause water circulation in the basin to be below what it was before the marina's construction. In an area already protected from wave action, such as a cove or inlet, marinas can potentially introduce pollutants to an area with limited natural circulation or water exchange. Over time, reduced circulation and increased pollutant generation can increase pollutant concentrations in the water column, sediments, and aquatic organisms.

The pollutants that might be generated at a marina and enter a marina basin include nutrients and pathogens (from pet waste and overboard sewage discharge), sediments (from parking lot runoff and

shoreline erosion), fish waste (from dockside fish cleaning), petroleum hydrocarbons (from fuel and oil drippings and spills and from solvents), toxic metals (from antifoulants and hull and boat maintenance debris), and liquid and solid wastes (from engine and hull maintenance and general marina activities). The effects of these pollutants on waterways and aquatic plants and animals are discussed in this section. Marina construction and reconstruction, in-water modifications at marinas, and propeller wash and boat wakes can also disturb aquatic habitats, plants, and animals.

Although nonpoint source pollution is a serious problem nationally, more is always being learned about effective ways to prevent and reduce it. The purpose of this section is to describe the general causes of nonpoint source pollution, the specific pollutants and problems of concern, and the general approaches to reducing the impact of pollutants and other problems on aquatic resources as these relate to marinas and recreational boating. Figure 2-1 illustrates the general types of problems that various pollutants can cause in aquatic systems.

Pollutant Types and Impacts

Marina construction can alter habitats at a site. Shoreline vegetation may be reduced at some locations. Bottom sediments may be stirred up more frequently with boating activity and dredging to maintain channel and basin depth. These kinds of alterations can have both negative and positive effects. For example, installation of marina pilings and bulkheads introduces a hard-surfaced habitat into a marina that previously might have been dominated by a soft-bottomed habitat of mud and silt. Organisms that prefer rocks and other hard surfaces (fouling organisms) will colonize this new habitat and in turn may attract other invertebrates and juvenile fish to the area.

The fact that a marina is present does not mean that water quality is poor. Many marinas have good to excellent water quality. Despite this, their aquatic habitats might not be healthy enough to support a natural diversity of aquatic organisms, and they might still have sediments contaminated by pollutants from storm water runoff or by antifoulants that have leached from ship hulls or piers.

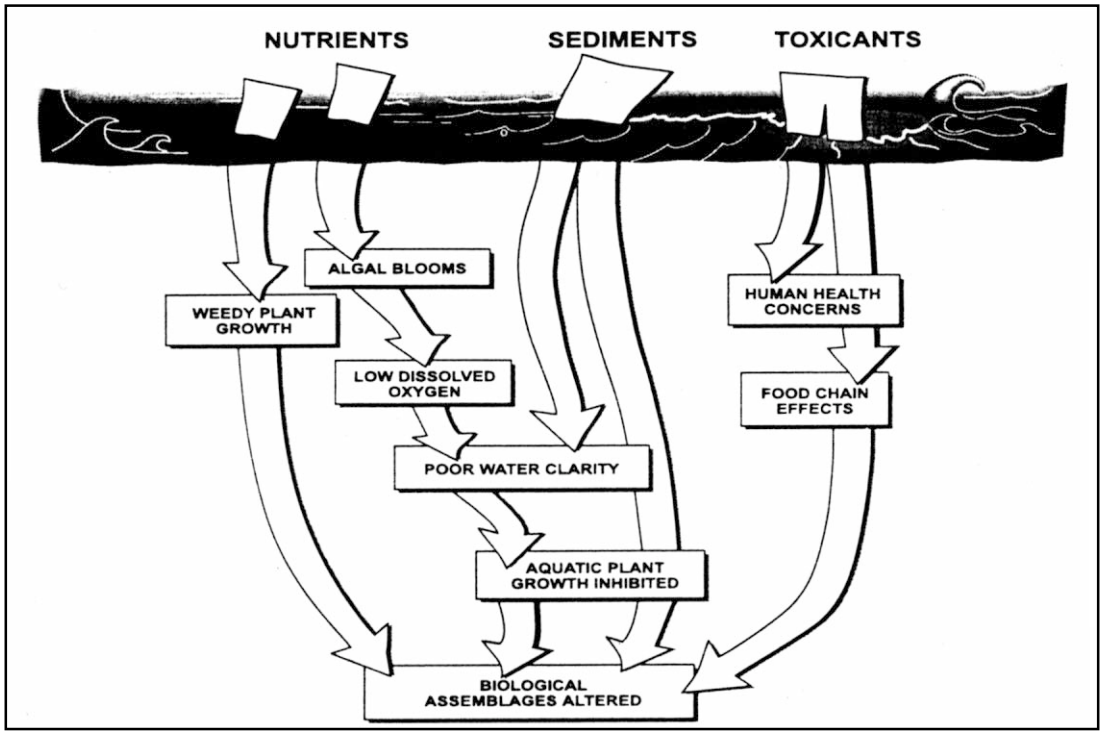

Figure 2-1. Effects of pollutants in aquatic systems.

Pollutants in the Water Column

Pollutants from marinas can cause pollution problems in the water column. These problems usually take the form of decreased levels of dissolved oxygen and increased levels of metals and petroleum hydrocarbons. Pollutants that cause these problems get into the water through storm water runoff, discharges from boats, and spills of fuel or bilge water.

Low Dissolved Oxygen

The organic matter in materials such as sewage discharged from recreational boats, trash tossed into surface waters or on the ground, pet waste carried to waterbodies in storm water runoff, and fish waste disposed of into surface waters consumes dissolved oxygen as it decomposes. The amount of dissolved oxygen required to decompose sewage and other organic matter is measured as the "biological oxygen demand" (BOD) of a waterbody. Consumption of oxygen by decomposing organic matter leaves less oxygen for fish, crabs, clams, and other aquatic organisms. Very low levels of dissolved oxygen can result when water temperatures are high (because hotter water holds less oxygen), which is often the case during the peak summer boating season. Decreases in dissolved oxygen in several northwestern marinas have been noted in the late summer and early fall, the peak times of marina use. An intensive study in several North Carolina marinas showed large differences in dissolved oxygen concentrations in the marinas compared to the concentrations in the adjacent waterbodies, with concentrations in the marinas being much lower.[1] These low concentrations of dissolved oxygen were thought to be due to high biological oxygen demand in the marina basins (due to unknown causes) and poor flushing.

Metals

Metals and metal-containing compounds have many functions in boat operation, maintenance, and repair. Arsenic is used in paint pigments, pesticides, and wood preservatives. Zinc anodes are used to deter corrosion of metal hulls and engine parts, and zinc is often a constituent of motor oil and tires. Copper is used as a biocide in antifoulant paints. Chromated copper arsenate (CCA) is used in wood as a preservative. Mercury is contained in many float switches for bilge pumps and shower water storage tank pumps and in air conditioning/heating thermostats. These switches can contain as much mercury as 100 fluorescent lamps. Nickel is a component of brake linings and pavement material, and cadmium is present in batteries and brake linings. These and other metals (aluminum, iron, and chromium) are used in various components used at marinas or by recreational boaters and can wash from parking lots, service roads, and launch ramps into surface waters with rainfall. High levels of zinc, chromium, and lead have been detected in the waters of some marinas.

Many of the antifoulants used for barnacle control in marine waters are used in fresh waters as well. Copper is the most common metal found at toxic concentrations in marina waters.[2] Dissolved copper has been detected at toxic concentrations at several marinas within the Chesapeake Bay.[3] Copper is leached to surface waters and sediments from bottom paints and scrapings. Tin in the form of butyltin, an extremely potent and non-specific biocide, has been detected at toxic levels in marina waters nationwide.[4] The use of butyltins in bottom paint is now restricted to paints with release rates of 4.0 micrograms per square centimeter or less and on vessels larger than 25 meters (82 feet) in length and on aluminum-hulled vessels regardless of size. Although butyltins are no longer used on most boats, the years of their use in antifoulants has left areas of low to high concentrations of these compounds in sediments. Disturbance of the sediments can reintroduce the toxic compounds into the water column, where they can be ingested by fish or other aquatic organisms and in turn by people.

[1] NCDEM, 1990.

[2] NCDEM, 1990, 1991; METRO, 1992.

[3] Hall et al., 1987.

[4] Grovhoug et al., 1986; Maguire, 1986; Stephenson et al., 1986; Stallard et al., 1987.

Petroleum Hydrocarbons

Sources of hydrocarbons at a marina include fueling stations; operation, maintenance, and repair of boat engines; and storm water runoff from the marina property and off-site upland areas. Petroleum hydrocarbons are contained in fuel, oil, grease, lubricants, finishes, and cleansers. Petroleum can be spilled directly into surface waters when fuel drips from fueling nozzles or a fuel tank is overfilled at a dock. Older 2-stroke marine engines discharge unburnt fuel and oil directly to the atmosphere and surface waters while they are operating. Oil, fuel, paint, anti-freeze, or other liquids dripped from engines or paint brushes or spilled while draining oil or fuel from engines enter surface waters indirectly with storm water runoff or in flows of ground water after the substances have seeped into the ground. Rainwater washes anything dripped, spilled, deposited, or disposed of from building roofs, parking areas, boat ramps, and maintenance areas on the marina property and nearby properties to the nearest downstream surface water, which is often the marina basin.

Solvents

Solvents like methylene chloride, tetrachloro-ethane, trichloroethene, and trichlorethylene are contained in degreasing agents, varnishes, paint removers, and lacquers. They are used at marinas for engine maintenance and repair activities and vessel painting and cleaning. If not properly contained, solvents can potentially enter marina waters through surface water runoff or through ground water transport from hull maintenance areas. Solvents are stable compounds that are insoluble in water, which makes them very mobile in ground water. They are usually heavy, long-chain organic compounds, so they sink to an impermeable bottom layer in the ground (like bedrock) and accumulate. Many solvents are known cancer-causing compounds (carcinogens).

Antifreeze

Antifreeze is used at marinas in dry storage of boats and engine maintenance. It contains either ethylene glycol or propylene glycol. Propylene glycol antifreeze is reported to be much less toxic to aquatic organisms than ethylene glycol and is therefore preferred for use in boats. Both types of antifreeze, however, are considered toxic and should be poured, stored, and drained carefully to avoid spillage. Used antifreeze should be taken to a hazardous waste collection center and recycled if possible.

Acids

Batteries contain battery acid, which is very corrosive and toxic and often contains high levels of toxic metals like lead. Cleaning compounds and detergents often contain strong acids or lye. These materials can be washed into the marina basin with the next rain along with the petroleum hydrocarbons, solvents, paint chips, and other material spilled on the ground. Many hazardous waste collection stations accept used batteries.

Surfactants

Surfactants are compounds used in detergents and other cleaning agents to reduce surface tension. Some are known to be very deadly to aquatic organisms. Surfactants can also accumu-late at the water surface and create a barrier against the transfer of dissolved oxygen across the air-water interface, resulting in lowered dissolved oxygen concentrations in the water. For these reasons, surfactants are best not used on boats that are in the water or on upland areas where runoff washes into surface waters.

Pollutants in Aquatic Organisms

Many aquatic organisms feed by sifting through sediments or eating organisms that filter food particles out of the water. The aquatic organisms thus ingest any pollutants attached to or mixed in with the sediments or suspended particles. The pollutants they ingest accumulate in their tissues rather than being excreted. When many smaller organisms, each of which has accumulated some pollutants in its tissues, are eaten by an organism higher in the food chain (for instance, a fish), that organism then accumulates in its tissues all of the pollutants accumulated by the lower organisms. This process, called bioaccumulation, is the reason that very small quantities of pollutants in the water column can result in dangerous concentrations of pollutants in fish, oysters, and other aquatic

organisms. Numerous studies conducted from the late 1970s through early 1990s have demonstrated this effect and, in particular, the effect on marinas when proper pollution prevention is not practiced.[5] Copper and zinc have been found at higher concentrations in oysters from marinas than in oysters from sites outside marinas; higher-than-normal concentrations of copper, cadmium, chromium, lead, tin, zinc, and PCBs have been found in mussels from marina waters; after 3 months, concentrations of lead, zinc, and copper were two to three times higher in oysters transplanted to marinas than in oysters left outside marinas; and concentrations of copper in green algae and fouling organisms (barnacles, etc.) were much higher in a marina area than in adjacent areas.

Pollutants in Sediments

Many contaminants generated from boat maintenance and general marina use (e.g., oil and grease drippings from cars) do not dissolve well in water and accumulate to higher concentrations in sediments than in the overlying water. Contaminated sediments may, in turn, act as a source from which these contaminants can be released into overlying waters. Benthic organisms—those organisms that live on the bottom or in the sediment—are exposed to pollutants that accumulate in sediments. Pollutants ingested by these organisms become increasingly concentrated in animal tissue as the pollutants are passed up the food chain, and thus can reach levels dangerous for human consumption. Many fish advisories are issued for this reason.

Metals

Copper is the major contaminant of concern in sediments because many common antifouling paint preparations contain cuprous oxide as the active biocide component.[6] In most cases metals tend to sink and accumulate in sediments and not stay in the water column, though they do attach to small suspended particles and can be distributed in the water column with these particles. When attached to suspended particles, metals are often associated with small particles, so they settle out of the water column slowly and are mixed upward easily. In marinas, higher levels of some metals (such as copper and lead) have been found near maintenance area drains and fuel docks than at other locations, suggesting that maintenance areas and fueling stations are sources of metals to the water and good targets for pollution prevention practices.[7]

Petroleum Hydrocarbons

Petroleum hydrocarbons, particularly polynuclear aromatic hydrocarbons (PAHs), tend to attach to suspended particles and sediments. Because they can stay in sediments for years, they can be ingested by mussels, oysters, or other bottom-dwelling organisms long after they are spilled or washed into the water. Studies have found high concentrations of petroleum hydrocarbons in marinas, though the studies have also found that concentrations of these compounds are much lower in the sediments of well-flushed marinas.[8] Such findings support the supposition that sufficient flushing in a marina basin is important to prevent a buildup of pollutants in marina sediments.

Pathogens

Studies that have attempted to determine whether there is a correlation between boating density and pathogen (fecal coliform) concentrations in lakes and reservoirs are divided in their conclusions. Pathogens are added to surface waters by wildlife, dogs and cats, seeping septic tanks, and combined sewer outfall overflows, and these sources could have a larger impact than boaters on pathogen concentrations. Some violations of health standards for fecal coliform bacteria (the bacteria found in human and animal wastes) have been related to periods of high-intensity recreational use, such as holiday weekends. These violations could be due to either boater discharges

[5] CARWQCB, 1989; Marcus and Stokes, 1985; McMahon, 1989; NCDEM, 1991; Nixon et al., 1973; SCDHEC, 1987; Wendt et al., 1973; SCDHEC, 1987; Wendt et al., 1990; Young et al., 1979.

[6] METRO, 1992.

[7] McMahon, 1989; NCDEM, 1991; Soule et al., 1991.

[8] Marcus et al., 1988; McMahon, 1989; NCDEM, 1990; Voudrias and Smith, 1986.

or sediments where pathogens are concentrated being stirred up, or both.

Studies conducted in Puget Sound, Long Island Sound, Narragansett Bay, North Carolina, and Chesapeake Bay have shown that boats can be a source of fecal coliform bacteria in areas with high boat densities and poor flushing.[9] Human health problems can result, especially if nearby waters are used for swimming, surfing, wind surfing, water skiing, or other recreational activities that involve significant water contact.

Bacterial and viral contamination of waters can result from improper use of marine sanitation devices (MSDs). If a vessel has an installed toilet, the law requires that it be equipped with an MSD. Incorrect configuration of the toilet and MSD can lead to direct discharge of waste to surface waters. Discharge of the contents of portable toilets to surface waters also results in contamination. Boats with portable toilets are not required to have MSDs, and their contents should be disposed of at a sanitation facility.

Currently a number of states have designated all or nearly all of their surface waters as no discharge zones (NDZs). These states include Michigan, Missouri, New Hampshire, New Mexico, Rhode Island, and Wisconsin. Boats on fresh waters in New Hampshire, Missouri, and New Mexico must be configured such that wastes cannot be discharged directly into the water (i.e., Y-valves must be disabled), and boats may be inspected to see that this requirement is met. In addition, other states have segments of their surface waters designated as NDZs. These states include California, Florida, Georgia, Massachusetts, Minnesota, New Jersey, Nevada, New York, South Carolina, Texas, and Vermont. NDZs are approximately evenly divided (in number of areas designated) between fresh waters and marine or estuarine waters. A no-discharge policy is also in effect on all Army Corps of Engineers reservoirs.

[9] Fisher et al., 1987; Gaines and Solow, 1990; Milliken and Lee, 1990; NCDEM, 1990; Sawyer and Golding, 1990; Seabloom et al., 1989.

Debris and Litter

The numerous activities that occur at marinas—vessel and engine repair and maintenance, recreation on and off boats, fueling, dock maintenance, and building and grounds maintenance—are sources of a variety of debris and litter. Paper towels and cups, plastic bags, plastic and glass bottles, fish netting, fishing line, discarded oil filters and engine parts, discarded rags, debris from sanding or pressure washing, pet droppings, aluminum cans, and other forms of trash all find their way into surface waters if not disposed of properly. Coastal cleanups result in the collection of millions of pounds of trash and debris from U.S. coasts annually. The most common items found along the nation's coasts are cigarette butts, plastic pieces, foamed plastic pieces, plastic food bags/wrappers, plastic caps/lids, paper pieces, glass pieces, plastic straws, metal beverage cans, glass beverage bottles, plastic beverage bottles, and foamed plastic cups. These wastes are dangers to marine animals, which can die from becoming entangled in items like fishing nets and lines and from ingesting small pieces of debris that are mistaken for food. The trash and debris are dangerous to people visiting the coasts, who might accidentally step on discarded items, injure themselves, and risk infection. They are also unnatural, unsightly additions to the coastal landscape.

Sediment and Habitat Alterations

Dredging can disturb aquatic habitats; resuspend bottom sediments (and recirculate toxic metals, hydrocarbons, pathogens, and nutrients that are found in sediments into the water column); and increase turbidity, which reduces sunlight available to algae and aquatic vegetation. Increased turbidity lowers the rate of photosynthesis and decreases the rate at which dissolved oxygen is added to the water. Because dredging usually occurs over a short time period and then ceases, impacts that result from it, such as turbidity and dissolved oxygen reductions, are usually temporary and do not have long-term negative effects. Other consequences of dredging, such as habitat disruption and deterioration, can have lasting impacts.

Boat operation can cause these same problems in the water column and for aquatic organisms by disrupting shallow habitats and communities and mixing nearshore sediments into the water column.[10] Propeller-driven boats operated too fast near the shoreline can cause bank erosion.[11] Shallow waterways can be affected by propellers cutting off or uprooting aquatic plants from the bottom and propwash mixing sediments into the water.[12] The latter not only reduces photosynthesis, but also can interfere with fish and other sight-feeding animals, clog fish gills, and smother plants and animals.

The effect that boat traffic and motor operation can have on water quality and biological communities in lakes, reservoirs, rivers, and estuaries varies and depends on the characteristics of the waterbody and the type of watercraft being operated on it.[13] The effects are most acute in soft-bottomed lakes and reservoirs, quiet side channels of rivers and streams where fine sediment accumulates because of the lack of strong currents, and waterbodies that have sediments rich in nitrogen and phosphorus.

The impact of boats on rooted plants depends on the depth of the plants below the surface. Where submerged aquatic vegetation (SAV) occurs in shallow areas, boats passing through the area can create troughs where the vegetation is eliminated or severely reduced. Most direct effects of motorboats on submerged aquatic vegetation take place in water less than 5 feet deep, and motorboats can effectively remove all rooted vegetation in water less than 3 feet deep, especially in areas with sandy sediments. Recovery of submerged aquatic vegetation beds can take years, and loss of vegetation can lead to increased erosion and invasion by other species. Submerged aquatic vegetation protects shorelines from erosion and is an important resource for many aquatic organisms because it provides food and shelter.

Larval and juvenile fish can be killed directly by boat propellers and propeller wash. Spawning or nesting fish can be disturbed, and propeller wash can be powerful enough to destroy fish eggs. Fish populations can be lowered if survival of young-of-the-year fish is diminished and reproductive success is lowered. Manatees and other aquatic animals that swim near the water surface also suffer from propeller strikes. Many manatees in Florida bear the scars of propeller cuts.

Shoaling and Shoreline Alterations

Shoaling and shoreline erosion result from the physical transport of sediment caused by waves and currents. These waves and currents can be natural (wind-induced, rainfall runoff, etc.) or human-induced by boat wakes or in-water structures that change currents or reflect waves.

When waves caused by passing vessels or reflected from breakwaters reach the shallow margins of a waterway, they can erode banks and nearby bottom sediments. This effect tends to wash away plants loosely rooted in sediments near the shore and the associated animal life. A substantial volume of the sediment that causes shoaling is eroded from banks, and removing this material by dredging is a costly recurrent expense. Frequent dredging can be necessary where boat traffic causes extensive bank erosion. No wake zones and travel lanes located away from shorelines can reduce and help prevent bank erosion and shoaling. There is a direct relationship between factors such as the distance of a boat from shore, boat speed, slopes of the sides of a bank, type of sediment, and depth of the waterway and the amount of erosion and subsequent shoaling that results. The location of travel lanes should be determined for each specific case with these factors in mind.

The amount of shoreline erosion caused by boat wakes in lakes and reservoirs depends on the same factors as in coastal environments—design features of the boat (size, hull shape, and draft), distance of the boat from the shoreline, water depth, channel width (if the boat is passing through a channel), shoreline soil condition, slope of the shoreline bank, and amount of shoreline vegetative cover. In contrast to coastal environments, in lakes and reservoirs vegetation often grows up to the shoreline, currents are minimal, and there are no tides. Therefore, although boat

[10] Chmura and Ross, 1978.
[11] British Waterways Board, 1983.
[12] USEPA, 1974.
[13] USFWS, 1982.

wakes may be a primary source of erosive energy in lakes with a large amount of boating activity, vegetated shorelines reduce the potential for erosion in lakes. Boat wakes are most likely to cause lake shoreline erosion where the shoreline has been altered and not stabilized and is therefore already susceptible to erosion.