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to the structures, and the physical dimensions of the docks (width, height, plank width, and spacing between planking—they did not include orientation). They found that dock height was the only statistically significant variable; docks less than 12–16 inches above the marsh shaded out all vegetation in every study site. Any impacts from dock width, plank width, and plank spacing were not statistically significant. However, it should be noted that a National Marine Fisheries Service study that assessed dock impacts on marsh grass vegetation in Connecticut, Rhode Island, and Massachusetts cast some doubt on the methodology and statistical analyses of Kearney *et al* (1983) (Colligan and Collins, 1995).

In a field study conducted in Waquoit Bay, Falmouth/Mashpee and Nantucket Harbor (all in Massachusetts), Burdick and Short (1999) found that dock height was not the only factor influencing shading impacts on eelgrass beds but that the orientation of the dock and dock width also played significant roles. According to their data, North-South orientated docks had less impact than East-West orientated ones.

While orientation may be an important factor in northern latitudes, it may not play a significant role in lower latitudes. Sanger and Holland (2002) assessed impacts on *S. alterniflora* from 32 docks in the Charleston, SC area*.* The structures represented a range of lengths, orientations, and ages. They found no significant difference in reduction in *S. alterniflora* density due to shading between North-South oriented docks and those with an East-West orientation.

The National Marine Fisheries Service suggests that spacing between decking planks on the order of an inch or two has little effect on shading impacts, particularly in northern latitudes (Michael Ludwig, NMFS, Personal Communication, 2003). There appears, however, to have been little systematic research on this topic.

In summary, it appears that dock height and width are significant factors that contribute to shading impacts on vegetation. However, but it is still unclear whether orientation and spacing between decking boards have measurable impacts. There appear to be differences in these impacts between northern and southern latitudes.

## Models to Predict Shading—

McGuire (1990) measured the effects of shading by open pile structures on *S. alterniflora* density in a fringe marsh in the York River Estuary (VA). She subsequently developed a computer program to calculate the total number of hours of shading produced by each structure based on height, width and orientation of the structure and compared the computer projections with the results of her field studies. The computer program developed as part of this project appears to hold promise as a predictive tool. Unfortunately, no electronic copies of the program remain (the text of the program is available) and it is written in Pascal. To be effective the program would have to be rewritten in a contemporary, and more user-friendly, format.

Burdick and Short (1998) modeled the impact of shading on eelgrass. They presented their results in an informational CD entitled “Dock Design with the Environment in Mind: Minimizing dock impacts to eelgrass beds.” The CD contains illustrative estimates of impacts to *Zostera* from docks of specific height, width, and orientation. They did not attempt to develop a process to assess the impacts from differently sized and oriented docks but feel that a computer model could be produced to predict impacts from any combination of design factors (personal communication, 2005).

## Cumulative Impacts from Shading—

The issue of cumulative impacts to vegetation from shading or dock construction has not been heavily researched. Consequently is it not clear whether such impacts are additive or have some greater effect.

# *Chronic Impacts from Storage of Floats and Boats—*

Floats, boats, or any other solid structure stored, either permanently or seasonally on the marsh face will significantly shade, and therefore destroy, any vegetation present.

# *Ramifications of Impacts to Vegetation—*

Shading of vegetation, to the point where its health is impaired, can have several adverse impacts.

Lessening of input to the Aquatic Food Web—

Marsh and seagrass vegetation and the detritus they produce constitute a major portion of food available to the base of the aquatic food web. For example, these habitats are critical to the life cycle of shellfish and juvenile finfish that inhabit embayments and estuaries. Significant loss of vegetation may adversely affect populations of these species (Teal, 1986).

# Modification of topography and lessening productivity of the marsh—

Compaction of marsh peat from construction or continually walking to and from a dock changes the marsh topography and may lead to long-term changes in marsh vegetation and drainage (Hruby, 1990). The distribution and species of marsh vegetation are strongly linked to elevation in relation to tidal flooding. Ponding of salt water on the marsh face will eventually lead to changes in vegetation to less productive species (Lefor, 1992).

*Fragmentation of habitat—*

Marshes are important for many species, including fish, birds, mammals and reptiles. Similarly many aquatic organisms, including game fish, shellfish, and the food they eat, depend on submerged aquatic vegetation. Docks, piers and associated walkways to docks fragment these valuable wetland habitats. The presence of docks or subsequent damage to the surrounding vegetation can deter wildlife from frequenting the area. Small docks also fragment eelgrass beds (Burdick and Short, 1999)—primarily through shading of the grasses. There are, unfortunately, limited research results available to quantify the impacts due to habitat fragmentation.

There is a body of empirical evidence showing that fragmentation of habitat causes changes in species diversity and composition (Wilson, 2002). These changes may be in small beds or an entire estuary. Rare or specialized species tend to be the first to disappear from impacted environments (Wilson, 2002.

**Impacts from Contaminants Related to Docks—**

The most common contaminant-related concern associated with small docks is leaching of wood preservatives. Wood continuously exposed to water can decay rapidly. Pilings are also subject to wood-boring and fouling organisms that speed their break-down. To protect the wood and ensure docks will have a reasonable lifespan, the wood is typically treated with preservative chemicals that, in turn, can leach into surrounding waters. Historically, the most commonly used materials were oil-based: creosote or pentachlorophenols. Presently, wood products pressure-treated with chromated copper arsenate (CCA) are the most common material used for dock construction.

# *Creosote and Pentachlorophenol—*

Oil based preservatives containing creosote (CRT) or pentachlorophenol (PCP), applied to the surface of wood materials, leach readily and have wide-spread environmental and human health impacts Most states have banned their use for small docks and piers.

# *Chromated copper arsenate (CCA)—*

CCA-treated wood comes in a variety of “strengths” (the amount of preservative retained in the wood after treatment. The Southern Pine Council (2004) makes the following recommendations for specific uses:

|  |  |
| --- | --- |
| Concentrations of CCA Wood TreatmentsRecommended for Various Uses | |
| Retentions *(lbs./cu.ft.)* | Uses/Exposures |
| 0.10 – 0.25  0.21 – 0.41  0.31– 0.61  2.50 | Above ground  Soil & Freshwater use  Permanent Wood Foundation  Saltwater use |

**Table 1.** Concentrations of CCA wood treatments recommended for various uses.

As can be seen, protection of wood products, generally pilings, in marine waters requires a far heavier treatment than in most other environments.

Weis *et al.* (1991, 1992), in laboratory studies, found that leaching occurs in saline waters and that it can have toxic effects. The leaching rate decreases by about 50% daily once the wood is immersed in seawater. Approximately 99% of the leaching occurs within the first 90 days in the marine environment. (Cooper, 1990; Brooks, 1990; in Sanger and Holland, 2002).

The metals that leach from CCA-treated woods (Copper, Chromium, and Arsenic) adsorb more readily onto fine-grained sediments (silts and clays) than sand (Luoma and Davis, 1983). Field studies by Weis *et al.* (1992, 1998) found elevated concentrations of metals in fine sediments adjacent to (within 1 meter) bulkheads (solid walls of treated lumber, as opposed to dock pilings) constructed of CCA-treated material. The distance at which elevated levels could be found varied according to the sediment types. At most test sites, the impacts were limited to one meter from the structure. In some other sites where fine-grained sediments were predominant, the elevated levels could be found out to approximately 10 meters (Weis *et al.*, 1998).

Elevated concentrations of metals from CCA-treated wood can be found in organisms living on treated pilings and in the areas near to the pilings (Wendt *et al.*, 1996; Weis and Weis, 1996). In sediments with higher contaminant levels, species richness was depressed (Weis and Weis,1998).

Snails in the laboratory fed marine algae gathered from CCA-treated pilings became inactive in 3-4 weeks; they initially curled up inside their shells and then died (Weis *et al.*, 1991). A field study of oysters living on CCA-treated wooden bulkheads showed that they were smaller than control populations and had taken up measurable levels of copper (Weis *et al.* 1993). When copper concentrations are high enough, the oysters’ digestive glands shrink, leading to death. Wendt *et al.,* (1996), however, evaluated uptake of metals by white shrimp, mud snails and two species of fish (mummichogs and red drum) and found no increase in mortality in individuals placed adjacent to 5–12 month old docks for 96 hours. As noted previously, 99% of all leaching occurs within the first three months; the 5–12-month age of the docks in Wendt *et al.’s* study is outside the period when significant leaching occurs.

Factors involved in impacts to biota appears to include sediment type (mentioned above), amount of CCA-treated material (piers vs. bulkheads), length of time the CCA-treated material has been immersed in marine waters (more than or less than 3 months), and the flushing rate of the water body. In an unpublished “gray literature” study prepared for the New Jersey Department of Environmental Protection, Weis and Weis (1998) looked at sediments and shellfish in the Navesink-Shrewsbury River system (NJ) in relation to distance from docks constructed with CCA-treated materials. They found that concentrations of metals in sediments adjacent to pilings at their test sites “were generally not significantly elevated … it appears that leachates from pilings, in reasonably flushed areas have negligible ecological effects, while those from bulkheads, particularly new ones and ones in poorly flushed regions, have demonstrated, clear-cut, ecological effects.” Sanger and Holland (2002) report that, “it is unlikely that the bioaccumulation of dock leachates by marine biota is having or is likely to have an impact on living resources in South Carolina estuaries and tidal creeks.” Reasons given are that approximately 99% of the leaching takes place in the first three months after installation, that the size of the area around the dock that might be affected is small, and high rates of tidal flushing will dilute and flush any accumulations in the water column.

While Weis *et al.* (1991) noted mortality in snails fed algae grown on CCA-treated wood in laboratory tanks, there have been, thus far, no reports of the transfer of metals from the CCA treatment up the food chain to higher predators (P. Weiss in Kelty and Bliven, 2003).

As of 2004, pressure-treated lumber intended for residential and recreational (including docks in freshwater) is no longer treated with CCA. (CCA-treated materials are still used in marine waters.) Alternative treated wood intended for freshwater applications include: Alkaline Copper Quat (ACQ) and Copper Azole (CA, “Wolmanized”®). These are not recommended for marine use.

To summarize, issues to consider in management decisions relating to CCA-treated materials include:

the area of exposed surface of CCA-treated materials (bulkheads have greater surface exposed to water than dock pilings so have a greater potential to leach contaminants into the environment),

the age of the materials used (most leaching occurs within the first 90 days,

the types of sediments in the area (fine-grained sediments with high organic content take up more contaminants than larger grained sediments), and

the flow of water through the system.

Despite these research efforts however, a tidal flushing threshold for contaminant impacts has not been identified, and data do not exist to evaluate the importance of dilution in high flow areas with different benthic community composition.

# *Impacts from Flotation Materials—*

Plastic, non-enclosed foam billets are occasionally used as floatation material for docks. Sometimes referred to by the tradename Styrofoam or “beadboard.” Open-cell foam absorbs water over time and reduces flotation support. More importantly to environmental effects, it breaks down easily into small beads that are virtually indestructible. Pieces of these billets may litter the shoreline or be ingested by wildlife. It may choke air-breathing species or take up considerable space in the digestive tract of species that ingest it, lessening their ability to take up nutrients. Use of this material as dock flotation has been banned in many jurisdictions (Burns, 1999).

*Impacts from Painting and Seasonal Upkeep—*

Painting, staining, scraping or other seasonal maintenance to docks can introduce contaminants into the water column. To avoid potential pollution caused by this type of dock maintenance activity, the Maine State Planning Office (1997) discourages painting and staining, suggesting that “all coatings pose a local environmental threat, damage floatation materials, and have only minimal effect on a structure’s longevity.”

*Impacts from Fuel Leakage—*

Fueling that takes place at small docks generally consists of pouring fuel from a portable tank into an outboard engine’s fuel tank—often with the engine attached to the stern of the boat directly over the water. This offers the opportunity for spillage or overflows. Poorly designed or maintained engines also may discharge fuel during operation. Petroleum products in marine waters can have significant impacts to be discussed further in the following section on boating impacts.

**Impacts of Small Docks on Sediments and Sedimentation—**

During a permit review or planning exercise, coastal managers sometimes hear concerns that small, pile supported docks may cause changes to sediments topography and composition in the vicinity of the structure. This may be attributed to erosion, increased sedimentation, or resuspension and movement of specific particulate sizes or types. Generally, one of the following three mechanisms are suggested:

Changes in water movement due to pilings redirecting water flow or speeding movement around the pile resulting in scour,

Disruption of sediments during piling installation,

Suspension of sediments as floats or boats attached to docks touch or approach the bottom at low tides and lift sediments as they rise with the tide (“pumping”).

# *Altering currents—*



