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cant 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.*



