White Paper
Research Project T1803, Task 35
Overwater Whitepaper

EXECUTIVE SUMMARY— OVERWATER STRUCTURES: MARINE ISSUES

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Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

June 2001

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. WA-RD 508.2	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Overwater Structures: Marine Issues (Executive Summary)		5. REPORT DATE June 2001
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Barbara Nightingale, Charles Simenstad		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Washington State Transportation Center (TRAC) University of Washington, Box 354802 University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. Agreement T1803, Task 35
12. SPONSORING AGENCY NAME AND ADDRESS Research Office Washington State Department of Transportation Transportation Building, MS 47370 Olympia, Washington 98504-7370 Jim Schafer, Project Manager, 360-407-0885		13. TYPE OF REPORT AND PERIOD COVERED White Paper
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This paper synthesizes 30 years of literature documenting the potential effects specific overwater structures pose to important estuarine and nearshore marine habitats for juvenile salmon and other fishes in the Pacific Northwest. While the fish and shellfish species discussed are known to specifically use nearshore habitats, we also examine potential impacts at the broader scale of the nearshore ecosystem.

Overwater structures have been proved to pose potential mortality and fitness risks to these animals and their ecosystems. Mechanisms of impact are characterized as changes in light, wave energy, and substrate regimes. Modifications to these regimes by the construction of, presence of and operations around overwater structures have been found to produce significantly different distributions of invertebrates, fishes, and plants in under-dock environments than in adjacent non-shaded vegetated habitats.

Effects of light limitation (shading) from overwater structures on migratory organisms such as juvenile salmon have been characterized as 1) behavioral barriers that can deflect or delay migration; 2) reduced prey resource production and availability (i.e. “carrying capacity”), and 3) altered predator-prey relationships associated with high intensity night lighting alterations to the nighttime ambient light regime. This paper identifies known visual thresholds associated with light limitation for salmonids and other juvenile fishes.

Empirical findings indicate that the cumulative impacts of overwater structures can have significant impacts on ambient wave energy patterns and substrate types. Given what is known concerning biota and substrate relationships and shoreline geomorphology (drift cell) processes determining those substrates, the basic unit of measurement for establishing change thresholds to identify overwater structure effects is likely related to drift cell characteristics and scale. At this time, drift cell thresholds are not established; however, we conclude that thresholds are needed to avoid and mitigate cumulative effects. Further studies are recommended to determine plant and animal behavioral thresholds and the nature and extent of direct and cumulative effects.

17. KEY WORDS docks, ramps, overwater structures, breakwaters, environmental impact, marine, estuarine, fish, shellfish, eelgrass, cumulative effects, underwater light, shoreline structure, habitats, salmon	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
None	None		

DISCLAIMER

Executive Summary: Overwater Structures: Marine Issues

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As part of the process outlined in Washington's *Statewide Strategy to Recover Salmon: Extinction is Not an Option* the Washington Departments of Fish and Wildlife, Ecology, and Transportation were charged to develop Aquatic Habitat Guidelines employing an integrated approach to marine, freshwater, and riparian habitat protection and restoration. Guidelines will be issued, as funding allows, in a series of manuals addressing many aspects of aquatic and riparian habitat protection and restoration.

This document is one of a series of white papers developed to provide a legitimate scientific and technical basis for developing Aquatic Habitat Guidelines. The white papers address the current understanding of impacts of development and land management activities on aquatic habitat, and potential mitigation for these impacts. Individual white papers will not necessarily result in a corresponding guidance document. Instead, guidance document development, addressing management and technical assistance needs, may incorporate information synthesized from one or more of the white papers.

The scope of work for each white paper requested a “comprehensive but not exhaustive” review of the peer-reviewed scientific literature, symposia literature, and technical (gray) literature, with an emphasis on the peer-reviewed literature. The reader of this report can therefore expect a broad review of the literature, which is current through late 2000. Several of the white papers also contain similar elements including the following sections: overview of the guidelines project, overview of the subject white paper, assessment of the state of knowledge, summary of existing guidance, recommendations for future guidance documents, glossary of technical terms, and bibliography.

This paper synthesizes the extent and nature of scientific information about how overwater structures and associated activities potentially affect habitats and key ecological functions that support recruitment and sustainability of estuarine and marine fauna in Washington State. The mechanisms of potential overwater structure effects are characterized as alterations to ambient light and alterations to wave energy and substrate regimes.

Regional findings pertaining to such overwater structure effects to these ecosystem regimes are presented and discussed. We also identify and discuss both direct and cumulative effects to natural shorelines and urban industrialized shorelines and present measures to mitigate and control for direct and cumulative impacts. Existing scientific gaps and recommendations for future exploration are presented along with an overview of the existing regulatory framework pertaining to overwater structures.

Prey resource production, refugia, and reproduction are key ecological functions provided by shallow nearshore habitats. These functions are important to the recruitment and survival of the region's fish and shellfish species. Overwater structures and associated activities can impact the ecological functions of habitat through the alteration of those controlling factors that support key ecological functions such as spawning, rearing, and refugia. Whether any of these impacts occur and to what degree they occur at any one site depend upon the nature of site-specific factors and the type, characteristics, and use patterns of the overwater structure located at a specific site.

Over the past 25 years, many studies have identified these impacts. Often these studies have been focused upon particular species of concern such as juvenile salmonids and Dungeness crab. This paper broadens the species of concern to include representative fish and shellfish species with a dependence upon the region's nearshore marine ecosystems. Those species represented in this paper include a wide variety of ecologically important and vulnerable species known to utilize nearshore habitats during different life-history stages. For most species, juvenile stages have an important dependency, albeit at different magnitudes, upon nearshore marine and estuarine ecosystems. This paper presents an overview of such animal dependencies upon specific habitat characteristics, the controlling factors determining habitat characteristics, and information sources pertaining to known and potential effects posed by various forms of overwater structures. The description of habitat impacts are limited to those occurring within those ecosystems located between the tidal levels of mean high water spring (MHWS) and -15 meters below mean lower low water (MLLW). Descriptions and definitions of these intertidal and shallow subtidal ecosystems are also included.

Conceptual Framework for Identifying Impacts

As overwater structures are typically located in intertidal and shallow subtidal areas, the focus of this paper is upon habitats located within those tidal elevations. The primary physical processes controlling habitat attributes and functions are depth (elevation), substrate type, wave energy, light, and water quality. It is widely recognized that changes to these factors can change the nature of these nearshore habitats.

Ambient Light Regimes

By virtue of light refraction from the water's surface, the underwater light environment is by nature a light- reduced environment. Light reduction reduces the amount of energy available for the photosynthesis of phytoplankton, benthic algae, attached macroalgae, eelgrass and associated epiphytes, and other autotrophs. These photosynthesizers are an important part of the food webs supporting juvenile salmon and other fishes in estuarine and nearshore marine environments.

Plants and Light

Without proper precautions, shade cast from docks, piers, and pilings limits light availability. In the Pacific Northwest, distributions of invertebrates, fishes, and plants have been found to significantly differ from distributions found in under-dock environments when compared to adjacent non-shaded vegetated habitats.

Animals and Light

Most teleost fishes, a classification that includes all fish identified in this paper, depend upon sight for feeding, prey capture, and schooling. For these fishes, sight is of tremendous importance for spatial orientation, prey capture, schooling, predator avoidance, and migration. The sediment structure strongly influences the vegetation assemblages at given locations with the nature of the vegetation assemblage determining the availability of fish and shellfish prey resource and refugia and ultimately shaping fish distribution and growth rates. For example, reduced light levels can limit the extent of eelgrass at a given site. This reduction of eelgrass extent can directly limit the availability of important fish prey resources associated with those epiphytes that colonize on eelgrass shoots. The presence of eelgrass, in turn, determines the abundance of fish preferred prey species. Given the strong association of important fish prey resources with eelgrass, limitations to the extent of eelgrass pose a potential risk of also reducing prey resource availability. Prey resource limitations likely impact migration patterns and the survival of many juvenile fish species.

Overwater structures can also impact fish migratory behavior by creating sharp underwater light contrasts through the casting of shade under ambient daylight conditions and artificial night lighting changes. Daytime light reduction through dock shading poses a risk of delaying migration and driving the migration of juveniles into deeper waters during daylight hours. Migratory delays may pose risks to survival through risks associated with altered migration timing and limited growth. Driving migrating juveniles into deeper waters poses the risk of predation by larger predators occupying pelagic waters. Nighttime artificial lighting can change ambient light regimes and pose risks of increased mortality through changes to fish nighttime distributions and consequently prey and predator relationships.

Wave Energy and Substrate Regimes

The abundance and types of epibenthic prey available for juvenile salmonids and other small nearshore fishes appear to be closely linked to substrate size and type, bottom elevation and gradient, and wave and current exposure. Wave energy and water transport alterations imposed by docks, bulkheads, breakwaters, ramps, and associated activities can alter the size, distribution, and abundance of substrate and detrital materials. Such changes in sediment transport patterns can present potential barriers to the natural processes that build spits and beaches and provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning.

Characterizing Specific Structural Effects

A growing body of literature, accumulated over the past 30 years, documents what is known about the impacts of overwater structures to important habitats for juvenile marine fishes and juvenile salmon migratory corridors in the Pacific Northwest. This paper identifies those information sources and their findings. Overwater structures have been documented to pose the following potential risks for increasing the mortality of juvenile fishes utilizing shallow estuarine and nearshore marine habitats.

- "Behavioral barriers" that can deflect or delay migration
- Reduced prey resource production and availability (i.e. "carrying capacity")
- Altered predator-prey relationships associated with high intensity night lighting changes to the nighttime ambient light regime

Effects vary in the nature of extent of habitat effects depending upon structural types, site characteristics, structural configuration, and the nature of the construction materials utilized. This paper identifies what is known about specific structure types and recommends site selection criteria, structural design, and construction materials to avoid negative effects to animals and habitats. Findings and recommendations are specific to the following structural types: 1) fixed docks; 2) floating docks; 3) marinas; 4) floating breakwaters and wave boards; 5) barges, rafts, booms and mooring buoys, and 6) boat ramps, hoists and launches.

Conclusions

Light and Animals

Empirical findings support the notion that overwater structures can have measurable effects on the distribution and abundance of marine resources. Based on the existing state of the knowledge and the fact that light levels are measurable and variable with each structure and location, we conclude that light limitation assessment and mitigation in the development of overwater structures is integral to ecosystem-based resource management. Fish feeding and migration abilities are closely linked to the predominant ambient light wavelengths of the natural marine environment. To the extent that under-dock environments block important wavelengths, they diminish prey and directional orientation visibility levels and cause behavioral changes. Laboratory studies have shown that the threshold for the lowest levels of maximum prey capture for juvenile chum and pink salmon occurs between 10^{-1} and 1 foot-candles which is partially equivalent to 0.5 (PAR) Photosynthetically Active Radiation. This represents the lowest end of light levels characterizing dawn or dusk which ranges from 10^{-1} to 100 ft-candles. Measurements of light levels under ferry terminals have identified under-dock areas that drop below the threshold even in the high light conditions of summer. When light intensity falls below this threshold, the fish must "dark adapt" to rod vision. During this time they are in a state of blindness with visual adaptation taking between 35 to 50 minutes. This "dark adapt" process is likely what is reflected in fish pause or directional change behavior. We conclude that during daylight hours, at very minimum, under-dock light levels must be maintained at levels above 0.5 PAR to avoid this behavioral interference. This lower threshold of light level, however, only addresses the issue of migration delays and behavioral alterations associated with required visual adaptation to light intensity variations and transitions from cone to rod vision. Cone vision is often the only form of vision for larval marine fishes. Fish visual development takes place on varying levels. Within juvenile cone vision development stages, there are also varying levels of sensitivity to the full spectrum of ultraviolet wavelengths. As visual development proceeds, juvenile marine fishes are known to behave and feed in response to specific ultraviolet wavelengths. They are known to respond to the full spectra of ultraviolet light contained in outdoor light as compared to forms of artificial light, such as fluorescent lights. Such artificial lighting does not contain both UV-A and UV-B spectra. Evidence reveals that juvenile fish, such as salmonids, feeding in shallow nearshore waters utilize ultraviolet wavelengths for prey capture. Therefore, we also conclude that allowing the transmission of increasing levels of natural light to the under-dock environment to include the transmission of required ultraviolet light spectra will reduce structural interference with fish ability to capture under-dock prey.

Light and Plants

Light thresholds for vegetation vary with species. Eelgrass in Puget Sound is light limited at levels below the photosynthetically Active Radiation (PAR) level of 300 nm; while intertidal macroalgae species may require 400-600 nm and sublittoral macroalgae may require less than 100nm. We conclude that overwater structures can minimize negative impacts to prey resources and habitats if the PAR levels required by vegetation native to the given site are provided by the overwater structure. Overwater structures that reduce light levels below these thresholds limit the growth of these plants and the abundance of prey resources and refugia associated with them. Given the known light threshold needs of plants and fishes in marine nearshore environments, the degree that (PAR) light levels between 300-550 nm are maintained is to the degree that both plants and animals will not be light limited in under-dock environments.

Wave Energy and Substrate Type

Empirical findings support the notion that overwater structures can pose significant impacts to ambient wave energy patterns and substrate types. Given what is known concerning biota and substrate relationships and the drift cell processes determining those substrates, the basic unit of measurement for establishing change thresholds to identify overwater structure effects is likely based in the drift cell. At this time, drift cell thresholds are not established. However, we conclude that such thresholds are needed to mitigate impacts. We also conclude that such thresholds will require development on a corridor and drift cell-specific basis.

Cumulative Effects

Given the apparent increasing demand for overwater structures, structural design to allow maximum light transmission and to mitigate energy and substrate changes are required to protect the ecosystems marine fishes rely upon. Given what is known concerning overwater structure impacts to marine and estuarine ecosystems, we conclude that multiple placements of overwater structures in marine waters can pose substantive risks of significant changes to the immediate and surrounding marine and estuarine ecosystems. These risks require the assessment of existing cumulative light limitation effects and wave energy and substrate effects to the shoreline environment. These risks require assessment at the drift cell level before considering the addition of new structures.

Recommendations

We recommend further exploration to: 1) determine the conditions for and the significance of avoidance of shoreline structures by migrating juvenile salmon; 2) measure the effects of using artificial lights in under-pier environments to avoid interference with natural ambient light patterns in shallow nearshore habitats; 3) further quantify the effects of overwater structures on salmonid prey resource abundance; and 4) develop a scientifically based approach to determine cumulative impact thresholds.

For long-range planning, we recommend the development of scientifically based cumulative assessment to guide overwater structure placement and design. We recommend that such assessment should include steps to:

- Develop a landscape scale model of shoreline processes that create and maintain biological habitats;
- Develop assessment indices for identifying ecological responses to overwater structures within the context of the model;
- Identify landscape-level sub-units, such as shoreline drift cells (sectors), and
- Identify landscape elements in terms of connectivity and homogeneity using the fundamental definitions of corridors, matrices, patches and other landscape attributes.