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EXECUTIVE SUMMARY— DREDGING ACTIVITIES: MARINE ISSUES

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16. ABSTRACT

This paper synthesizes scientific information on the effects of dredging activities on marine habitats. Direct and long-term effects, dredge methods, regulatory framework, contaminated sediment issues, and a separate bibliography of contaminated sediment-related reports are also presented.

Direct behavioral effects include entrainment, increased turbidity, fish injury due to suspended sediment exposure, decreased dissolved oxygen levels, and the effects of noise. A turbidity threshold of 200 mg/L could reduce dredge-induced salmonid prey-predator reaction changes. High sediment load-related fish injury deserves further analysis. Gill injury thresholds specific to marine environments have not been identified. Suspended sediment size, shape, and exposure duration are likely important risk assessment factors for salmonids and other fishes. The most relevant issue is likely the fish ability to avoid plumes and dredge areas. Benthic infauna, epibenthic and demersal organisms, such as borrowing shrimp, crabs, and fish, are subject to entrainment risks. A clearer understanding of dredging effects to biota requires further synthesis of physiology, life-history strategies, water column use, and timing.

In Washington State, maintenance dredging conversion of shallower subtidal to deeper subtidal habitats is much more frequent than new construction dredging conversion of intertidal to subtidal habitats, which is rarely allowed. Loss of intertidal habitats represents potential reductions in coastal habitat carrying capacity. The fish effects of channel deepening alteration to estuarine-freshwater mixing are most evident during early life history stages. Productivity recovery rates range from three months to many years, depending on the species. Lack of long-term and dredge pre- and post-project monitoring makes it difficult to conclusively identify effects.

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DISCLAIMER

Executive Summary: Dredging Activities: Marine Issues

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Characterizing Marine Resource Dredging Effects in Washington State

This paper synthesizes the extent and nature of scientific information about how dredging activities in Washington State potentially affect habitats and key ecological functions supporting recruitment and sustainability of estuarine and marine organisms. A companion paper addresses the same issues in freshwater environments. We present conceptual tools to identify criteria for assessment of potential impacts associated with dredging activities. Identified impacts include: animal injury, behavioral effects, the effects of removing a measured amount of productivity from the landscape, and ecosystem-scale changes due to changes in estuarine circulation. Potential dredging effects are discussed as direct behavioral effects and long-term or cumulative effects. Long-term effects are approached from a landscape ecology perspective with the goal of facilitating the identification of critical regions in a given estuarine or marine landscape area and better identify critical habitat functions and the changes associated with dredging that could affect the realized functions of those habitats

Information pertaining to the disposal of contaminated sediments is provided in a brief overview of disposal mechanisms and decision-making and a bibliography providing access to extensive literature specific to disposal and contaminated sediments.

This paper describes the existing federal and state regulatory framework regulating dredging and disposal activities. Federal and state authorities under the Clean Water Act, the Rivers and Harbors Act of 1899, the Ocean Dumping Act, and applicable state laws are summarized. Prohibited Work Periods (existing and proposed), Hydraulic Code Rules, Habitats of Special Concern, Tidal Reference Areas, and Technical Provisions Applicable to Dredging Activities are also presented.

Dredging Purposes

Marine dredging can be generally characterized as either large-scale "construction" dredging for the creation of new projects or deepening waterways or periodic "maintenance" dredging that serves to maintain existing facilities and sustain existing hydrologic features. Maintenance dredging tends to occur periodically on a regular basis in existing navigation channels in response to the continuous deposition of sediments from freshwater runoff or littoral drift. By far, most dredging in Washington State over the recent past has been maintenance dredging, with few new or expanded projects. Maintenance dredging poses different risks and alterations to marine ecosystems than the nature of those risks posed by new construction.

Including the amount of dredged sediment removed from the Columbia River estuary, annually an average of approximately 5.3 million cubic meters of sediments are dredged from Washington State waterways.

Dredging and Disposal Methods

Dredging methods are divided into two primary categories, hydraulic and mechanical, with each consisting of a variety of equipment types. Dredging methods are selected based upon specific site characteristics such as substrate type, site bathymetry, wave energy, contamination potential, and spatial feasibility.

The physical and chemical nature of the materials dredged determines the disposal methods used. In general, disposal methods include: confined disposal, open-water disposal, and beneficial uses. Dredge materials undergo an extensive evaluation that includes a review of site history for potential contamination and laboratory analysis for the presence of chemicals of concern. If chemicals of concern are identified in site samples, biological testing is then undertaken. Sediments assessed to be unacceptable for open water placement due to contaminant levels being above determined threshold levels, thereby posing risks of unacceptable adverse environmental or human health effects, are typically placed in confined disposal facilities (CDF's). In confined disposal, the dredged material is contained by a diked structure that separates the dredge materials from the water column and the surrounding benthic environments.

When dredged sediments are assessed to be suitable for in-water disposal, both in terms of substrate type and free of contaminant risks, the materials can be used for beneficial purposes above and beyond simple disposal. Beneficial uses include meeting habitat restoration, landfilling, and construction needs. Potential nearshore beneficial uses include: supplementing the beach profile, by adding material to the littoral zone, and beach nourishment, where natural sediment sources and shoreline drift have been impacted. This can decrease nearshore wave heights and reduce damage from erosive waves and storms. Similarly, fish and shellfish habitats that have been historically impacted by dredging or contamination may be rehabilitated or created by the deposition of uncontaminated dredged material.

Beneficial use projects have been most effective, and have provided documented ecological responses, where dredged material sediments are replacing a natural source, and normal shoreline erosion and accretion processes are allowed to operate. However, disposal of dredged material in highly engineered estuarine or nearshore marine features that are atypical for these types of sediments often provide only short-term benefits, require high maintenance, or are sometimes even ecologically counterproductive. Considerable technical thought and evaluation should be required for any beneficial use proposal involving dredged material.

Direct Behavioral Effects

Identified dredging effects can include entrainment of organisms, increased turbidity at the dredging site, fish injury associated with exposure to suspended sediments and decreased dissolved oxygen, and fish behavioral effects due to the effects of noise. Environmental windows are used to constrain dredging and disposal operations to specific periods of operation in order to protect sensitive biological resources and their habitats from detrimental effects. In the identification of direct behavioral effects, this paper presents documented examples of effects identified in entrainment, turbidity, noise, and fish injury field and laboratory studies. Those studies report effects to Dungeness crab, shrimps, salmonids, sturgeon, geoducks, and, in the case of entrainment, to marine fishes such as sculpins, sole, gunnels, prickleback, and smelt. Based on documented life-history strategy similarities shared with those species reported in the above studies, this paper expands the analysis of potential behavioral effects to include a wider range of species using estuarine and marine nearshore habitats.

Entrainment

Entrainment occurs when organisms are trapped during the uptake of sediments and water by dredging machinery. Benthic infauna are particularly vulnerable to being entrained by dredging uptake, but mobile epibenthic and demersal organisms such as burrowing shrimp, crabs, and fish may also be susceptible to entrainment under some conditions.

Turbidity

Turbidity is a natural characteristic of estuarine habitats. It is a product of the receipt of sediments and organic particulates from uplands and freshwater drainages and estuarine and marine primary production levels, combined with the effects of tidal flows, currents, and storms.

Fish Injury

Although juvenile fishes of many species thrive in rivers and estuaries with naturally high concentrations of suspended sediments (SS), studies have shown that the size and shape of suspended sediment and the duration of exposure can be important factors in assessing risks posed to salmonid and other fish populations.

Noise

It has been documented that underwater noise can influence fish behavior. This is likely linked to the importance of sound to fish when they hunt for prey, avoid predators, and engage in social interaction.

Mitigation of Direct Short-Term Behavioral Effects

The site-specific selection of dredging equipment and methods, and operational procedures, can mitigate some of the negative direct effects of dredging. For example: use of a closed or sealed bucket clamshell dredge can be used to minimize the effects of increased turbidity and contain contaminated materials.

Cumulative and Long-term Effects

Long-term effects of dredging include the cumulative effects associated with the dredging or disposal of contaminated materials and the landscape-scale changes in estuarine/marine bathymetry and habitat characteristics resulting from dredging activities. Long-term landscape-scale changes that result from dredging include productivity changes, the conversions of shallow subtidal to deeper subtidal habitats, the conversion of intertidal to subtidal habitats, and changes to estuarine circulation which, through salinity and other changes, can indirectly influence the distribution of estuarine and nearshore marine biota.

Contaminated Sediments and Water

Potential cumulative and long-term effects of dredging include delayed detrimental responses of biota to changes in habitat, water quality, and other conditions that may occur after the actual dredging activity. For instance, contaminant mobilization, contaminant leaching, bioaccumulation, and trophic transfer through the food web can occur during or as a result of the dredging or disposal of contaminated sediments but may not be immediately manifested in exposed biota.

Conversion of Shallow Subtidal to Deeper Subtidal Habitats

Maintenance dredging, by far the most frequent form of dredging in Washington State, converts shallower subtidal habitats to deeper subtidal habitats through periodic deepening to remove accumulated sediments. Depending upon site characteristics, maintenance dredging may occur at varying time intervals. Different dredging timelines likely represent different disturbance regimes both in terms of the ability of the benthos to recolonize prior to redisturbance and the magnitude of benthic productivity affected.

Conversion of Intertidal to Shallow Subtidal Habitats

New construction dredging poses the risk of converting intertidal to subtidal habits. Such conversions are rarely allowed and are only associated with large new construction projects such as marinas. Intertidal conversions pose the risk of impacting plant and animal assemblages uniquely adapted to the particular light, current, and substrate regimes of intertidal areas. The loss of intertidal habitat, given the important rearing and refugia functions that such habitats provide for migrating juvenile salmon and other important fish and shellfish, represent potential reductions in coastal habitat carrying-capacity and connectivity.

Alterations to Estuarine Circulation and Salinity Structure

Estuarine biota is most likely to be subjected to long-term shifts in critical factors such as salinity distribution if dredging significantly changes estuarine bathymetry in regions of sharp salinity gradients (e.g., within the region of salinity intrusion). Effects may be most evident among anadromous and other fishes (e.g. early life history stages) that are particularly sensitive to salinity, especially during transitions from fresh water to saline waters. Deepening an estuarine channel can alter the degree and form of estuarine mixing as the extent of mixing of fresh waters and salt waters in estuaries is dependent, in part, on channel bathymetry, fluvial and tidal energy, substrate roughness, and other lesser factors.

Productivity Changes

For both rural and industrialized urban estuaries, the action of sediment removal and consequently the removal of plants and animals associated with the sediments removes some level of productivity from the system. Such changes alter to some, typically undocumented, degree the habitat structure and ecosystem landscape processes beyond the local influence of the dredge or disposal site. Depending on sediment characteristics, recovery rates have been found to range from within three months, for some benthic macroinvertebrates such as *corophium,* to many years for slow developing macroinvertebrates such as geoducks. In general, consistent long-term productivity, recolonization, and recovery rates are unavailable due to a lack of long-term pre- and post project monitoring to incorporate seasonal and natural variabilities.

Conclusions

Direct Biological Effects

The direct biologic effects of both maintenance and new construction dredging activities include entrainment mortalities, behavioral effects, contaminant release, and noise effects that can induce behavioral change or cause injury and fitness risks. In the case of maintenance dredging, entrainment mortalities and behavioral and noise effects tend to be temporary and localized. The literature reflects that fish gill injury from exposure to high suspended sediment loads is likely the principle mechanism of injury, but to what extent is uncertain and deserves further analysis. Thresholds for gill injury specific to marine and estuarine environments have not been identified. The most relevant issue is likely the ability of fish to volitionally avoid plumes and dredge activity areas. This requires an understanding of the behavioral nature of fish present and the options available to them in order to avoid the dredge areas. We conclude that a clearer understanding of the effects of dredging on a variety of marine fish and shellfish would come from a further synthesis of what is known about their physiology, life-history strategies, water column use, and timing of a wide variety of marine fishes in specific areas. This would enable the development of environmental windows to avoid entrainment and limit risk. We conclude that further identification of injury thresholds and the distribution of species across all life-history stages is required to further assess animal risks.

Based on present data, a turbidity threshold of 200 mg/L in dredging areas would avoid documented juvenile salmonid prey-reaction and predator avoidance changes due to dredge induced turbidity increases. This would also avoid higher levels of turbidity that are known to cause physical injury. This favors the use of the hydraulic cutterhead dredge equipment and requires special precautions, such as no overflow allowance, when dredging in clay and silty substrates. However, this would not necessarily apply if the natural background turbidity at a given site approached or exceeded that threshold, as animals in that area would likely be adapted to high ambient turbidity levels.

Long-Term Effects

The lack of long-term pre- and post project monitoring and documentation of effects of individual dredging projects on the larger ecosystem make it difficult to conclusively identify effects. Conclusive identification of effects is further complicated by the dynamic nature of estuarine and nearshore marine ecosystems and the history of freshwater and marine dredging. The lack of documentation specific to the nature and timing of recolonization preclude the ability to make conclusive statements on long-term effects. Based on what is known about the needs of marine and estuarine biota, we conclude that management of dredging projects and the beneficial use of dredged materials could be an effective tool for protecting and restoring ecosystem functions if projects were planned on an ecosystem landscape scale basis that is specific to the life-history needs of biota utilizing the larger landscape.

Recommendations

Risk Assessment

To improve risk assessment for direct behavioral and long-term ecosystem effects, we recommend: 1) more extensive use of multi-season pre- and post-dredging biological surveys to assess animal community impacts; 2) incorporation of cumulative effects analysis into all dredging project plans; 3) increased use of landscape-scale planning concepts to plan for beneficial use projects most suitable to the area's landscape ecology and biotic community and food web relationships; 4) further identification of turbidity and noise thresholds to assess fish injury risks, and 5) further analysis and synthesis of the state of knowledge on what is known about the spatial and temporal distribution of fish and shellfish spawning, rearing, and migration behaviors. Such an analysis could improve the identification of potential dredging environmental windows and further evaluate the applicability of accepted dredging environmental windows based on best available science.

Dredge Operational Practices

Dredging effects to marine resources can be further minimized through: 1) reducing the volumes of dredged materials removed; 2) reducing the frequency of dredging; 3) avoiding projects that convert intertidal to subtidal habitat; 4) requiring that dredges and barges completely contain dredged material to minimize turbidity increases; 5) employing best management practices to reduce changes to ambient light conditions, and 6) avoiding geoduck losses by avoiding dredging in geoduck tracts. Technological tools such as the "Silent Inspector" should be considered whenever particularly sensitive habitats or organisms are at risk due to dredging proximal to sensitive habitats or in projects where sediments both suitable and unsuitable for unconfined open water disposal will be dredged adjacent to each other.