Technical Note DOER-E2
December 1998

Environmental Windows Associated with Dredging Operations

PURPOSE: This technical note summarizes the types of concerns that lead to requests for environmental windows for Federal navigation dredging projects in both marine and freshwater systems, as well as the frequencies of occurrence of these concerns among U.S. Army Corps of Engineer (USACE) Districts. The information presented is derived from responses received from a survey sent to all USACE District offices that perform operations and maintenance (O&M) dredging in either marine or freshwater environments. This note serves to update earlier surveys by LaSalle et al. (1991) for dredging operations conducted in coastal and Great Lakes areas and by Sanders and Killgore (1989) for seasonal restrictions associated with dredging operations in freshwater systems.

BACKGROUND: For several decades, State and Federal resource agencies have routinely requested that various aspects of dredging projects be restricted to specified time periods known as environmental windows. Agencies began requesting environmental windows soon after passage of the National Environmental Policy Act in 1969. In the interim, this practice has become relatively commonplace, affecting a majority of all Federal dredging projects on an annual basis. This is not surprising since logic dictates that the simplest means of protecting sensitive biological resources or their habitats from potentially detrimental effects of dredging would be to avoid dredging-induced perturbations while resources perceived to be at risk are present. While requests for windows are generally complied with, it is the opinion of most dredging project managers that windows are inconsistently applied, as evidenced by variation in window start/end dates from state to state, even for protection of identical resources in contiguous waterways. In addition, windows are often viewed as being overly conservative and based largely on limited, poorly quantified data or merely on subjective opinion. Certain environmental windows have been imposed despite the existence of technical information contradicting the stated technical basis for the restriction (LaSalle et al. 1991). Compliance with environmental windows would not be problematic if doing so did not complicate scheduling, cause contractual delays, and substantially increase project costs. Often, individual dredging projects are subject to multiple restrictions which cumulatively tend to confine dredging to winter months when biological activity is considered to be minimal. This in turn tends to increase risk to personnel safety for dredge crew members and limit contingencies for repairs and severe weather shutdowns. Maintaining navigable waterways while protecting valuable aquatic resources can only be accomplished by a more indepth understanding of the technical issues underlying requests for environmental windows. The information contained herein was compiled to assist in identification and prioritization of those technical issues that, with further research, can hopefully be resolved.

INTRODUCTION: Environmental windows are routinely recommended by resource agencies with the intent to protect sensitive biological resources or their habitats from potentially detrimental effects of dredging and disposal operations. On an annual basis, about 80 percent of all civil works O&M dredging projects are subject to environmental windows. Under the Environmental Windows

Focus Area of the Dredging Operations and Environmental Research (DOER) Program, research is being conducted to address gaps in the state of knowledge pertaining to windows-related issues. Prioritization of the research required identification of those issues that are most problematic in terms of inflated dredging costs. One phase of this process involved an evaluation of the economic effects of compliance with restrictions. The results of the evaluation are summarized by Dickerson, Reine, and Clarke (1998).

As part of the economic assessment, an environmental windows survey was sent to all USACE Districts and Divisions in March 1997 asking each office for information related to: (a) the types, occurrences, and technical reasons for environmental windows on dredging and disposal operations in their respective geographic areas, (b) background information regarding number of yearly dredging projects, dredged material volume, and specific modes of dredging and disposal, (c) percentage of dredging projects affected and the frequency of restrictions associated with various modes of dredging, (d) a listing of specific resources of concern (e.g., endangered species) and the reasons given for the restriction by the resource agency, (e) start/end dates for windows linked to each resource of concern, (f) restrictions associated with water quality concerns (e.g., dissolved oxygen depletion), and (g) identification of appropriate State or Federal agencies from which restriction requests originate. In addition there was a section for general comments.

USACE District responses confirmed that dredging projects are often delayed and, in rare cases, canceled because of restrictions. A wide variety of issues arise in connection with windows. Examples of persistent issues include: (a) disruption of avian nesting activities and destruction of bird habitat, (b) sedimentation and turbidity issues involving fish and shellfish spawning, (c) disruption of anadromous fish migrations, (d) entrainment of juvenile and larval fishes, (e) entrainment of threatened and endangered sea turtles as well as disruption of their nesting activities during beach nourishment projects, (f) burial and physical removal of protected plants, and (g) disruption of recreational activities.

SURVEY RESULTS: Sixty-four percent of the personnel asked to participate in the survey responded, representing thirty-seven of the thirty-eight Districts surveyed. A list of Districts and Divisions surveyed can be found in Table 1. Only four Districts (Albuquerque, NM; Fort Worth, TX; Tulsa, OK; and Vicksburg, MS) reported no environmental windows. Several of these Districts have very limited dredging requirements. Five Districts (Galveston, TX; St. Louis and Kansas City, MO; Omaha, NE; and Memphis, TN), which had previously reported no environmental windows in Sanders and Killgore (1989), did report windows-related issues or concerns in this survey.

Corps-wide, over 115 Federal dredging projects are potentially affected annually by environmental windows (Dickerson, Reine, and Clarke 1998). A 10-year (1987-1996) assessment of annual dredging contracts, by region, indicated that the Pacific Ocean and South Pacific Divisions have the highest percentages of dredging contracts subject to environmental windows at nearly 100 percent. This was followed closely by the North Atlantic and South Atlantic Divisions, with approximately 85 percent of all dredging projects having environmental windows (Dickerson, Reine, and Clarke 1998). The Mississippi Valley Division reported the lowest annual percentage (17.7 percent) of dredging contracts with restrictions.

Table 1
U.S. Army Corps of Engineers District Offices Receiving Environmental Windows Survey

Great Lakes and Ohio River Division (LRD)	**Mississippi Valley Division (MVD)**
Buffalo District (LRD)	Memphis District (MVM)
Chicago District (LRC)	New Orleans District (MVN)
Detroit District (LRE)	Rock Island District (MVR)
Huntington District (LRH)	St. Louis District (MVS)
Louisville District (LRL)	St. Paul District (MVP)
Nashville District (LRN)	Vicksburg District (MVK)
Pittsburgh District (LRP)	
North Atlantic Division (NAD)	**South Atlantic Division (SAD)**
Baltimore District (NAB)	Charleston District (SAC)
New England District (NAE)	Jacksonville District (SAJ)
New York District (NAN)	Mobile District (SAM)
Norfolk District (NAO)	Savannah District (SAS)
Philadelphia District (NAP)	Wilmington District (SAW)
Northwestern Division (NWD)	**Southwestern Division (SWD)**
Kansas City District (NWK)	Fort Worth District (SWF)
Omaha District (NWO)	Galveston District (SWG)
Seattle District (NWS)	Little Rock District (SWL)
Portland District (NWP)	Tulsa District (SWT)
Walla Walla District (NWW)	
South Pacific Division (SPD)	**Pacific Ocean Division (POD)**
Albuquerque District (SPA)	Alaska District (POA)
Los Angeles District (SPL)	Honolulu District (POH)
Sacramento District (SPK)	
San Francisco District (SPK)	

Responses to the survey were used to establish 20 general categories of concern (Table 2). Within these categories, over 83 protected or sensitive species have been identified. All USACE Divisions reported environmental windows in some of the categories (range = 4 to 15, $\bar{x}$ = 10). The North Atlantic Division listed the most diverse concerns, representing 15 of 20 categories. Three Districts in that Division (Baltimore, New York, and New England) had the largest number of requested windows by State and/or Federal resource agencies, most often related to the protection of fish and shellfish. The second most diverse assemblage of windows-related concerns (windows in 13 of the 20 categories) was reported by the South Atlantic Division. The Southwestern Division indicated the fewest categories of concerns with only four, dealing mainly with the protection of birds (e.g., terns, brown pelicans, whooping cranes) and sea turtles in the Galveston District. Two Southwestern Districts (Fort Worth, TX, and Tulsa, OK) reported no environmental windows, while one District (Little Rock, AR) had only one window category, involving protection of least terns.

Table 2
Distribution of Environmental Windows Categories by U.S. Army Corps of Engineers Divisions

Category	NAD	SAD	POD	SPD	NWD	SWD	LRD	MVD	Total
Fish (Entrainment)	X	X	X		X		X	X	6
Fish (Turbidity)	X	X	X		X		X	X	6
Fish (Sedimentation)	X	X			X		X	X	5
Fish (Phy. Disturbance)	X	X	X	X	X		X	X	7
Fish (Dissolved Oxygen)	X	X	X		X		X		5
Fish (Migration)	X	X	X	X	X		X		6
Bird (Nesting)	X	X		X	X	X	X	X	7
Bird (Important Habitat)	X			X	X	X		X	5
Sea Turtles (Pelagic)	X	X	X			X		X	5
Sea Turtles (Nesting)		X							1
Oysters/Shellfish	X				X			X	3
Crab/Lobster	X				X				2
Shrimp		X			X	X			3
Marine Mammals	X	X	X	X					4
Sub. Aqua. Vegetation	X			X					2
Seabeach Amaranth		X							1
Freshwater Mussels							X		1
Hunting/ Recreational	X	X	X				X	X	5
Indiana Bat					X			X	2
Tiger Beetles	X								1
Total	15	13	8	6	12	4	9	10	77

RESOURCES ASSOCIATED WITH RESTRICTIONS: Potential detrimental impact to either individual or groups of sport and anadromous fishes is the most commonly cited reason for environmental windows (Table 3). Another major topic of concern frequently cited involved the protection of threatened and/or endangered species (e.g., sea turtles, marine mammals). USACE Districts along the Gulf of Mexico and Atlantic coasts frequently cited sea turtles as problematic in fulfilling dredging or beach nourishment requirements. Additional protected ecologically sensitive

Table 3
Distribution of Supporting Rationales for Environmental Windows by USACE Division/District

	USACE Division/District Responses																																
	North Atlantic					South Atlantic					Great Lakes/ Ohio River						Mississippi Valley					Northwestern					South-western		South Pacific			Pacific Ocean		Total
Rationale for Restrictions	NAB	NAE	NAN	NAO	NAP	SAW	SAC	SAS	SAJ	SAM	LRC	LRH	LRL	LRN	LRP	LRE	MVN	MVP	MVR	MVS	MVM	NWK	NWO	NWS	NWP	NWW	SWG	SWL	SPK	SPN	SPL	POA	POH	33*
Physical Disturbance and Habitat/Nesting Destruction	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		28
Disruption to nesting activities	X	X	X	X	X	X	X	X	X	X			X			X	X	X	X	X	X		X	X	X		X	X			X			23
Important bird habitat	X		X		X			X		X							X		X	X			X		X		X				X			12
Fish spawning habitat	X		X		X	X				X					X	X				X			X		X	X			X	X	X	X		15
Sea turtle nesting activities						X	X	X	X	X																									5
Burial/removal of aquatic plants	X			X																									X	X	X			5
Turbidity and Sedimentation	X	X	X	X	X	X	X	X		X		X	X	X	X	X		X		X	X	X	X	X	X	X			X	X		X		25
Sedimentation on fish spawning	X	X		X	X	X		X					X		X	X		X		X		X	X						X	X				15
Turbidity on fish spawning	X	X	X	X	X	X	X	X				X	X	X		X		X		X	X	X	X		X	X			X	X		X		22
Sedimentation or turbidity on shellfish spawning	X	X	X	X						X			X	X										X	X									9
Entrainment/Vessel Strike	X	X	X	X	X	X	X	X	X							X	X							X	X	X	X				X	X	X	18
Entrainment (fish)			X					X								X	X								X	X						X		7
Entrainment (sea turtles)	X	X	X	X	X	X	X	X	X								X										X						X	12
Entrainment (shellfish)	X							X																X	X									4
Collisions with marine mammals	X	X				X	X	X	X																						X	X	X	9
Migration (spring/fall/fish)	X	X	X		X		X		X		X					X								X	X	X			X	X	X	X		15
Water Quality (DO reduction)	X		X		X	X		X			X	X				X								X										9
Recreational Activities		X							X							X	X	X														X		6
TOTAL	15	11	12	9	11	11	9	13	8	7	2	3	6	3	4	11	7	6	3	7	4	3	7	8	11	7	5	2	7	7	8	9	3	239

* Four additional Districts reported no restrictions. A total of 37 Districts responded.

or commercially important species included: colonial waterbirds (e.g., herons, egrets), nesting birds (e.g., brown pelicans, least terns), fishes (e.g., sturgeon, salmonids), mussels (e.g., pink muckets, orange footed pimplebacks), marine mammals (e.g., right whales, West Indian manatees), and shellfish (e.g., Dungeness crabs, oysters). Other categories included detrimental effects to submerged aquatic vegetation and to recreational activities. The highest number of individual species being protected by environmental windows was reported collectively by the 5 Districts of the North Atlantic Division at 43. A listing of species identified by USACE Districts with regards to environmental windows can be found in Table 4.

TECHNICAL JUSTIFICATIONS FOR WINDOWS: Because environmental windows have become routinely applied to so many dredging projects and involve protection of a tremendous diversity of resources, it is not surprising that the technical foundations for specific windows range from well documented to merely anecdotal. Frequently in the dredging project coordination process, a request for a window may simply state "to protect fish and shellfish" with no further elaboration of specific concerns. The concerns discussed below, therefore, represent just that fraction of all requests from which concerns could be determined. Reasons stated by resource agencies to justify the necessity of specific dredging windows can be categorized as follows: physical disturbance of nesting and spawning; habitat destruction; detrimental effects of suspended sediments, turbidity and sedimentation; hydraulic entrainment; vessel strikes; barriers to migration; reduced water quality; and impediments to recreational activities (Table 3).

Physical Disturbance of Habitat/Nesting: Physical disturbance caused by dredging activities generally involves either the generation of noise, which can interrupt nesting/breeding activities, or damage to critical habitat. Major categories of physical disturbance include: disturbance of fish spawning (e.g., anadromous fishes), disruption of bird nesting/breeding activities (e.g., terns, plovers, pelicans), and/or disruption of sea turtle (e.g., loggerhead, green, leatherback) nesting activities at beach nourishment projects. In the case of colonial-nesting birds, particularly those using dredged material disposal sites, concerns include either periodic placement of additional dredged material or noise disturbance by dredging and disposal operations in the immediate vicinity of a colony (LaSalle et al. 1991). Activities near nest sites have the potential to disrupt reproductive and parental care behaviors, which may lead to lowered hatching success or nest abandonment. Impacts to sea turtle nesting include burial of existing nests and changes in the substrate composition and compaction of beach sand, preventing the excavation of nests. Physical disturbance to habitat and nesting activities was widely reported by USACE Districts in the present survey. Of the Districts responding to the survey, 76 percent (28 Districts) reported that physical disturbance of bird nesting activities was a concern associated with requests for windows, while 32 percent (12 Districts) reported physical disturbance or alterations of bird habitat. Physical disturbance of fish spawning activities was reported in 41 percent of the Districts surveyed (15 Districts), while approximately 14 percent (5 Districts) listed windows related to physical disturbance of sea turtle nesting behavior.

Turbidity, Suspended Sediments, and Sedimentation: Of the Districts surveyed, 68 percent (25 Districts) reported turbidity, suspended sediments, and/or sedimentation issues as a reason for environmental windows (Table 3). In the protection of commercial and sport fish species, dredge-induced turbidity/resuspended sediments was cited as an issue of concern for 22 Districts (59 percent), followed by sedimentation for 15 Districts (41 percent), as the most common reason

Table 4
Species Identified by Corps Districts with Regards to Environmental Windows

Species	Name	Districts with Restrictions
	Avian	
Migratory Birds*	Unspecified species	LRE, SAS, NAP, SAW
Colonial Waterbirds*	Unspecified species	SWG, SAW, NAB, SAM
Protected Shorebirds*	Unspecified species	NAO, NAP, SAM, SAC, SAS
Bald Eagle	*Haliaeetus leucocephalus*	NAB, MVR, MVP, NAP, NWO, MVN, MVS, NWP
Peregrine Falcon	*Falco peregrinus*	NAP, SPL
Raptors	Unspecified species	NWO
Osprey	*Pandion haliaetus*	NAP
California Least Tern	*Sterna antillarum browni*	SPL
Caspian Tern	*Sterna caspia*	LRE
Least Tern	*Sterna antillarum*	MVM, NWO, NAB, NAE, SAJ, SAS, LRL, MVS, SWL
Roseate Tern	*Sterna dougalli*	NAN, NAE
Herring Gull	*Larus argentatuscd*	NAB
Piping Plover	*Charadrius melodus*	NWO, NAP, NAE, SAC, SAW, NAN
Western Snowy Plover	*Charadrius alexandrinus nivosus*	SPL
Brown Pelican	*Pelecanus occidentalis*	SWG, MVN, SAC, NWS
Cormorant	*Phaethontidae* spp.	MNS
Black Duck	*Anas rubripes*	NAB
Herons	*Ardeidae* spp.	NAP, MVR
Whooping Crane	*Grus americana*	SWG
	Fish	
Fishes*	Unspecified species	NWK, LRE, SAW, NWO, NAP, LRL, NAE, NAB, LRH, MVP
Anadromous Fishes*	Unspecified species	NWW, NAO, NAB, NWP
Sport Fishes*	Unspecified species	LRP
Fish Larvae*	Unspecified species	SAS, NAB
Gulf Sturgeon	*Acipenser oxyrhynchus*	NAN, SAM
Shortnose Sturgeon	*Acipenser brevirostrum*	SAJ, NAP, SAC, NAE
Green Sturgeon	*Acipenser medirostris*	SPN
Pallid Sturgeon	*Scaphirhynchus albus*	NWO, MVS, NWK, MVM
Alewife	*Alosa pseudoharengus*	SAW, NAB, NAO, NAE, NAN
American Shad	*Alosa sapidissima*	NAP, NAB, SAW, NAO, NAE, NAN
Hickory Shad	*Alosa mediocris*	NAB
Blueback Herring	*Alosa aestivalis*	SAW, NAO, NAE, NAN
Pacific Herring	*Clupea harengus pallasi*	POA, SPN
Salmonids*	*Oncorhynchus* spp.	POA, LRE, NWS, NWP

(Continued)

* District did not list individual species of concern.

Table 4 (Continued)		
Species	**Name**	**Districts with Restrictions**
Fish (Continued)		
Atlantic Salmon	*Salmo salar*	NAE
Chinook Salmon	*Oncorhynchus tshawytscha*	NWW, LRE, SPN, LRC, SPK
Coho Salmon	*Oncorhynchus kisutch*	LRC, NAP
Rainbow Trout	*Salmo gairdneri*	LRC
Lake Trout	*Salvelinus namaycush*	LRC
Steelhead Trout	*Oncorhynchus mykiss*	NWW, LRE, SPN, SPL, SPK
Delta Smelt	*Hypomesus transpacificus*	SPK
Rainbow Smelt	Osmerus mordax	NAE
Striped Bass	*Morone saxatilis*	NAB, NAO, NAP, SAS, NAE, NAN, LRC, SAM
White Perch	*Morone americana*	NAB
Yellow Perch	*Perca flavescens*	NAB, LRC
Bluefish	*Pomatomous saltatrix*	NAE
Butterfish	*Peprilus triacanthus*	NAN
Bass/Crappie	*Centrarchidae* spp.	LRN
Tidewater Goby	*Eucyclogobius newberryi*	SPK
Northern Kingfish	*Menticirrhus saxatilis*	SAW
Weakfish	*Cynoscion regalis*	NAN
Pompano (Juvenile)	*Trachinotus carolinus*	SAW
Atlantic Tomcod	*Microgadus tomcod*	NAN
California Splittail	*Pogonichthys macrolepidotus*	SPN
Sacramento Splittail	*Pogonichthys macrolepidotus*	SPK
Cave Fish	*Amblyopsis rosae*	MVS
Winter Flounder	*Pseudopleuronectes americanus*	NAN, NAE
California Grunion	*Leuresthes tenuis*	SPL
Shellfish (Mollusks)		
Freshwater Mussel Resources*	Unspecified species	MVR, LRL, MVS
Hard Clam	*Mercenaria mercenaria*	NAN
Soft Shell Clam	*Mya arenaria*	NAE, NAB
Surf Clam	*Spisula solidissima*	NAN
Eastern Oyster	*Crassostrea virginica*	MVN, SAM, NAN, NAE, NAB, NAO
Bay Scallop	*Argopecten irradicans*	NAN, NAE
Blue Mussel	*Mytilus edulis*	NAN
Orange Footed Pimpleback	*Plethobasus cooperlanus*	LRN
Pink Mucket Pearly Mussel	*Lampsillis orbiculata*	LRN, NWK
Shellfish (Crab/Lobster/Shrimp)		
Blue Crab	*Callinectes sapidus*	NAN, NAB
Dungeness Crab	*Cancer magister*	NWS, NWP
Horseshoe Crab	*Limulus polyphemus*	NAP

Table 4 (Concluded)

Species	Name	Districts with Restrictions
Shellfish (Crab/Lobster/Shrimp)		
American Lobster	*Homerus americanus*	NAN, NAE
Commercial Shrimp* (Adult & Juvenile)	Unspecified species	SAW, SWG, NWS
Marine Turtles		
Loggerhead Sea Turtle	*Caretta caretta*	MVN, NAB, NAN, NAO, NAP, NAE, POH, SAC, SAJ, SAM, SAS, SAW, SWG
Kemps Ridley Sea Turtle	*Lepidochelys kempi*	
Green Sea Turtle	*Chelonia mydas*	
Leatherback Sea Turtle	*Dermochelys coriacea*	
Hawksbill Sea Turtle	*Eretmochelys imbricata*	
Marine Mammals		
Marine Mammals*	Unspecified species	POA
Fin Whale	*Balaenoptera physalus*	NAB
Humpback Whale	*Megaptera novaeangliae*	POH, NAB
North Atlantic Right Whale	*Eubalaena glacialis*	NAE, SAC, SAS, SAJ, SAW
Sea Otters	*Enhyfra lutris nereis*	SPL
West Indian Manatee	Trichechus manatus	SAJ, SAS
Miscellaneous Concerns		
Indiana Bat	*Myotis sodalis*	NWO, MVR
Seabeach Amaranth	*Amaranthus* spp.	SAC, SAW
Submerged Aquatic Vegetation	*Potamogeton pectinatus* *Potamogeton perfoliatus* *Zannichellia palustris* *Rupia maritima*	NAB
	Zostera marina	SPN, SPK
Tiger Beetle	*Cicindela dorsalis dorsalis*	NAO
Valley Elderberry Longhorned Beetle	*Desmocerus dimorphus*	SPK

for dredging restrictions. How egg and larval stages of marine and estuarine species are affected by dredging and disposal operations has been a focus of many resource agency requests for windows. Many fish species deposit demersal eggs that remain on the bottom until larval hatching. Resource agencies suspect high mortality of eggs by smothering, as a result of sedimentation, and of larvae by clogging or abrasion of gill tissues caused by suspended sediment particles. For adult and juvenile fishes, the potential blockage of migratory pathways of various anadromous species due to their hypothetical avoidance of turbidity plumes was frequently an issue of concern. Anadromous fishes such as striped bass, American shad, alewife, sturgeon (e.g., shortnose, gulf, pallid), and a number of salmonids (e.g., chinook, coho) were the most frequently listed species of concern. Sedimentation issues are also implicated to support windows to protect submerged aquatic vegetation and shellfish. The burial of aquatic plants such as eelgrass (e.g., *Zostera marina*) due to dredging activities was reported as a windows-related issue in five Districts surveyed. Shellfish such as mobile crustaceans (e.g., shrimp, crabs) and sessile molluscs (e.g., oysters, clams) are also

suspected to be negatively affected by increased levels of turbidity and sedimentation. Nine USACE Districts (24 percent) currently list shellfish with regards to turbidity and sedimentation as a concern leading to windows. Major concerns involve siltation effects on suitability of clutch material settlement by larvae of the eastern oyster (*Crassostrea virginica*) and siltation-induced suffocation of oyster bars.

Hydraulic Entrainment: Entrainment can be defined as the direct uptake of aquatic organisms by the suction field generated at the draghead or cutterhead. Forty-nine percent of the Districts (18 Districts) reported issues of potential entrainment of aquatic organisms as a reason for environmental windows (Table 3). Specifically, dredge-induced entrainment issues were cited for: threatened/endangered species (primarily sea turtles) by 32 percent of the Districts surveyed (12 mostly Atlantic and Gulf of Mexico coastal Districts); commercial and sport fisheries (e.g., anadromous fishes) by 19 percent of Districts surveyed (7 Districts); and shellfish (primarily larval oysters and Dungeness crabs) by 11 percent of the Districts surveyed (4 Districts).

Hydraulic dredging has been implicated in the hypothetical entrainment of numerous commercial fish, shellfish, and threatened and endangered species. Both demersal and pelagic fish eggs and larvae are perceived to be susceptible to entrainment by suction dredges due to their inability to escape the suction field around the intake pipe. Entrainment of adult fishes, such as sturgeon, has also been documented. Observed fish entrainment rates have generally been low for all species, including anadromous fishes. Shellfish such as larval oysters and juvenile and adult Dungeness crabs have been protected by environmental windows placed upon hydraulic dredging in the Pacific northwest. Hopper dredging remains prohibited in Puget Sound and in Grays Harbor, Washington, for most of the year to protect Dungeness crabs. Certain resource agencies, such as the Maryland Department of Natural Resources, have concluded that pelagic larval stages of the American oyster are at risk of being entrained during this phase of its life history. In the present survey, only the Baltimore and Savannah Districts listed windows specifically related to entrainment of larval oysters.

Three species of sea turtles (loggerhead, green, and Kemps Ridley) have been determined by the National Marine Fisheries Service to be put at risk by hopper dredging activities (a fact well documented since 1980). While some Districts (Baltimore, Philadelphia, Wilmington, and Honolulu) are required to place observers aboard dredges to monitor entrainment, USACE Districts along most of the Atlantic and Gulf of Mexico coasts are generally prohibited from hopper dredging from April through November. A continuous restriction is imposed on hopper dredging in Cape Canaveral Harbor due to the high abundance of sea turtles in the area throughout the year. Both biological and engineering studies have led to reduced sea turtle entrainment rates in recent years (Dickerson et al. 1993).

Vessel Strikes: While dredging is generally not prohibited, nine east and west coast Districts (24 percent) reported restrictions to some degree to avoid injuries and/or fatalities to marine mammals from collisions with dredges. Monitoring programs are mandated in which observers spot whales so that they can be avoided. Additional restrictions include reducing dredge speed to and from disposal sites to 4 knots when right whales are known to be in the area and avoiding intentional approaches within 91 m (100 yd) of marine mammals. Species most often cited were the right and humpback whales, West Indian manatees, and sea otters.

Migration Blockage: Fifteen Districts (41 percent), primarily representing the North Atlantic, South Atlantic, South Pacific, and Northwestern Divisions, reported migration of anadromous fishes as a major reason for environmental windows (Table 3). Channel blockage, by the physical presence of the dredge and/or disposal operation or by the presence of a turbidity plume, is believed by some resource agencies to have an effect on the migration of juvenile and adult anadromous fishes. There appears to be no conclusive, documented evidence that dredging operations impede fish migration; however, this remains a recurring reason for compliance with windows in some districts (e.g., Alaska, Detroit, Walla Walla). In addition to migration blockage concerns involving anadromous fishes, the Galveston District is required to prevent the disruption of migratory patterns of commercial shrimp (*Penaeus* spp.) through tidal passes connecting the Gulf of Mexico and the Laguna Madre Estuary. In the case of both fishes and shellfish, the only available information on the subject consists of a few anecdotal observations of the attraction of fishes and shellfish to dredging operations and a report of comparative trawl catch data taken in a dredged material disposal plume versus "clear" ambient water (Maragos et al. 1977 and Harper 1973 as cited in LaSalle et al. 1991).

Reduced Water Quality: Environmental windows based on concerns related to dissolved oxygen (DO) reduction around dredging and/or disposal operations were specifically mentioned in 24 percent of the responses (Table 3). Resource agencies were frequently concerned about DO concentrations during times of fish migrations and spawning activities. DO reduction is a function of the amount of resuspended sediment in the water column, the oxygen demand of the sediment, and the duration of resuspension (reviewed in LaSalle et al. 1991). Studies have indicated a wide variation in DO levels associated with dredging from minimal, or no measurable reduction, to large reduction in DO levels. Water quality parameters (e.g., turbidity, dissolved oxygen) are often required by regulatory agencies to be monitored, and significant changes in water quality can result in cessation of the dredging project. While models have indicated that only minimal reduction in DO can be expected during normal dredging operations, this remains a cause for environmental windows in nine USACE Districts (Table 3).

Disruption of Recreational Activities: Sixteen percent of the Districts reported potential conflicts with or disruptions of various recreational activities (Table 3). These activities included hunting (New Orleans, St. Paul, and Alaska Districts), fishing (New England and Jacksonville Districts), and other boating or tourist activities. Associated restrictions varied widely in time of year and duration.

DATES OF RESTRICTIONS: The majority of environmental windows constrain dredging operations during spring and summer months (March-September) to avoid potential conflicts with biological activities such as migration, spawning, and nesting. Consequently, many dredging projects must occur during winter months. However, many Districts encounter requests for restrictions during all seasons, often making it difficult to fulfill dredging requirements. For example, the New York District has restrictions in winter and spring months to protect striped bass, American shad, Atlantic tomcod (spawning), and winter flounder (spawning and hopper dredge entrainment); whereas summer and fall months have dredging restrictions to protect weakfish (turbidity/reduced DO), sea turtles (entrainment), and plovers and terns (physical disturbance). Often, multiple restrictions are applied to the same dredging project, which has the cumulative effect

of curtailing any dredging activity throughout much of the year. An example is given in Figure 1 which depicts a "typical" profile taken from a dredging project file in the New England District.

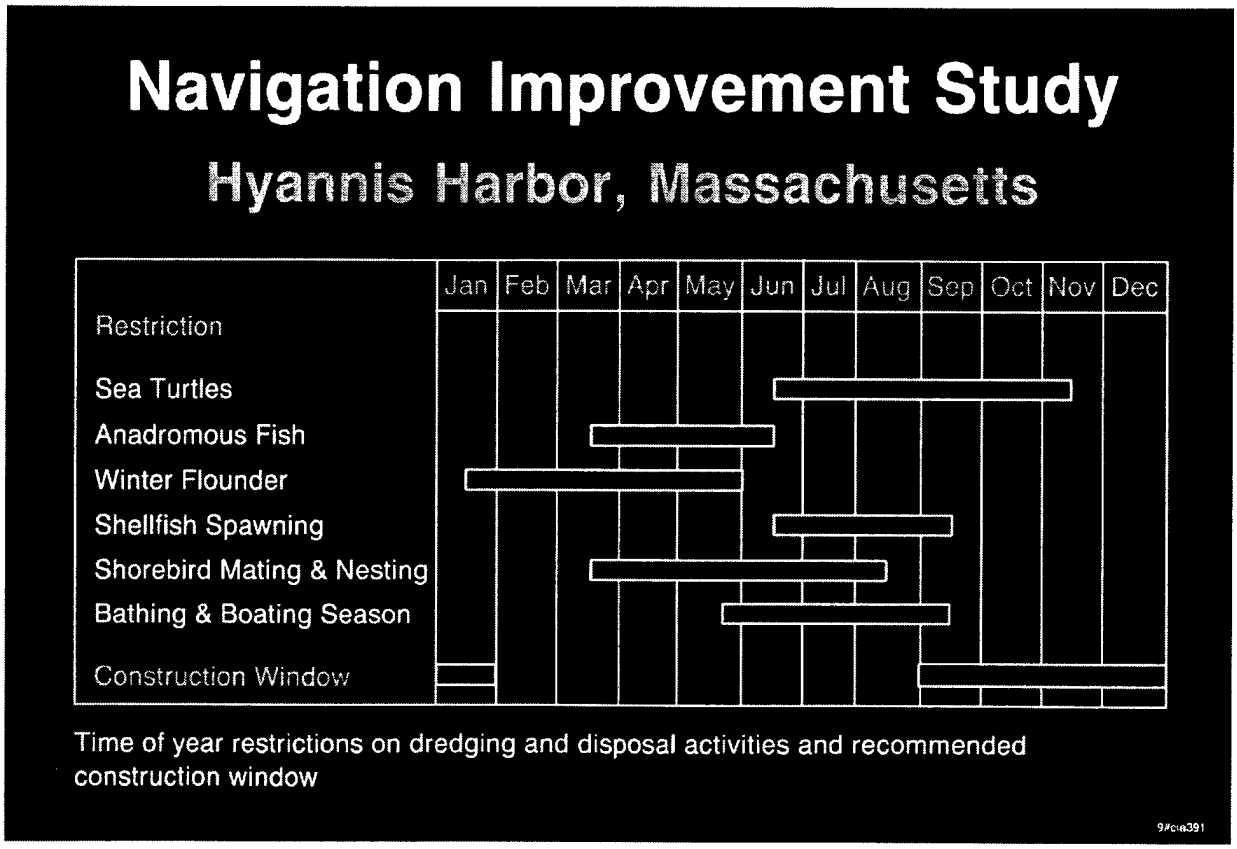

Figure 1. An example of the cumulative effect of multiple environmental windows applied to the same dredging project. In this example the dredging operation could not be completed within the remaining unrestricted period, necessitating an "exemption" during September through mid-November and the latter half of January

PROJECT TYPE OR ACTIVITY OF CONCERN: Maintenance dredging and disposal activities were the most common operations affected by environmental windows. Other types of dredging operations included bank or upland disposal, transportation of dredged material, instream dredging (note that instream dredging refers to commercial sand/gravel extraction rather than navigation dredging) during low flow conditions, instream construction, placement into a Confined Disposal Facility (CDF), beach nourishment activities, and channel improvement projects. Although fewer dredging projects are conducted using hopper and mechanical dredges than with hydraulic pipeline dredges, a higher proportion of restrictions were identified for hopper (83.2 percent) and mechanical (84.5 percent) dredges than with pipeline (66.7 percent) dredges (Dickerson, Reine, and Clarke 1998).

AGENCIES REQUESTING WINDOWS: Restrictions were frequently requested for given dredging projects by more than one State or Federal agency. Agencies most frequently requesting windows consisted of the U.S. Fish and Wildlife Service, the National Marine Fisheries Service,

the U.S. Environmental Protection Agency, and various state entities charged with protection of biological resources (e.g., Departments of Natural Resources, Fish and Game, etc.).

SUMMARY: Environmental windows are imposed on many USACE dredging projects in both coastal and inland waterways. Over 83 protected or sensitive species have been identified which fall into at least 20 general categories of concern for potentially negative impacts from dredging and disposal operations. Recurring concerns are related to the physical disturbance of nesting and spawning, habitat destruction, detrimental effects of turbidity, suspended sediments and sedimentation, barriers to migration, hydraulic entrainment, vessel strikes, degradation of certain water quality parameters, and impediments to recreational activities. The most widely occurring concern is physical disturbance of habitat and nesting, cited as a technical justification for windows in over three-quarters of all USACE Districts, followed closely by turbidity, suspended sediments, and sedimentation issues. Resources of particular concern that were frequently cited in requests for windows included anadromous fishes (e.g., salmon, striped bass, American shad), colonial nesting waterbirds (e.g., terns, plovers, pelicans), and endangered species (sturgeon, sea turtles, right whales).

Often, the data used to justify the validity of certain environmental windows are limited, subjective, or nonexistent. For example, the potential blockage of migratory pathways of various anadromous adult and juvenile fishes due to their hypothetical avoidance of turbidity plumes was frequently an issue of concern associated with windows compliance by many USACE Districts, although such blockage has not been conclusively demonstrated by field studies. Additionally, the entrainment of larval, juvenile, and adult fishes and larval oysters was frequently stated as a reason for environmental windows, although observed entrainment rates have generally been low for all fish species, including anadromous fishes. Compliance with windows based on rigorous technical evidence would not generate controversy. However, since compliance with environmental windows has been shown to increase the cost associated with dredging operations, restrictions should be reevaluated as new data become available. Until sufficient scientific data are obtained to address the individual issues of potential negative impacts, environmental windows will remain a source of conflict in dredging project coordination.

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> Reine, K. J., Dickerson, D. D., and Clarke, D. G. (1998). "Environmental windows associated with dredging operations." *DOER Technical Notes Collection* (TN DOER-E2). U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/dots/doer*

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