Massachusetts Department of Fisheries and Game
Division of Marine Fisheries

Summary of Marine Fisheries Resource Recommendations

for
Municipal Maintenance Hydraulic Dredging Activities on Cape Cod and the Islands

Prepared by:

Kathryn Ford, Ph.D., Eileen Feeney, and N. Tay Evans

MA Division of Marine Fisheries
South Shore Field Station
1213 Purchase Street, 3rd Floor
New Bedford, MA 02740

March 2012

FOREWORD

In 1996, the Massachusetts Department of Environmental Management and Barnstable County established the County Dredge program to handle most of the Cape and Islands dredging needs. The concept was that by conducting routine maintenance dredging of estuaries that the size of the projects, and associated impacts, could be significantly reduced and the tidal flushing of estuaries stabilized over the long-term. County Dredge operations began in fall of 1996 and at first there was no problem scheduling the dredging operations around the Division of Marine Fisheries Time of Year (TOY) restrictions and Natural Heritage and Endangered Species Program TOY restrictions. These restrictions are based primarily upon protection of spawning marine fish, horseshoe crabs, and nesting shore birds associated with estuaries. In inlet channels, much of the marine fisheries concerns relate to the ability of fish to pass through channels during dredging. Because of these concerns, as permits were being renewed, more projects were receiving TOY restrictions. For example, some areas that formerly could be dredged in late spring were restricted to no later than 15 January. By 2000, it became apparent that all the dredging needs could not be accommodated using existing equipment and manpower within the time available based on TOY restrictions and seasonal concerns. As a result there was much discussion concerning scheduling within the Barnstable County Dredge Advisory Committee meetings as early as October 2006.

These growing concerns resulted in the development of an ad hoc group of involved parties in 2008: Falmouth (Selectman Carey Murphy, Harbormaster Gregg Fraser and Waterways Commissioner), Mashpee (Jim Hanks, former Waterways Commissioner, and Harbormaster Perry Ellis), and Barnstable County (Dredging superintendant Wayne Jaedtke, Assistant County Administrator Maggie Downey, Barnstable County Commissioner Sheila Lyons), with additional requested technical support (Brian Howes, SMAST-UMD). Based upon a joint assessment of the issues such as sustaining beneficial tidal flushing and dredging during the best times to avoid interfering with tourism, versus potential effects on the selected species of concern, these parties determined that it was necessary to formulate an approach for seeking relief from the untenable scheduling situation.

Led by Falmouth Selectman Carey Murphy, concerned representatives from several towns met several times at the Falmouth Harbormaster's office. These meetings culminated in a letter being sent in July 2008 to Senators Therese Murray and Robert O'Leary with signatures from the participating towns. The letter highlighted the issues and requested a meeting with the interested parties and representatives from State and local governments. It was copied to the 14 Cape municipalities that have navigable waterways, the Island communities on Martha's Vineyard and Nantucket, the Cape's Legislative delegation, and to the Director of the Division of Marine Fisheries, Mr. Paul Diodati.

The newly established group agreed that a small technical working group should form to work on resolving the issues and present results to the next meeting of the full group. The working group included Division of Marine Fisheries representatives (Dr. Kathryn Ford and Eileen Feeney) and Cape and Islands representatives (Wayne Jaedtke, Barnstable County Dredge Superintendant, Jim Hanks, former Mashpee Waterways Commissioner, Dr. Brian Howes, School of Marine Science and Technology (SMAST), Gregg Fraser, Falmouth Harbormaster, and Ken Bates, Mashpee Waterways Commissioner). The group met several times to develop an approach to solving the issues, find common ground, and construct a document that had the element of mutual benefit in preserving the environmental concerns of the Division of Marine Fisheries and meeting the needs and realities of the County Dredge operational schedule. This document represents efforts the

group made to both identify dredge and resource concerns, and then establish a mutually beneficial and transparent approach to enabling dredging while protecting marine resources. All of the participants anticipate the need to continue this work and the working group looks forward to working with the state to further refine these recommendations in the future.

Ken Bates, Gregg Fraser, Jim Hanks, Brian Howes, Wayne Jaedtke, Carey Murphy
March 14, 2012

A list of the participants (and their affiliations) who attended the larger meetings is below:
Carey Murphy, Selectman, Town of Falmouth
Ken Bates, Chairman Mashpee Waterways Commission
Jim Hanks, former Mashpee Waterways Commission (Chairman)
Dr. Brian Howes, Mashpee resident, Professor, School of Marine Science and Technology (SMAST)
Perry F Ellis; Mashpee Harbormaster
Mike Kinney, Chairman Falmouth Waterways Committee
Joe Voci, Falmouth Waterways Committee
Lynne Fraker, Dredging Consultant to Falmouth and Martha's Vineyard Towns
Gregg Fraser; Falmouth Harbormaster
Robert Whritenour, Falmouth Town Manager
Terry Clen, Dennis Harbormaster
Mark Galkowski; Town of Sandwich Natural Resource Officer
Karl Von Hone, Yarmouth Department of Natural Resources and Harbormaster
Ted Keon, Chatham Natural Resources Officer
Henry Lind, Eastham Harbormaster
Lou Chiarella, NOAA
Steve McKenna, CZM
Bob Boeri, CZM
Dr. Kathryn Ford, MA DMF
Eileen Feeney, MA DMF
John Logan, MA DMF
David M Keddell, USACE
Richard Kristoff, USACE
Michael Leitzel, Bourne
Mo Johnson,
Jo Ann Muramoto, APCC
Elizabeth Kouloheras, Mass DEP Division of Waterways
Lealdon Langley, Mass DEP Division of Wetlands and Waterways
Kevin Mooney, DCR - Waterways
Tom Leach, Harwich Harbormaster
Curt Duane, Bourne
Wayne Jaedtke, Barnstable County Dredge Superintendant
Maggie Downey, Assistant County Administrator County
Sheila Lyons, Barnstable County Commissioner
Sen. Rob O'Leary
Rep. Sarah Peake, Provincetown
Stefanie Coxe, aide to Cleon Turner
Rep. Cleon Turner, State Representative, First Barnstable District
Micaelah Morrill, Chief of Staff for Dan Wolf
Jacqueline Horigan, aide to Sen. Murray
Sue Rohrbach, aide to Senator O'Leary

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ACE	United States Army Corps of Engineers
APCC	Alliance to Protect Cape Cod
ASMFC	Atlantic States Marine Fisheries Commission
CMR	Code of Massachusetts Regulations
Con Comm	Conservation Commission
cy	cubic yards
CZM	Massachusetts Office of Coastal Zone Management
DCR	Massachusetts Department of Conservation and Recreation
DEP	Massachusetts Department of Environmental Protection
DFG	Massachusetts Department of Fish and Game
DMF	Massachusetts Division of Marine Fisheries
EFH	Essential Fish Habitat
ENF	Environmental Notification Form
GIS	Geographic Information System
MA CZM	Massachusetts Office of Coastal Zone Management
MA DMF	Massachusetts Division of Marine Fisheries
MA EEA	Massachusetts Executive Office of Energy and Environmental Affairs
MarineFisheries	Massachusetts Division of Marine Fisheries
MassGIS	Massachusetts Geographic Information System
MEPA	Massachusetts Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
SMAST	School for Marine Science and Technology
TOY	Time of year (restriction)
UMD	University of Massachusetts at Dartmouth
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WQC	Water Quality Certification

ABSTRACT

Dredge projects can result in deleterious impacts to marine fisheries resources and habitats, but the degree of impact varies widely depending on the method, frequency, timing, and location of dredging operations. In Massachusetts, on Cape Cod and the Islands, maintenance dredging associated with coastal embayments has become routine as a result of municipal dredging programs. In order for the towns to plan the timing of their dredging work, there is a need to better define time of year (TOY) restrictions and how they are applied depending on the location of the dredging activity within a waterbody. With assistance from the Massachusetts Department of Environmental Protection, the Massachusetts Office of Coastal Zone Management, and a Barnstable and Dukes County dredging workgroup, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) has prepared a summary of the recommendations for municipal maintenance dredging projects on the Cape and Islands in order to address marine resource concerns with these projects in a coordinated manner. The major species, groups of species, or habitats targeted by this summary are winter flounder, diadromous species, shellfish species, horseshoe crabs, eelgrass, and lobster habitat. The impacts to these species and habitats are addressed based on a mapped classification of the major waterbody features of embayment, inlet channel, and approach channel. The summary does not provide recommendations for natural resources outside of *MarineFisheries'* jurisdiction, such as shorebirds. It addresses potential impacts of dredging and beach disposal activities but additional conditions for disposal activities may be needed in some cases.

MarineFisheries standard recommendations are as follows:

- In-water, silt-producing work should be avoided during time of year restrictions (TOYs).
- A diadromous TOY is recommended in all embayments and inlet channels where diadromous spawning runs are known or expected to occur. If work in an embayment or inlet channel is 3 days or less and is within a cumulative impact cap (e.g. no more than 3 embayments or inlet channels in a given region), a TOY waiver is granted.
- A winter flounder TOY is recommended in all embayments and inlet channels. If work in an inlet channel is 3 days or less and is within a cumulative impact cap (e.g. no more than 3 inlet channels in a given region), a TOY waiver is granted. Embayments are not eligible for waivers.
- In approach channels, projects <10,000 cubic yards (cy) do not need a winter flounder or diadromous TOY. Projects >10,000 cy receive project-specific recommendations.
- A horseshoe crab TOY is recommended for dredging in all embayments, inlet channels, and approach channels with mapped horseshoe crab spawning beaches. If dredging is >750 feet from the beach a TOY waiver is granted. If dredging will avoid a 5-day period around the new and full moons and is 3 days or less a TOY waiver is granted. No TOY waivers are granted in the Stage Harbor complex.
- A horseshoe crab TOY is recommended for all beach disposal activities on horseshoe crab spawning beaches. If fill is above the extreme high water mark and no construction activity is conducted on the beach a TOY waiver is granted.
- If dredging occurs within 25 feet of shellfish resources, town propagation sites, aquaculture facilities, eelgrass habitat, or lobster habitat, TOYs, silt curtains, and/or turbidity monitoring may be recommended. Removal of shellfish or lobster resources prior to dredging may be recommended.

INTRODUCTION

It is well established that dredge projects can result in deleterious impacts to marine fisheries resources and habitats (Newcombe and Jensen 1996; Wilber and Clarke 2001; Erftemeijer and Lewis 2006; Wilber et al. 2006). The impacts of dredge and fill projects on the marine environment have been studied, particularly with respect to impacts on species covered under Essential Fish Habitat consultation and the Endangered Species Act (Johnson et al. 2008; Hanson et al. 2003). Impacts to marine resources associated with dredging projects include some or all of the following: direct habitat removal or burial, increased water column turbidity, reduction in dissolved oxygen, release of contaminants and nutrients, changes in benthic sediment characteristics, changes in benthic infaunal composition, and entrainment. The degree of impact varies widely, and is dependent on the method, frequency, timing, and location of dredging operations as well as the marine resources present in a system. A review of these issues can be found in Johnson et al. (2008).

In Massachusetts, there are frequent, routine maintenance dredging projects occurring on Cape Cod and the Islands since sediment frequently shoals in navigable waterways as a result of storms and tidal action. These activities occur at the same locations either annually or every few years by the same three relatively small hydraulic dredges. Barnstable County, the county encompassing the towns on Cape Cod (south and east of the Cape Cod Canal), owns and operates its own dredge, "Codfish". Similarly, the Town of Edgartown owns and operates its own dredge, which dredges primarily on Martha's Vineyard Island each year. The U.S. Army Corps of Engineers (ACE) operates "Currituck," which dredges navigable waterways on the Cape each spring (funding and logistics permitting). A study examining the impacts of the Barnstable County dredge was commissioned by Massachusetts Office of Coastal Zone Management and found that there is potentially significant risk of impact to specific resources as a result of hydraulic dredging and the risk can be minimized by the use of seasonal restrictions (MACZM 2007). In order to balance municipal maintenance dredging needs with marine fisheries resource protection for such projects, the Massachusetts Division of Marine Fisheries (*MarineFisheries*), assisted by the Massachusetts Department of Environmental Protection (DEP), the Massachusetts Office of Coastal Zone Management (CZM), and a Barnstable and Dukes County dredging workgroup, generated this report to clarify when and where different time of year restrictions (TOYs) are needed and to identify other standard resource recommendations. This report is the culmination of several years of coordination between the state and the Cape Cod and Islands towns.

This report only considers resources under the jurisdiction of *MarineFisheries*, which includes marine and diadromous fishes, shellfish, lobsters, horseshoe crabs, and their habitats. Other resource recommendations from other agencies may need to be considered (including, but not limited to, reptiles, birds, and marine mammals). With this information, individual towns and dredge programs can plan and sequence their dredging activities to minimize impacts to marine resources. Through such an approach, we endeavor to lower the risk of impact to marine resources and their habitats while

improving the efficiency of the dredge programs and encouraging regional sediment management.

The geographic extent of the programmatic recommendation described herein is towns on Cape Cod (south and east of the Cape Cod Canal including the eastern side of Buzzards Bay), Martha's Vineyard, and Nantucket Island (Figure 1). The types of dredging activities covered are public maintenance dredging activities of <10,000 cubic yards (cy) conducted by the Barnstable County hydraulic dredge ("Codfish"), the Edgartown hydraulic dredge, and the U.S. Army Corps of Engineers hydraulic dredge ("Currituck") only. This programmatic recommendation does not cover improvement dredging projects, deepening of channels, advanced maintenance dredging, private dredging projects, or projects >10,000 cy. This framework prioritizes and makes allowances for work necessary to ensure that channels and waterways remain in a condition that permits access and safe passage of vessels. Disposal of material on a beach is considered within the framework, but disposal in nearshore or offshore locations will require separate site-specific review. This programmatic recommendation is only applicable in areas where the definitions of embayment, inlet channel, and approach channel are reasonable (see Section 3).

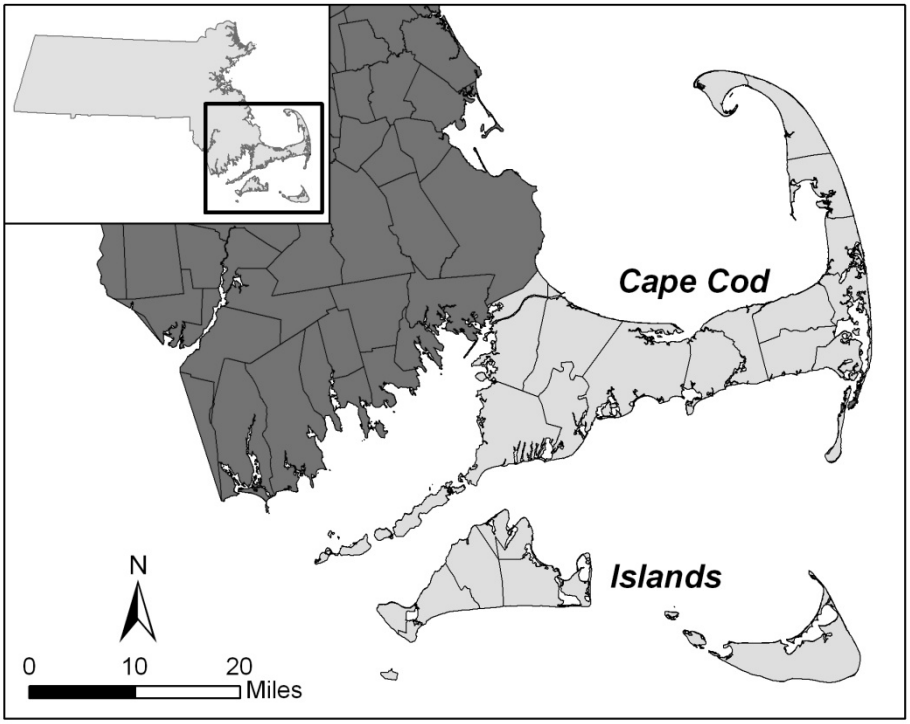


Figure 1. Geographic extent of this document: Cape Cod and Islands, Massachusetts.

The audience for this document includes 1) the regulatory community to whom we provide technical review for projects that potentially have adverse impacts on marine fisheries resources and 2) dredge coordinators. The regulatory community includes Conservation Commissions, DEP, CZM, and ACE. This document is also relevant to natural resource agents, harbormasters, shellfish constables, and others planning dredging operations. This document has been reviewed by the National Marine Fisheries Service (NMFS) and is consistent to the maximum extent practicable with NMFS resource

recommendations. The essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act require the federal action/permit agency to consult with NMFS on projects that may adversely affect EFH. Information regarding the EFH consultation process can be found at http://www.nero.noaa.gov/ro/doc/webintro.html. *MarineFisheries* may amend or discontinue using this document at any time and will provide notice to the regulatory community regarding such changes.

MARINE FISHERIES RESOURCES

MarineFisheries manages hundreds of species either directly or indirectly. However, the review process for coastal construction permit applications targets only a few species that are more vulnerable to impacts associated with construction activities based on their habitats and life history. For routine, small coastal projects, including dredging projects <10,000 cy and associated beach fill, the resources that we are commonly concerned with are as follows.

- **Diadromous fishes.** The diadromous fish species on Cape Cod include the anadromous species blueback herring, alewife, rainbow smelt, shad, and white perch, which all utilize fresh and tidal waters for spawning. The catadromous American eel spawns at sea but uses estuarine and freshwater habitats for forage, refuge, and development. Most of these diadromous species are at historically low population levels in Massachusetts. For example, species such as river herring (alewife and blueback herring), which were previously important commercial and recreational fisheries, are in such a serious state of decline that possession has been prohibited since 2006. These species migrate through, and in some cases inhabit, nearshore marine and estuarine waterbodies. Because of their dependence on channels for migrations and their high degree of aggregation during migrations, these species have a high risk of impact when dredging projects coincide with migration routes or occur in areas of spawning and settlement (Funderburk et al. 1991; Dadswell 1996).
- **Winter flounder.** Winter flounder is a major commercial and recreational fish species that is undergoing a severe population decline (NOAA 2008; King et al. 2008). The commercial harvest of this species is strictly regulated due to declining populations. Cape Cod divides two major winter flounder stock regions: the Gulf of Maine stock occurs in Cape Cod Bay and the Southern New England /Mid Atlantic Bight stock complex occurs along the outer Cape and all areas south of Cape Cod. Both stocks are highly dependent on nearshore bays and estuaries for spawning and nursery habitat. Trawling is prohibited in Massachusetts inshore areas to protect nursery habitats of winter flounder. Winter flounder eggs are sensitive to the impacts of sedimentation (D. Nelson, NMFS, unpub. data as cited in Berry et al. 2003; Klein-MacPhee et al. 2004; Berry et al. 2005). Therefore, this species has a high risk of impact when dredging and nearshore disposal projects coincide with spawning and settlement.
- **Shellfish.** The Massachusetts shellfishery is one of the top grossing fisheries in the state, and is an important source of seafood and jobs in Massachusetts (MAEEA 2009). Shellfishing is also highly valued as a recreational activity in many coastal towns across the state. All species have vulnerable life stages, in

particular the larval stages, and local success of seed sets may vary dramatically due to a variety of environmental factors (e.g., temperature, salinity, current; Belding 1909). Impacts to shellfish resource and habitats are a concern because of their importance as a commercial and recreational fisheries resource and, of equal importance, their role in ecosystem dynamics as a forage species. Therefore, these species may have a high risk of impact during dredging and nearshore disposal projects in certain circumstances.

- **Horseshoe crabs.** Horseshoe crabs utilize beaches for spawning and nearshore channels for migration and possibly burial (Loveland and Botton 1992; Avissar 2006; S. Michels, DE DFW, 2009, pers. comm.). Spawning surveys and the stock assessment show that this population is declining in New England (Widener and Barlow 1999; ASMFC 2009). This species is still commercially fished, but there are no new entrants allowed to the fishery, the quota was halved in 2008, and harvest timing restrictions were introduced in 2010. Because of its dependence on nearshore shallow beaches and channels as habitat, this species has a high risk of impact during dredging and beach and nearshore disposal projects (Avissar 2006).
- **Lobster.** The lobster fishery, though still very large, is seeing populations at a 25 year low (R. Glenn, MA DMF, 2009, pers. comm.). Availability of complex seafloor (e.g. cobble bottom) is thought to be a population bottleneck for lobster (Wahle and Stenick 1991; Phillips 2006). Therefore, this species and its habitat have a high risk of impact during dredging and nearshore disposal projects in areas with complex seafloor.
- **Eelgrass.** Eelgrass is an important submerged coastal habitat that not only provides critical nursery and shelter for many marine fish and invertebrates, but also provides ecosystem functions such as buffering the shoreline from erosion and improving water quality (e.g. Orth et al. 1984; Heck et al. 1989; Hughes et al. 2002). In New England, eelgrass is perennial, continuing to grow and photosynthesize year-round (McRoy 1969; Evans et al. 1986; Jarvis et al. 2012). Eelgrass is sensitive to light limitation and therefore is particularly sensitive to turbidity plumes resulting from coastal alteration projects. This sensitivity has been demonstrated in both the winter and the summer (Olesen and Sand-Jensen 1993; Hauxwell et al. 2006). Eelgrass is also sensitive to burial. Recent studies indicate that as little as 2 to 4 cm of sand burial can result in 70 to 90% mortality of eelgrass (Mills and Fonseca 2003; Cabaço et al. 2008). Eelgrass is designated as a Special Aquatic Site in the Clean Water Act. Beds are at very low spatial extents to those estimated historically (e.g. Short and Burdick 1996; Paling et al. 2009; Costello and Kenworthy 2011). This habitat has a high risk of impact from dredging, beach fill, and nearshore disposal projects.

In order to protect the above resources, *MarineFisheries* often recommends standard best management practices for the protection of eelgrass, shellfish, and lobster habitats and time of year restrictions (TOYs) to protect species during vulnerable life stage events (aggregations, spawning, and settlement) of marine and diadromous fishes and shellfish.

Time of year restrictions are date ranges during which

there is a higher risk of significant lethal, sub-lethal, or behavioral impacts to marine fisheries resources.

For some resources, different regions of the state have different date ranges. How these regions of the state were identified and where they occur are described in Section 3 and Figure 2. The TOYs recommended in Massachusetts are:

Alewife (*Alosa pseudoharengus*)
- * Upstream spawning migration **April 1 to June 15**
- * Juvenile emigration **Sept. 1 to Nov. 15**

Blueback herring (*Alosa aestivalis*)
- * Upstream spawning migration **April 1 to June 30**
- * Juvenile emigration **Sept. 1 to Nov. 15**

American shad (*Alosa sapidissima*)
- * Upstream spawning migration **May 1 to July 15**
- * Juvenile emigration **Sept. 30 to Oct. 31**

Rainbow smelt (*Osmerus mordax*)
- * Spawning migration **March 1 to May 31**

American eel (*Anguilla rostrata*)
- * Elver upstream migration **March 15 to June 30**
- * Silver eel emigration **Sept. 15 to Oct. 31**

White perch (*Morone americana*)
- * Upstream spawning migration **April 1 to June 15**

Winter flounder (*Pseudopleuronectes americanus*)
- * South Cape Cod East and West, Buzzards Bay East and West, Islands **Jan. 15 to May 31**
- * North Cape Cod, South Coastal **Feb. 1 to June 30**
- * Boston Harbor and North Shore to NH **Feb. 15 to June 30**

Shellfish
- * Bay scallop (*Argopecten irradians*) **June 1 to Sept. 30**
- * Blue mussel (*Mytilus edulis*) **May 15 to Aug. 31**
- * American oyster (*Crassostrea virginica*) **June 15 to Sept. 15**
- * Northern quahog (*Mercenaria mercenaria*) **June 15 to Sept. 15**
- * Soft shell clam (*Mya arenaria*)
  - * South Cape Cod East and West, Buzzards Bay East and West, Islands **April 15 to Sept. 15**
  - * North Cape Cod, South Coastal to NH **May 1 to Sept. 30**
- * Razor clam (*Ensis directus*) **June 15 to Sept. 15**

Horseshoe crabs (*Limulus polyphemus*)	
* Dredging (e.g. in-water)	**May 1 to June 30**
* Beach fill	**May 1 to July 31**
Lobster (*Homarus americanus*)	**Protection of habitat year round**
Most vulnerable time periods for spawning adults:	
* South Cape Cod East and West, Buzzards Bay East and West, Islands	**May 15 to July 1**
* East side of (outer) Cape Cod	**June 15 to Aug. 15**
***** North Cape Cod, South Coastal to NH	**May 31 to July 31**
Eelgrass (*Zostera marina*)	**Protection of habitat year round**

The specific TOY restrictions for finfish and horseshoe crabs generally will not vary, since they are based on life history information. The shellfish and lobster TOYs are most commonly recommended where *MarineFisheries* has site-specific monitoring data for these resources. Site-specific data are collected by *MarineFisheries* biologists, municipal natural resource agents, or project consultants. In the case of shellfish the TOY listed above may vary based on the individual species present at a particular site.

Considerable detail regarding the life history for each of the above resources and how each TOY was established is available in Evans et al. (2011). The sources of data used to support the TOY recommendations include general life history references, peer reviewed studies, NOAA NMFS technical reports, ASMFC fishery management plans, *MarineFisheries* technical reports and estuarine monograph series, the *MarineFisheries* resource assessment trawl survey time-series, and the best professional judgment of marine fisheries biologists. They are consistent to the maximum extent practicable with TOY recommendations provided by the NOAA NMFS Northeast Region Habitat Conservation Division and have been reviewed by state and federal regulatory agencies.

The TOYs may be recommended in any waterbody in which marine resources are known or presumed to occur. The marine resources listed above are those typically most vulnerable to maintenance dredging activities on the Cape and Islands. There are additional marine resources for which TOY recommendations are frequently made in other parts of the state and for other types of projects (e.g. Atlantic sturgeon and the North Atlantic Right Whale). For a full listing of TOYs in the state, please reference Evans et al. (2011).

DESCRIPTION OF WATERBODY FEATURES

Because the impact to a marine fisheries resource can vary based on the geophysical location of the source of impact and the resource being considered, we first defined and mapped the major tidally influenced waterbody features relevant to the species we manage. It is assumed that within each feature type the impacts of dredging are similar (i.e. the impact in one inlet channel will be similar to the impact in another inlet channel). There are three feature types:

Embayment: Embayments are tidally influenced enclosed or semi-enclosed areas of the coastline where the fresh water from groundwater and streams is mixed with salt water from the open ocean. The definition includes coastal lagoons, drowned river valleys, harbors, and other relatively shallow water bodies that are connected by an inlet channel or bay mouth either ephemerally or permanently. Many of these features are locally known as salt ponds or harbors. Multiple life stages of many species of animals occur seasonally or year-round in Embayments. Embayments extend from the extreme high water mark to subtidal waters.

Inlet Channel: Inlet Channels are tidally influenced and they connect Embayments to the open ocean. The definition includes channels and bay mouths. These are either known or presumed to have coarser grain sizes than Embayments and higher velocity current flow than Embayments or Approach Channels. Inlet Channels provide passage to animals from the open ocean to the Embayment. Inlet Channels extend from the extreme high water mark to subtidal waters.

Approach Channel: Seaward of the Inlet Channel, an Approach Channel is the tidally influenced area where animals may stage for entrance into an Embayment. These are either known or presumed to have coarser grain sizes than Embayments and higher wave energy than Embayment or Inlet Channels. These may or may not include channels through beach shoreface deposits that are visible on aerial photos. Approach Channels extend from the extreme high water mark to subtidal waters.

The term "waterbody" is used to refer to a physiographic region that encompasses all of these features in most cases. However, in some areas, the general physiographic region has named subdivisions, and those named subdivisions are considered waterbodies (for example, Hyannis Harbor is within Lewis Bay). Therefore, not all waterbodies have each of the defined features.

Existing habitat maps, namely the DEP Wetlands maps and the Natural Heritage and Endangered Species Program Classification of the Natural Communities of Massachusetts, focus on plant communities. In those maps, the Embayments, Inlet Channels, and Approach Channels are classified as "Open Water," "Open Water Ocean," "Open Water Tidal, Brackish, Salt Pond," "Marine Subtidal," and/or "Estuarine Subtidal." The boundaries and definitions used in those habitat mapping efforts were not of the appropriate scale to benefit this project.

The Cape and Islands were divided into "drainage sub-basins" or coastal regions based on our understanding of how marine resources exhibit regional characteristics (Figure 2). These coastal regions were generated using the Major Drainage Basins polygon layer available from MassGIS that originated from the USGS Water Resources Division and the MA Water Resources Commission (MassGIS 2003). Boundaries from the Drainage Sub-basins polygon layer (MassGIS 2007) were used to divide North Cape Cod, South

Cape Cod, and Buzzards Bay East. Therefore, the coastal regions are slightly different than those considered "watersheds," "major basins," or "major sub-basins." South Cape Cod was further subdivided into South Cape Cod West and South Cape Cod East based on workgroup recommendations using Pt. Gammon, Yarmouth as a breakpoint. Buzzards Bay East includes Onset and Buzzards Bay in Wareham to reflect sensible resource recommendations in that particular area.

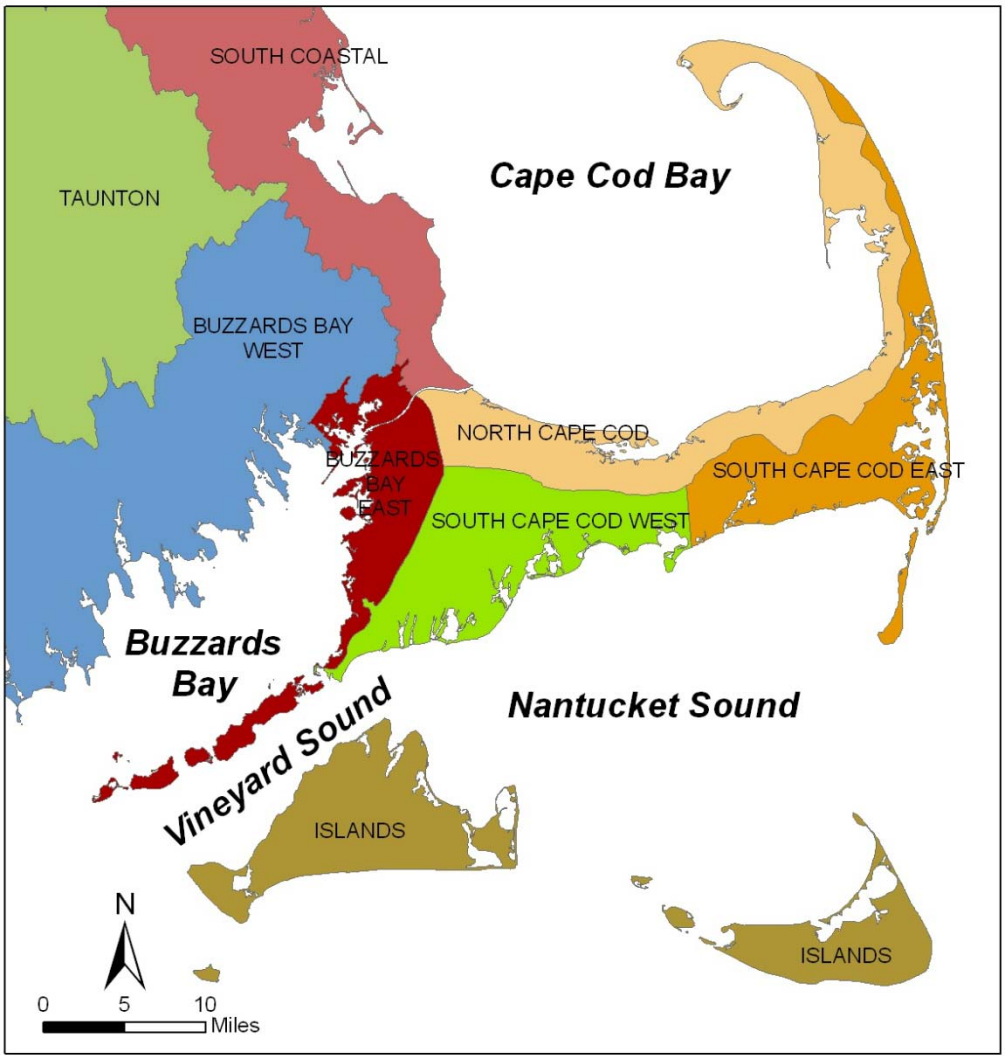


Figure 2. Regions used for considering impacts to resources.

Within each region, *MarineFisheries* biologists digitized the Approach Channel, Inlet Channel, and Embayment waterbody features as polygons using 2005 aerial photography in ArcGIS 9.2 at a 1:5,000 scale. Some of these boundaries were altered based on advice of other biologists and workgroup members to better define the features according to how they are defined. The feature shorelines were clipped using MassGIS Coastline (1992) updated as follows: areas of the original wetlands layer shoreline that were wrong or inaccurate based on shoreline surveys conducted routinely by the *MarineFisheries* Shellfish Sanitation program were corrected and the updated shoreline was used for clipping the waterbody features. All feature types by definition extend from the extreme

high water mark to subtidal waters. The shoreward boundary may not adequately represent the extreme high water mark at a scale relevant to that of an individual project. *MarineFisheries* will provide its resource recommendation based on a reasonable approximation of the waterbody feature within which the project is occurring. The shoreward waterbody feature boundaries should be considered an approximation of how and where we make our resource recommendations. In contrast, the boundaries between inlet channel and approach channel and inlet channel and embayment are treated as fixed boundaries for the purposes of our recommendations. For embayments with a wide mouth and no clearly defined inlet channel, the five meter depth contour was used to identify the seaward boundary (e.g., Red Brook Harbor). The five meter contour was selected since NOAA uses this contour to define preferred spawning conditions for winter flounder.

It is anticipated that the waterbody feature boundaries will be updated as needed to reflect additional information and the dynamic shoreline. The current boundaries, by town, are available in Appendix A. The waterbody features GIS layer is available on the *MarineFisheries* website: http://www.mass.gov/dfwele/dmf/programsandprojects/fish_hab_publications.htm.

One important feature type, *Tidal River*, has not been mapped since they are not targeted by municipal dredging activities on the Cape and Islands. The tidal rivers start at the head of tides and end at the river mouth defined by an opening wider than the main stem of the river as it empties into an embayment. Diadromous species use tidal rivers for passage to and from spawning grounds. Many of these features are currently listed as embayments. This distinction may be important in some circumstances since diadromous species in some tidal rivers may be more vulnerable to dredging impacts as a result of proximity to spawning grounds. Projects in some tidal rivers may also have a particularly high risk of impact due to the population status of a site specific spawning run, or a large percentage of the river impacted by the dredge operation.

The regions of most relevance to the Barnstable County Dredge activities are North Cape Cod, South Cape Cod East, South Cape Cod West, Islands, and Buzzards Bay East. In those regions, a total of 74 waterbodies were mapped of which 59 are dredged. The waterbodies contain 35 fish runs, 46 horseshoe crab beaches, and 73 winter flounder embayments (Table 1). The regions include 23 towns and 105 dredge sites (Appendix B).

Table 1: Summary of waterbodies and resources in each region.

Region	**# of water-bodies**	**# waterbodies dredged**	**# of dredge sites**	**# winter flounder embayments**	**# of spawning runs**	**# horseshoe crab beaches**
Buzzards Bay East	12	9	15	11	4	8
Islands	17	17	37	17	11	7
North	18	9	13	18	10	15

Cape Cod						
South Cape Cod East	11	9	11	11	5	5
South Cape Cod West	16	15	29	16	5	11
TOTAL	74	59	105	73	35	46

Town maps with feature types identified are available in Appendix A or by downloading either a Google Earth file or ArcGIS file which are both available on the *MarineFisheries* website: http://www.mass.gov/dfwele/dmf/programsandprojects/fish_hab_publications.htm. All embayments that were mapped and their associated dredge sites and recommended TOYs are listed in Appendix B.

POTENTIAL RESOURCE IMPACTS

The following assumptions regarding potential dredging impacts were made in order to assess risk of impacts to resources caused by small hydraulic dredge projects:

- Dredging is conducted for a maximum of 12 hours/day during daylight only.
- Approximately 1,000 cy are dredged during a day.
- Dredging is conducted using a small hydraulic dredge.
- Turbidity potential in coarse sediment is lower.
- Turbidity potential in fine sediment is higher.
- Entrainment/impingement risk is lower for pelagic life stages than for demersal life stages.
- Entrainment/impingement risk is lower for mobile demersal life stages than that for less mobile demersal life stages, but higher than that for pelagic life stages.
- Entrainment/impingement risk is highest for less mobile demersal life stages.
- More time spent dredging at any given location increases the risk of impact to resources at that location.

If these assumptions do not pertain to a dredging project, the recommendations for the protection of marine fisheries resources may be different than those outlined in this document.

The following assumptions apply to the waterbody features:

- Embayments have finer grained sediment (e.g. silts, clays, muds) and lower current velocities.
- Inlet channels and approach channels have coarser grained sediment (sands, gravelly sands).

- Inlet channels have higher current velocities than embayments or approach channels.
- Approach channels have higher wave energy than inlet channels or embayments.

If these assumptions do not pertain to a waterbody feature, the recommendations for the protection of marine fisheries resources may be different than those outlined in this document.

Based on the resources and physical setting of the features, we identified potential impacts on those resources that could be caused by hydraulic maintenance dredging. The types of impacts associated with dredging activities are as follows:

Direct mortality. We presume that the risk of direct mortality as a result of hydraulic dredging activities is limited to demersal life stages with limited mobility.

Indirect mortality. Turbidity and potential habitat disturbance associated with dredging activities can smother or prevent the settlement of various species, resulting in reduced spawning success and mortality.

Behavioral modifications (e.g. impediments to passage). Due to the dredging activity, including the presence of the dredge and the disturbance of the seafloor and water column (via increased turbidity and noise), some animals may avoid the dredge area, be unable to pass by the dredge area, or experience stress and delayed spawning. Impacts that cause behavioral modification may not cause direct or indirect mortality, but the extent of the behavioral modification may reduce the resilience of an individual or a population.

Cumulative impact. Cumulative impact in this report refers specifically to the occurrence of multiple municipal dredge projects within a region. Dredging multiple times within a TOY increases the risk of impact to a given species. A cumulative impact cap is the number of waterbodies that can be dredged within a time of year restriction.

RECOMMENDATIONS

Winter Flounder and Diadromous fishes

Winter flounder are known to utilize coastal embayments for spawning. Seine surveys conducted annually by *MarineFisheries* since 1976 in six coastal ponds have consistently caught young of the year winter flounder in Great Pond, Waquoit Bay, Cotuit Bay, Lewis Bay, Bass River, and Stage Harbor (MADMF 2007). Studies have shown that the same individuals have returned to the same spawning location multiple times suggesting spawning site fidelity (Howe and Coates 1975). Therefore, all but one waterbody (the Cape Cod Canal) are considered winter flounder spawning habitat.

Diadromous TOYs will be recommended only in waterbodies where fish runs are known to occur. *MarineFisheries* has mapped these runs (MADMF 1997) and assembled the most recent information in our Time of Year Recommendations document (Evans et al. 2011). For the past two years efforts have been made to improve the diadromous maps, including more specific information about where in a waterbody the fish are migrating and spawning. Once those maps are ready, they will be merged with the waterbodies features maps developed for this report.

Embayments

Recommendation: A TOY for winter flounder and diadromous species is recommended for municipal dredging projects in embayments. No waivers are recommended for winter flounder; a three day TOY waiver under the cumulative impact cap can be granted for diadromous fishes.

> **North Cape Cod:** Winter flounder TOY of 2/1 to 6/30 includes all diadromous TOYs (except shad, which is not found in those embayments). Therefore, no waivers are available.
>
> **South Cape Cod East, South Cape Cod West, Buzzards Bay East, and Islands:** Winter flounder TOY of 1/15-5/31. Diadromous waivers can be granted under the cumulative impact cap for each region after 5/31.

Reasoning: It is assumed that the greatest risk to winter flounder is in lower energy embayments because they contain finer grained sediments that, if dispersed, may cause more damage to winter flounder eggs and newly settled larvae. Because the distribution of specific winter flounder spawning areas within an embayment is unknown and could change each year, any dredging within an embayment should occur outside of the winter flounder TOY restriction.

Some diadromous fishes utilize embayments for much of their lifetime (e.g. tomcod) while other species pass through embayments primarily to migrate to and from spawning habitat (e.g. river herring). The migration period is typically considered the most vulnerable time period for diadromous fishes since migration impediments can prevent entire runs from spawning in suitable locations for reproductive success. The primary objective of TOYs for diadromous fishes in embayments is to ensure that fish passage is unimpeded during migratory seasons. (In tidal rivers, which are currently mapped as embayments, it is also important to avoid direct impact to spawning habitat.) The degree to which fish migration is impeded by anthropogenic activities varies: some species view any disturbance as an impediment, some are more tolerant of disturbance (P. Brady, MA DMF, 2009, pers. comm.). Some reports have found egg reabsorption and reduced spawning success after a period of a week (Rideout et al. 2005; Dadswell 1996; Rottmann et al. 1991). Furthermore, diadromous fishes typically utilize the thalweg (the deepest part of the channel), which in these waterbodies often corresponds to or is very proximal to the location of the dredging. If fish try to avoid a disturbance in the thalweg by leaving the channel and entering shallower waters, predation risk increases.

Along a migratory pathway, multiple activities, natural and anthropogenic, can cause delays in a migration. Therefore, we conclude that in-water, silt-producing work within

the embayment may delay migration and spawning if stress or impediments to passage last for more than three days within the TOY. Three days was determined to be a reasonably precautionary threshold since the dredging conducted by the municipal dredges occurs <12 hours a day and does not occupy the whole width of an embayment. Since migratory pathways through embayments are poorly known and embayment widths vary widely, for the purposes of these recommendations they are treated as inlet channels for diadromous fishes.

Inlet Channels

Recommendation: A TOY for winter flounder and diadromous species is recommended for municipal dredging projects in inlet channels. A three day TOY waiver under the cumulative impact cap can be granted for winter flounder and diadromous fishes.

Reasoning: Inlet channels are presumed to function primarily as migration pathways for winter flounder. Because there is risk of impact to migrating groups of flounder but little information regarding the impacts of a persistent migratory delay, the same recommendation determined for diadromous fishes is provided for winter flounder.

Under the same reasoning provided for embayments, we conclude that in-water, silt-producing work within the inlet channel may delay migration and spawning if stress or impediments to passage last for more than three days within the TOY. Three days was determined to be a reasonably precautionary threshold since the dredging conducted by the municipal dredges occurs <12 hours a day and typically does not occupy the whole width of an inlet channel.

Approach Channels

Recommendation: As long as turbidity or other disturbance is not shown or expected to extend to spawning habitat, TOYs for winter flounder or diadromous species are not recommended for projects dredging <10,000 cy within approach channels.

Reasoning: Although winter flounder are known to spawn in nearshore areas outside of embayments (Howe and Coates 1975), the distribution of such spawning activity is poorly known. We presume that the risk of impact as a result of municipal dredging activities is less in approach channels since it is a more dynamic, higher energy habitat that covers much of the coastline.

Approach channels are unrestricted in width and prone to high energy turbidity events so we do not expect municipal dredging to impede the migratory behavior of winter flounder or diadromous fishes. Therefore, as long as turbidity or other disturbance is not shown or expected to extend to spawning habitat, projects dredging <10,000 cy within approach channels do not require a diadromous TOY. Since a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF) is required for projects >10,000 cy, project-specific recommendations will be provided for dredge volumes above that threshold.

Cumulative Impact

Dredging of multiple waterbodies in a single migratory season increases the risk of impact to winter flounder and diadromous fishes. In order to limit the cumulative impact associated with dredging during times of the year when risk of impact to resources is higher, *MarineFisheries* recommends a 30% cumulative impact cap. This cap was determined to be a reasonable threshold by the working group.

> Embayments: No embayments are eligible for a TOY waiver during the winter flounder time of year. After the winter flounder time of year, 30% of embayments in each region with diadromous fish runs can be eligible for a waiver (Table 3).
>
> Inlet channels: 30% of inlet channels in each region with winter flounder are eligible for a TOY waiver; 30% of inlet channels in each region with diadromous runs can also be eligible for a TOY waiver (Tables 3 and 4). Where a winter flounder inlet channel does not overlap with a diadromous run, the waiver does not count against the diadromous cap.

Additionally, we recommend that dredging should not be conducted on the same waterbody feature in the same waterbody more than once every six months if any dredging activity will occur during a TOY. Lastly, there may be unforeseen circumstances that result in a project-specific recommendation as a result of cumulative impacts caused by non-municipal dredging activities.

Table 3: Number of inlet channels and embayments that can be impacted during the diadromous TOY.

Region	Total # of waterbodies with fish runs	Cumulative impact cap	Total # of inlet channels and embayments that can be impacted during the TOY
Buzzards Bay East	4	30%	1
Islands	11	30%	3
North Cape Cod	10	30%	3
South Cape Cod East	5	30%	2
South Cape Cod West	5	30%	2

Table 4: Number of inlet channels that can be impacted during the winter flounder TOY.

Region	Total # of waterbodies with winter flounder	Cumulative impact cap	Total # of inlet channels that can be impacted during the TOY
Buzzards Bay East	11	30%	3

Islands	17	30%	5
North Cape Cod	18	30%	5
South Cape Cod East	11	30%	3
South Cape Cod West	16	30%	5

Disposal on beaches

Disposal on beaches is not anticipated to have significant risk of impact to winter flounder or diadromous habitat.

Recommendation Summary

- A TOY for winter flounder and diadromous species is recommended for municipal dredging projects in **embayments**. No waivers are recommended for winter flounder; a three day TOY waiver under the cumulative impact cap can be granted for diadromous fishes.
- A TOY for winter flounder and diadromous species is recommended for municipal dredging projects in **inlet channels**. A three day TOY waiver under the cumulative impact cap can be granted for winter flounder and diadromous fishes.
- TOYs for winter flounder or diadromous species are <u>not</u> recommended for projects dredging <10,000 cy within **approach channels**.

Horseshoe crabs

Horseshoe crab TOYs will be recommended only in waterbodies where horseshoe crabs are known to occur. *MarineFisheries* has mapped these waterbodies using spawning survey data and landings data and is preparing the dataset for release on MassGIS.

Embayments, Inlet Channels, Approach Channels

The horseshoe crab is a benthic organism that utilizes coastal waterbodies as spawning and nursery areas. Horseshoe crabs spawn on beaches during the high tides associated with full and new moons in May and June (e.g. Loveland and Botton 1992; Avissar 2006). Hatching occurs about a month after egg laying, and it is thought that juveniles utilize the nearshore coast adjacent to spawning beaches for several years (Botton and Loveland 2003). Horseshoe crabs can have limited mobility when buried in the sand, particularly when resting before and after spawning events (Michels 2009). There are two TOYs for horseshoe crabs: the dredging horseshoe crab TOY protects spawning adults; the beach disposal horseshoe crab TOY protects spawning nests and emerging juveniles.

Very little is known about how horseshoe crabs utilize the nearshore environment or how they are distributed during spawning and hatching seasons. Therefore, a buffer was

created as a guideline for determining if a dredging project is considered close to a spawning beach. The horseshoe crab beach buffer was designed to protect the beach and areas close to the beach for both spawning adults that utilize the nearshore up to the high tide line for spawning, and newly emerged and juvenile horseshoe crabs that occupy areas nearshore. A buffer of 750 feet was determined using a visual assessment of different buffer distances overlaid on aerial photos.

We conclude that in-water work within 750 feet of a horseshoe crab spawning beach may impact spawning success by interfering with spawning or juvenile animals or by significantly altering the slope of the nearshore environment. The Stage Harbor complex contains a large population segment so risk of impact is high regardless of distance from a beach.

Spawning activity has significant peaks at the new and full moons during the spawning season. Increased landings from hand and rake collection and increased spawning survey counts are associated with the period covering two days before and after full and new moons (MADMF 2010). Small impacts outside of these timeframes are presumed to have less risk of impact.

Small projects are presumed to have a lower risk of impact. Projects three days or less are considered small in order to be consistent with recommendations for other species.

Cumulative Impact

Fisheries regulations are increasingly stringent for horseshoe crabs. In 2010 and 2011, *MarineFisheries* harvest regulations prohibited the harvesting of horseshoe crabs during periods around the full and new moons in May and June. However, since commercial fishing has not been prohibited (as it has been for winter flounder and certain diadromous species), there is no cumulative impact requirement for horseshoe crabs.

Disposal on beaches

Horseshoe crabs spawn on beaches during the high tides associated with full and new moons in May and June (e.g. Loveland and Botton 1992; Avissar 2006). The female horseshoe crabs bury the eggs just below the high tide. The nests cannot be marked since the outgoing tide smoothes over the sand making the nests unidentifiable. The nests are susceptible to multiple human impacts including beach disposal activities for dredging projects. Beach disposal can bury the eggs too deeply and even modest alterations in beach profile or sediment sorting can reduce the suitability of a beach for spawning (Avissar 2006).

Nests cannot be identified so creating buffers around the nests and prohibiting beach disposal in those areas (similar to that done for piping plovers) is not an effective strategy for protection. Therefore, a TOY is recommended for all beaches identified as horseshoe crab spawning beaches.

Recommendation Summary

- A dredging horseshoe crab TOY is recommended for public maintenance dredging projects within Stage Harbor complex and for projects <750 feet from horseshoe crab spawning beaches in other waterbodies. TOY waivers can be granted if dredging is avoided on the new and full moons as well as two days before and after the full and new moons and is three days or less in duration.
- A beach disposal horseshoe crab TOY is recommended for any beach disposal activities on beaches identified as horseshoe crab spawning beaches. TOY waivers can be granted if fill is above the extreme high water mark and no construction activity is conducted on the beach.

Shellfish, Eelgrass, and Lobster Habitat

MarineFisheries has mapped suitable shellfish habitat and these maps are available on MassGIS (MADMF 2011). Shellfish TOYs are not commonly applied to municipal dredging activities under the presumption that the dredging activities are routine enough to prevent substantial new populations from setting in the dredge channels. However, in some cases the activity might impact newly settled spawn or other vulnerable populations in or near the dredging footprint and *MarineFisheries* will recommend a TOY or other impact minimization measure (such as a silt curtain). Shellfish TOYs are uncommon for routine municipal dredging activities on the Cape and Islands; they are considered on a project-specific basis.

Significant declines in eelgrass distribution have been measured in Massachusetts (Costello and Kenworthy 2011). Eelgrass grows in or near dredged areas and eelgrass is highly vulnerable to direct and indirect impacts associated with dredging. Eelgrass is also a particularly valuable habitat for many marine animals. The occurrence of eelgrass must be initially assessed using the DEP eelgrass layer available on MassGIS (MADEP 2006). Where eelgrass is mapped in or adjacent to a dredge area, a site-specific field assessment is needed to accurately map the extent of the eelgrass bed. In some cases, particularly if there is reason to believe eelgrass is present, if the DEP mapping project has not mapped the project area, or if beds are known to have occurred historically, site-specific information may be requested. There is no time of year restriction for eelgrass. *MarineFisheries* recommends that impacts to eelgrass be avoided.

We assume that all seafloor with pebble (grains 4 mm diameter) and larger sized sediment is Early Benthic Phase lobster habitat. This is currently not mapped and requires site-specific assessment which is requested in areas where we anticipate such habitat. In general, the maintenance dredging projects described herein will not require a lobster TOY.

Embayments, Inlet Channels, Approach Channels

A buffer was created as a guideline for determining if a dredging project is considered close to shellfish, eelgrass, or lobster (hard/complex bottom) habitat. This buffer was established by DEP under the Criteria for the Evaluation of Applications for Dredging and Dredged Material Management in the 401 Water Quality Certification (314 CMR 9.07). All dredging activities should occur further than 25 feet away from shellfish

habitat, town propagation sites, aquaculture facilities, eelgrass beds, and lobster habitat. Silt curtains will be recommended at locations where there is a greater risk of impact and where silt curtains can be used effectively. This recommendation applies year-round.

Disposal on beaches

A buffer also applies to disposal activities. There may be site-specific disposal conditions required on some permits including seasonal restrictions.

Recommendation Summary

- All dredging and disposal activities should occur further than 25 feet away from **shellfish habitat**, town propagation sites, and aquaculture facilities unless waived by a *MarineFisheries* shellfish biologist.
- All dredging and disposal activities should occur further than 25 feet away from **eelgrass habitat**.
- All dredging and disposal activities should occur further than 25 feet away from **lobster habitat**.

FLOWCHARTS

A set of flowcharts was prepared that illustrates how the above recommendations will be applied in practice. The next three pages contain the individual flowcharts for each waterbody feature type. Winter flounder and diadromous fish recommendations change based on the waterbody feature type. Horseshoe crabs, shellfish, eelgrass, and lobster recommendations are the same for all three waterbody feature types.

Embayment

Embayments are tidally influenced enclosed or semi-enclosed areas of the coastline where the fresh water from groundwater and streams is mixed with salt water from the open ocean. The definition includes coastal lagoons, drowned river valleys, harbors, and other relatively shallow water bodies that are connected by an Inlet Channel or bay mouth either ephemerally or permanently. Many of these features are locally known as salt ponds or harbors. Multiple life stages of many species of animals occur seasonally or year-round in Embayments. Embayments extend from the extreme high water mark to subtidal waters.

Date: 3/19/12

Winter Flounder

Is there winter flounder spawning habitat?

yes → Winter flounder TOY

All Embayments are considered winter flounder spawning habitat

Reason: minimize risk of vulnerable life stage habitat impact

Diadromous

Is there a diadromous fish run?

no → No diadromous TOY

yes → Diadromous TOY

 # embays that can be dredged w/ in the TOY for each region (X)

Buzzards Bay East	1
Islands	3
North Cape Cod	3
South Cape Cod East	2
South Cape Cod West	2

Waiver granted if

Turbidity from project is not shown or expected to extend to spawning habitat

AND Dredging is 3 days or less

AND X or less inlet channels are being dredged during the TOY

Reason: minimize risk of vulnerable life stage habitat impact

Reason: minimize risk of impediment to migration and direct impact

Reason: minimize risk of cumulative impact

Horseshoe Crab (HC)

Is footprint of project <750 feet from any part of a mapped HC beach or within the Stage Harbor Complex?

no → No horseshoe crab TOY

yes → Dredge horseshoe crab TOY

Waiver granted if

Dredging will avoid the new and full moons & 2 days before and after the full and new moons

AND Dredging is 3 days or less

No waivers in Stage Harbor Complex

No fill of HC beaches during beach HC TOY unless fill is above the extreme high water mark and no construction activity is conducted on the beach.

Shellfish

Is there mapped shellfish habitat, a town propagation area, or private aquaculture within 25 feet of site ?

no → No shellfish TOY

yes → Shellfish TOY if requested by DMF shellfish biologist

Reason: minimize risk of direct impact during vulnerable life stage

In some cases, it may be recommended that the shellfish resource should be removed prior to dredging

Eelgrass

Is project 25 feet from an eelgrass bed or is turbidity from project shown or expected to extend to eelgrass?

no → No recommendations

yes → Containment and/or turbidity monitoring

Reason: minimize risk of impact to vulnerable habitat

No dredging of eelgrass recommended; sites where eelgrass used to exist but doesn't now should be avoided and minimized where possible.

Lobster

Is project 25 feet from lobster habitat or is turbidity from project shown or expected to extend to lobster habitat?

no → No recommendations

yes → Containment and/or turbidity monitoring

Reason: minimize risk of impact to vulnerable habitat

No dredging or fill of pebble-cobble-boulder seafloor recommended

In some cases, it may be recommended that the lobster resource should be removed prior to dredging

STANDARD RECOMMENDATIONS

- **Avoid dredging in Special Aquatic Sites (eelgrass, salt marsh, intertidal flats).**
- **Avoid dredging of sediment pebble size or larger (4 mm).**
- **Avoid disposal of material on horseshoe crab beaches during TOY unless above extreme high tide line**
- **If dredging occurs during a TOY, no other dredging in the waterbody during that TOY is recommended**
- **Silt curtains may be recommended during time of year and non-time of year periods to protect other species and habitats.**

DISCLAIMER: These charts only apply to public hydraulic dredging for maintenance purposes on Cape Cod and the Islands. All projects may have site specific or project specific considerations that do not follow these charts especially if there are multiple project components and/or the project affects multiple feature types.

Inlet Channel

Inlet Channels are tidally influenced and they connect Embayments to the open ocean. The definition includes channels and bay mouths. These are either known or presumed to have coarser grain sizes than Embayments and higher velocity current flow than Embayments or Approach Channels. These provide passage to animals from the open ocean to the Embayment. Inlet Channels extend from the extreme high water mark to subtidal waters.

Date: 3/19/12

Winter Flounder

Is there winter flounder passage and/or spawning habitat? — no → No winter flounder TOY

yes → Winter flounder TOY

Waiver granted if

Turbidity from project is not shown or expected to extend to spawning habitat **AND** Dredging is 3 days or less **AND** X or less inlet channels are being dredged during the TOY

Reason: minimize risk of vulnerable life stage habitat impact

Reason: minimize risk of impediment to migration and direct impact

Reason: minimize risk of cumulative impact

# channels that can be dredged w/in the TOY for each region (X)	
Buzzards Bay East	3
Islands	5
North Cape Cod	5
South Cape Cod East	3
South Cape Cod West	5

Diadromous

Is there a diadromous fish run? — no → No diadromous TOY

yes → Diadromous TOY

Waiver granted if

Turbidity from project is not shown or expected to extend to spawning habitat **AND** Dredging is 3 days or less **AND** X or less inlet channels are being dredged during the TOY

Reason: minimize risk of vulnerable life stage habitat impact

Reason: minimize risk of impediment to migration and direct impact

Reason: minimize risk of cumulative impact

# channels that can be dredged w/in the TOY for each region (X)	
Buzzards Bay East	1
Islands	3
North Cape Cod	3
South Cape Cod East	2
South Cape Cod West	2

Horseshoe Crab (HC)

Is footprint of project <750 feet from any part of a mapped HC beach or within the Stage Harbor Complex? — no → No horseshoe crab TOY

yes → Dredge horseshoe crab TOY

Waiver granted if

Dredging will avoid the new and full moons & 2 days before and after the full and new moons **AND** Dredging is 3 days or less

No waivers in Stage Harbor Complex

No fill of HC beaches during beach HC TOY unless fill is above the extreme high water mark and no construction activity is conducted on the beach.

Shellfish

Is there mapped shellfish habitat, a town propagation area, or private aquaculture within 25 feet of site ? — no → No shellfish TOY

yes → Shellfish TOY if requested by DMF shellfish biologist

Reason: minimize risk of direct impact during vulnerable life stage

In some cases, it may be recommended that the shellfish resource should be removed prior to dredging

Eelgrass

Is project 25 feet from an eelgrass bed or is turbidity from project shown or expected to extend to eelgrass? — no → No recommendations

yes → Containment and/or turbidity monitoring

Reason: minimize risk of impact to vulnerable habitat

No dredging of eelgrass recommended; sites where eelgrass used to exist but doesn't now should be avoided and minimized where possible.

Lobster

Is project 25 feet from lobster habitat or is turbidity from project shown or expected to extend to lobster habitat? — no → No recommendations

yes → Containment and/or turbidity monitoring

Reason: minimize risk of impact to vulnerable habitat

No dredging or fill of pebble-cobble-boulder seafloor recommended

In some cases, it may be recommended that the lobster resource should be removed prior to dredging

STANDARD RECOMMENDATIONS

- **Avoid dredging in Special Aquatic Sites (eelgrass, salt marsh, intertidal flats).**
- **Avoid dredging of sediment pebble size or larger (4 mm).**
- **Avoid disposal of material on horseshoe crab beaches during TOY unless above extreme high tide line**
- **If dredging occurs during a TOY, no other dredging in the waterbody during that TOY is recommended**
- **Silt curtains may be recommended during time of year and non-time of year periods to protect other species and habitats.**

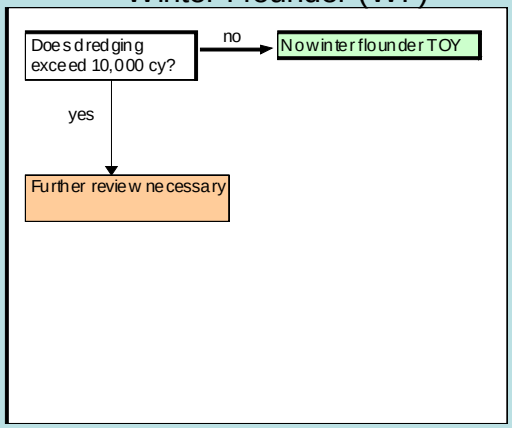
DISCLAIMER: These charts only apply to public hydraulic dredging for maintenance purposes on Cape Cod and the Islands. All projects may have site specific or project specific considerations that do not follow these charts especially if there are multiple project components and/or the project affects multiple feature types.

Approach Channel

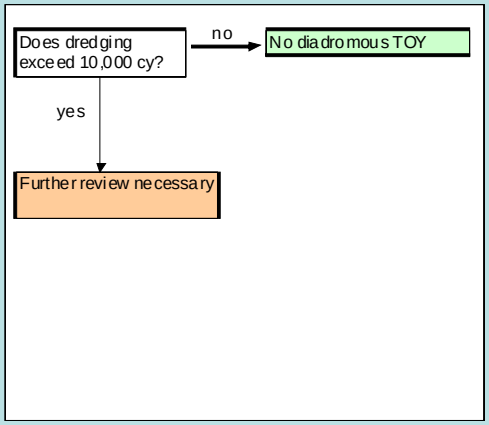
Seaward of the Inlet Channel, an Approach Channel is the tidally influenced area where animals may stage for entrance into an Embayment. These are either known or presumed to have coarser grain sizes than Embayments and higher wave energy than Embayment or Inlet Channels. These may or may not include channels through beach shoreface deposits that are visible on aerial photos. Approach Channels extend from the extreme high water mark to subtidal waters.

Date: 3/19/12

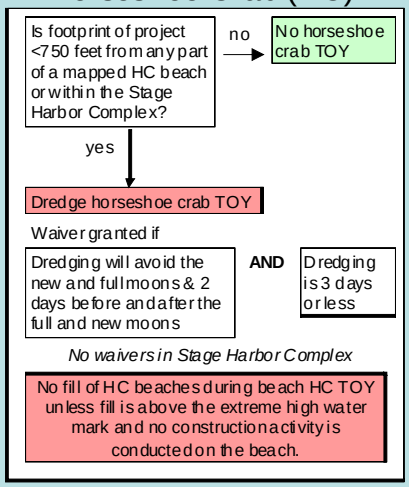
Winter Flounder (WF)



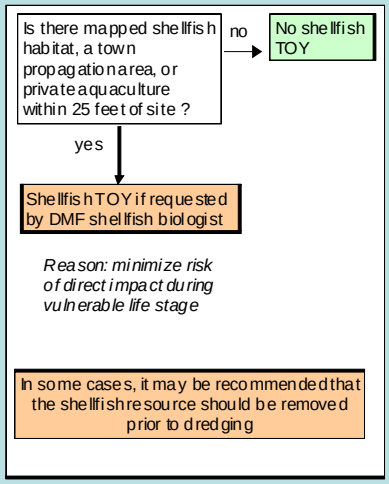
Diadromous



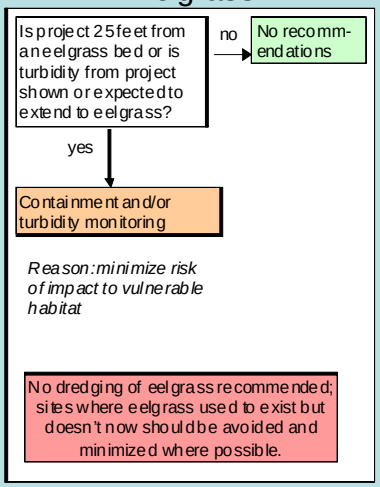
Horseshoe Crab (HC)



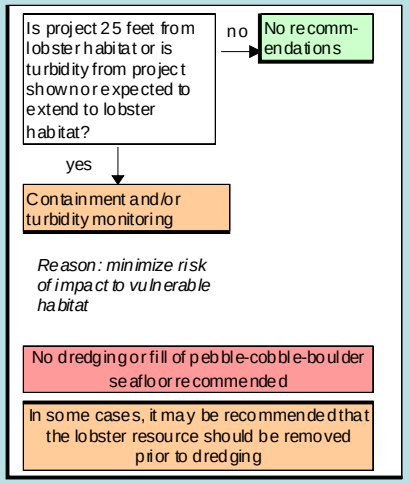
Shellfish



Eelgrass



Lobster



STANDARD RECOMMENDATIONS

- **Avoid dredging in Special Aquatic Sites (eelgrass, salt marsh, intertidal flats).**
- **Avoid dredging of sediment pebble size or larger (4 mm).**
- **Avoid disposal of material on horseshoe crab beaches during TOY unless above extreme high tide line**
- **If dredging occurs during a TOY, no other dredging in the waterbody during that TOY is recommended**
- **Silt curtains may be recommended during time of year and non-time of year periods to protect other species and habitats.**

DISCLAIMER: These charts only apply to public hydraulic dredging for maintenance purposes on Cape Cod and the Islands. All projects may have site specific or project specific considerations that do not follow these charts especially if there are multiple project components and/or the project affects multiple feature types.

OTHER RECOMMENDATIONS

The intent of this summary of recommendations is to allow greater transparency and enable simple application of these recommendations. However, there is potential for confusion particularly regarding projects that are located in more than one waterbody feature, such as an embayment and an inlet channel. The following recommendations were generated to provide guidance, and may not apply in all cases. We recommend that proponents and regulators confer with *MarineFisheries* if there is any lack of clarity.

1. Avoid dredging during TOYs whenever possible.
2. Whatever resource is occurring in the waterbody, the most conservative TOY recommendation will be followed.
3. If a project goes into more than one waterbody feature, the most conservative TOY recommendation will apply.
4. If a project goes into more than one waterbody feature, the maximum time spent in any one feature shall be limited to that of the feature and the whole project shall not exceed the maximum amount of time allowed in any feature being dredged.
5. A dredge day is daytime hours between sunrise and sunset. Any amount of dredging occurring within that timeframe counts as a full day. Filling or purging the pipe will not count as dredging.

Emergency dredging needs. Because of the site-specific nature of this type of action, we recommend coordination with *MarineFisheries* if emergency dredging activities must occur during a TOY. The guidelines herein described in no way affect the existing process for requesting and reviewing emergency actions.

PERMITTING

This document does not alter existing permitting practices. Municipalities first apply for a permit to dredge a certain volume at specific sites. Permit applications could be required for the town (Notice of Intent process), the state (DEP), and the federal government (ACE). Since permits are often written to cover multiple years, time of year recommendations written into the permits by the issuing authority are based on the assumption that the dredging will occur in all years of the permit duration for the maximum volume permitted.

MarineFisheries recommends that the permits have TOY restrictions, but if a town cannot schedule dredging during the allowed time of year, a waiver request can be made for a single dredging season. *MarineFisheries* has outlined in this document the circumstances under which we will accept waiver requests. *MarineFisheries* does not recommend writing TOY waivers into the permits for two reasons:

- TOY waivers are considered one time occurrences, and should be granted only if the municipality has demonstrated the inability to operate outside of the TOY restricted period (due to weather, scheduling backup, unanticipated storm deposition, etc).
- It is difficult to build them into the permits while addressing the cumulative impact concerns. There is a cap on the number of inlets that can be dredged

during a portion of the TOY restricted period. Giving a certain inlet an "automatic" TOY waiver in the permit process may prevent another municipality from being allowed to have the waiver time.

MarineFisheries provides comments regarding ways to avoid, minimize, and mitigate project impacts on marine fisheries resources to permitting agencies. It is outside the purview of *MarineFisheries* to write permit conditions. DEP provided the following language that it uses in 401 Water Quality Certifications which enables the mechanism whereby waiver requests can be granted without requiring a long-term modification to the permit. This language is provided to illustrate how the resource recommendations outlined in this document are accommodated in permits.

1. In order to protect spawning, larval and juvenile development of winter flounder, no dredging shall occur between January 15th and May 31st.

2. The applicant, or its contractor, shall make every feasible effort to complete the project within the permitted timeframe. Should the applicant, or their contractor, fail to complete the project and wish to request an amendment to the Certification for incursion into the no-dredge period, the written request shall be received by the Department by January 2nd. The following information shall be included in the request:

    a. project location and transmittal number,
    b. the date on which dredging started,
    c. the number of days and hours per day the dredge operated,
    d. expected daily average production rate and the actual daily average production rate,
    e. an explanation of why the project failed to remain on schedule,
    f. an account of efforts made to get the project back on schedule,
    g. a plan depicting the areas that remain to be dredged,
    h. the number of cubic yards that remain to be dredged,
    i. an accurate estimate of the number of days required to complete the project,
    j. an evaluation of the impact of continued dredging on the species of concern,
    k. a description of any efforts that will be made to minimize the impacts of the project on the species of concern, and a realistic assessment of any societal/financial effects of a denial of permission to continue dredging.

    The Department will share the information with other resource agencies and a decision to grant or deny the amendment shall be made by January 15th. Requests for amendment received after January 2nd will be considered at the Department's discretion.

The waiver request (also known as a permit amendment) is made to the regulatory agency that granted the permit (the Conservation Commission, DEP, ACE, or all three). In considering waiver requests, *MarineFisheries* considers the following:

- Volume requested and anticipated length of time of incursion

- Timing of the incursion (i.e. will the incursion occur in the last two weeks of January or in the middle of April?)
- Waterbody feature being dredged (embayment, inlet channel, or approach channel) and if efforts were made to schedule the project to minimize impact (e.g. approach channel is being done last)
- Other concurrent or previous incursion requests for the waterbody and the region
- Dredging history in the affected region
- Specific reasons for waiver request (i.e. weather, scheduling backup, unanticipated storm deposition, etc)

The regulatory agency typically confers with *MarineFisheries*, NMFS, or other agencies with jurisdiction over affected natural resources. If a waiver is granted, the municipality reports the following information to DEP upon conclusion of the dredging:

- Number of dredge days
- Production rate per day
- Total volume dredged

This information will be used by the DEP dredge coordinator in cooperation with *MarineFisheries* to determine if TOY waiver time remains for additional waiver requests.

During the first few years of this new programmatic approach to TOY waivers, these reports will be assessed by *MarineFisheries* and DEP to verify that the assumptions made herein are reasonable. We will also consider requests by the towns to assign TOY waiver time to individual towns.

AMENDMENTS

Some towns have higher resolution resource and waterbody information that could help improve the resource mapping and waterbody feature mapping. In order to request amendments at a given site (such as changing the boundary lines between features, for example), the town should contact the *MarineFisheries* Habitat Program. The type of information that should be provided includes:

- Grain size distribution (silt-clay-sand combinations, sand, gravel-cobble combinations)
- Current speed (specifically, what is the average maximum current velocity in the vicinity of the dredge project)
- Dredge footprint
- Volume of dredge material
- Frequency of dredging activity
- Location of geomorphic features (channels, tidal deltas, flats, etc)
- Location of resources (shellfish beds, horseshoe crab beaches, fish counts, eelgrass beds, etc)

These parameters were selected based on the process established to build the existing feature maps. This list was generated in conjunction with the Cape Cod Dredging Working Group which met over the course of 2008-2011. The information can be consolidated in ArcGIS or

Google Earth software or on hard-copy maps, preferably NOAA charts or orthophotographs. All information used to create the maps must be identified with the following information:

- Date(s) of collection
- Method(s) of collection
- Accuracy assessment (both spatial and data quality)

ACKNOWLEDGEMENTS

Many groups and individuals were instrumental in contributing to and reviewing this document: the Cape Towns Working Group as organized by Carey Murphy and Jim Hanks, the Mass. Department of Environmental Protection, Wetlands and Waterways Branch, the Mass. Office of Coastal Zone Management, the State Dredge Team, NOAA Habitat Conservation Division, and many Division of Marine Fisheries staff including Phil Brady, Paul Caruso, Brad Chase, Bruce Estrella, Frank Germano, Bob Glenn, Mike Hickey, Jeff Kennedy, John Logan, Vin Malkoski, Julian Race, Mark Rousseau, and John Sheppard.

REFERENCES

Atlantic States Marine Fisheries Commission (ASMFC). 2009. Stock Assessment Overview: Horseshoe Crab. http://www.asmfc.org/speciesDocuments/horseshoeCrab/HSCStockAssessmentOverview.pdf Accessed: 3/14/2012.

Avissar, N. 2006. Modeling potential impacts of beach replenishment on horseshoe crab nesting habitat suitability. Coastal Management. 34:427-441.

Belding, D.L. 1909. A Report upon the Quahaug and Oyster Fisheries of Massachusetts *in* The Works of David L. Belding M.D. Biologist, republished by Cape Cod Cooperative Extension, September 2004.

Berry, W., N. Rubinstein, B. Melzian, and B. Hill. 2003. The Biological Effects of Suspended and Bedded Sediment (SABS) in Aquatic Systems: A Review. EPA Internal Report. http:// www.epa.gov/waterscience/criteria/sediment/pdf/appendix1.pd. Accessed: 1/12/2010.

Berry, W., N. Rubinstein, E. Hinchey, G. Klein-MacPhee. 2005. Winter flounder *Pseudopleuronectes americanus* hatching success as a function of burial depth in the laboratory Society of Environmental Toxicology and Chemistry 26th Annual Meeting, Baltimore, MD, November 14-17, 2005.

Botton, M.L. and R.E. Loveland. 2003. Abundance and dispersal of horseshoe crab larvae in the Delaware Estuary. Estuaries. 26(6):1472-1479.

Cabaço S., R. Santos, C.M. Duarte. 2008. The impact of sediment burial and erosion on seagrasses: A review. Estuarine, Coastal and Shelf Science. 79:354-366.

Code of Massachusetts Regulations (CMR). 401 water quality certification for discharge of dredged or fill material, dredging, and dredged material disposal in waters of the United States within the Commonwealth. Chapter 314, Section 9.07.

Costello, C.T. and W.J. Kenworthy. 2011. Twelve-year mapping and change analysis of eelgrass (*Zostera marina*) areal abundance in Massachusetts (USA) identifies statewide declines. Estuaries and Coasts. 34: 232-242.

Dadswell, M.J. 1996. The Removal of Edwards Dam, Kennebec River, Maine: Its Effects on the Restoration of Anadromous Fishes. Draft Environmental Impact Statement, Kennebec River, Maine, Appendices 1-3. In: American Rivers. 2002. The ecology of dam removal, a summary of benefits and impacts. American Rivers, Washington, DC. 92 pp.

Erftemeijer, P.L.A. and R.R.R. Lewis III. 2006. Environmental impacts of dredging on seagrass: A review. Marine Pollution Bulletin. 52(12):1553-1572.

Evans, A.S., K.L. Webb, and P.A. Penhale. 1986. Photosynthetic temperature acclimation in two coexisting seagrasses, *Zostera marina* L. and *Ruppia maritima* L. Aquatic Botany. 24(2): 185-197.

Evans, N. T., K. H. Ford, B. C. Chase, and J. J. Sheppard. 2011. Recommended time of year restrictions (TOYs) for coastal alteration projects to protect marine fisheries resources in Massachusetts. Massachusetts Division of Marine Fisheries Technical Report, TR-47. http://www.mass.gov/dfwele/dmf/publications/tr_47.pdf Accessed: 10/18/2011.

Funderburk, S.L., S.J. Jorday, J.A. Milhursky, and D. Riley. 1991. Habitat requirements for Chesapeake Bay living resources, Second Edition. Prepared for Living Resources Subcommittee, Chesapeake Bay Program.

Hanson, J., M. Helvey, and R. Strach. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures, version 1. NOAA National Marine Fisheries Service Southwest Region, Long Beach, CA. 75 pp. http://www.nwr.noaa.gov/Salmon-Habitat/Salmon-EFH/upload/EFH-nonfishing.pdf Accessed: 1/12/2010.

Hauxwell, J., J. Cebrain, and I. Valeila. 2006. Light dependence of Zostera marina annual growth dynamics in estuaries subject to different degrees of eutrophication. Aquatic Botany. 84: 17-25.

Heck, K.L., Jr., K.W. Able, M.P. Fahay, and C.T. Roman. 1989. Fishes and decapod crustaceans of Cape Cod eelgrass meadows: species composition, seasonal abundance patterns and comparison with unvegetated substrates. Estuaries. 12:59-65.

Howe, A.B. and P.G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Transactions of the American Fisheries Society. 104:13-29.

Hughes, J.E., L.A. Deegan, J.C. Wyda, M.J. Weaver, and A. Wright. 2002. The effects of eelgrass habitat loss on estuarine fish communities of southern New England. Estuaries. 25: 235-249.

Jarvis, J.C., K.A. Moore, W.J. Kenworthy. 2012. Characterization and ecological implication of eelgrass life history strategies near the species' southern limit in the western North Atlantic. Marine Ecology Progress Series. 444:43-56.

Johnson, M.R., C. Boelke, L. Chiarella, P. Colossi, K. Green, K. Lessis-Dibble, H. Ludemann, M. Ludwig, S. McDermott, J. Ortiz, D. Rusanowsky, M. Scott, and J. Smith. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. NOAA National Marine Fisheries Service Northeast Region, Gloucester, MA. Technical Memorandum NMFS-NE-209. http://www.nefsc.noaa.gov/publications/tm/tm209/tm209.pdf. Accessed: 1/12/2010.

King, J., M. Camisa, V. Manfredi, and S. Correia. 2008. 2007 Annual Performance Report. Massachusetts Division of Marine Fisheries Resource Assessment Project. http://www.mass.gov/dfwele/dmf/programsandprojects/rap_2008_annual_report.pdf. Accessed: 1/12/2010.

Klein-MacPhee, G., W.K. Macy, and W.J. Berry. 2004. In Situ Effects of Suspended Particulate Loads Produced by Dredging on Eggs of Winter Flounder (*Pseudopleuronectes americanus*). Ninth Flatfish Biology Conference, December 1-2, 2004, Water's Edge Resort, Westbrook, CT. http://www.nefsc.noaa.gov/publications/crd/crd0413/orals.htm#1. Accessed: 1/12/2010.

Loveland, R.E. and M.L. Botton. 1992. Size dimorphism and the mating system in horseshoe crabs, *Limulus polyphemus*. Journal of Animal Behavior. 44:907-916.

Massachusetts Department of Environmental Management (MADEP). 2006. Eelgrass (EELGRASS polygon datalayer on MassGIS). http://www.mass.gov/mgis/eelgrass.htm. Accessed: 10/27/11.

Massachusetts Division of Marine Fisheries (MADMF). 1997. Anadromous fish (ANADFISH_PT point datalayer on MassGIS). http://www.mass.gov/mgis/anadfish.htm Accessed: 4/5/2010.

_____ 2007. Resource Assessment Annual Performance Report. http://www.mass.gov/dfwele/dmf/programsandprojects/f56r15_resource_2007_web1.pdf Accessed: 4/5/2010.

_____ 2010. Assessment of horseshoe crab landings from fishermen reports relative to moon phase. Analysis conducted by Micah Dean and Dan McKiernan, February 2010. 2 pp.

_____ 2011. Shellfish suitability areas (SHLFSHSUIT polygon datalayer on MassGIS). http://www.mass.gov/mgis/shlfshsuit.htm Accessed: 10/27/11.

Massachusetts Executive Office of Energy and Environmental Affairs (MAEEA). 2009. Massachusetts Ocean Management Plan, Volume 2: Baseline Assessment of the Massachusetts Ocean Management Planning Area. December 2009. 208 pp. + figures.

MassGIS. 1992. Coastline line layer (COAST25K_ARC datalayer). http://wsgw.mass.gov/data/gispub/shape/state/coast25k.exe Accessed: 1/2/2012.

_____ 2003. Major Drainage Basins polygon layer (MAJBAS_POLY polygon datalayer). ftp://data.massgis.state.ma.us/pub/shape/subbas/subbas.exe Accessed: 4/5/2010.

_____ 2007. Drainage Sub-basins polygon layer (SUBBASINS_POLY polygon datalayer). ftp://data.massgis.state.ma.us/pub/shape/subbas/subbas.exe Accessed: 4/5/2010.

Massachusetts Office of Coastal Zone Management (MACZM). 2007. Shallow water hydraulic dredge impact characterization. Report prepared by Normandeau Associates. 51 pp. + appendices.

McRoy, C.P. 1969. Eelgrass under Arctic winter ice. Nature. 224: 818-819.

Mills, K.E. and M.S.Fonseca. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series. 255:127-134

Newcombe, C.P. and J.O. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16: 693-727.

NOAA Northeast Fisheries Science Center. 2008. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. NOAA National Marine Fisheries Service, Northeast Fisheries Science Center Ref Doc. 08-15. 884 pp.

Oleson, B. and J. Sand-Jensen. 1993. Seasonal acclimatization of eelgrass *Zostera marina* growth to light. Marine Ecology Progress Series. 94: 31-99.

Orth, R.J., K.L. Heck, Jr., and J. van Montfrans. 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships. Estuaries. 7:339-350.

Paling, E.I., M. Fonseca, M.M. van Katwijk and M. van Keulen. 2009. Seagrass restoration. In: Coastal wetlands: an integrated ecosystem approach. G. Perillo, E. Wolanski, D. Cahoon and M. Brinson, eds. Elsevier, Amsterdam. pp. 687-713.

Phillips, B. 2006. Lobsters: Biology, Management, Aquaculture and Fisheries. Blackwell Publishing, Ames, IA. 528 pp.

Rideout, R.M., G.A. Rose, and M.P.M. Burton. 2005. Skipped spawning in female iteroparous fishes. Fish and Fisheries. 6:50-72.

Rottmann, R.W., J.V. Shireman, and F.A. Chapman. 1991. Introduction to hormone-induced spawning of fish. Southern Regional Aquaculture Center, Stoneville, MS. Publication No. 421. 4 pp.

Short, F.T. and D.M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries. 19:730-739.

Wahle, R.A. and R.S. Steneck. 1991. Recruitment habitats and nursery grounds of the American lobster *Homarus americanus*: a demographic bottleneck? Marine Ecology Progress Series. 69:231-243.

Widener, J.W. and R.B. Barlow. 1999. Decline of a horseshoe crab population on Cape Cod. Biological Bulletin. 197:300-302.

Wilber, D.H. and D.G. Clarke. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management. 21:855-875.

Wilber, D.H., D.G. Clarke, and M.H. Burlas. 2006. Suspended sediment concentrations associated with a beach nourishment project on the northern coast of New Jersey. Journal of Coastal Research. 22(5):1035-1042.