

***Marine Fisheries* strategies and priorities to address ecosystem changes and fisheries impacts resulting from climate change and ocean acidification.**

Summary of Key Strategies and Priorities

- The continuation of established time-series monitoring efforts should remain a Division priority
- Existing monitoring efforts should be expanded to incorporate the collection of additional climate related data identified as critical to improving long-term fisheries management strategies
- External funding opportunities should be identified and pursued to address climate change and ocean acidification research needs
- Partnerships with academia, research institutions, fisheries management entities, and the fishing industry should be established for the collection and analysis of relevant climate data
- An ocean acidification monitoring program should be instituted at strategically located near-shore locations to monitor long term trends in pH and surface ocean CO₂ partial pressure (pCO₂) and the potential impacts to calcification rates of important shellfish species
- An in house committee to coordinate work related to the collection and maintenance of time-series climate data should be established
- The creation of a webpage and other outreach materials highlighting current efforts, identifying future data needs, tracking “indicator” data, and outlining adaptation strategies for future fisheries management objectives should be developed
- Support for outside programs that collect climate and ocean acidification data used in fisheries management decision-making should continue
- A standardized approach to long term climate related data collection should be developed

This is an assessment of climate change and ocean acidification impacts on fisheries resources and a coordination of *Marine Fisheries*' approach to developing strategies in accordance with the 2010 – 2014 *Marine Fisheries Strategic Plan* to address climate change and ocean acidification. The objectives of this review are to identify *Marine Fisheries*' work related to collecting, maintaining and using time-series information and to provide recommendations for addressing matters involving climate effects on fishery resources and habitats, stock assessments, fisheries performance and fisheries management.

There is extensive global evidence that climate change is affecting marine resources and the environments they inhabit. Mean sea level (MSL) is predicted to rise over the next century as global temperatures increase, shifting the extent and distribution of coastal wetlands and other coastal habitats ([IPCC 2007](#)). Regional precipitation levels are forecasted to increase in frequency and intensity, changing salinity regimes, increasing surface runoff, river discharges and erosion into coastal ecosystems ([Hayhoe et al. 2006](#)). Sea surface temperatures have increased at a rate of 0.04°C per year since 1970 ([Nixon et al. 2004](#)) and are expected to continue rising throughout the century, permanently altering the range of suitable habitats for many commercially and recreationally important marine species. Interactions between the ocean and the increasing annual variability of atmospheric weather have been predicted to cause changes to

ocean circulation patterns affecting marine ecosystems and species distributions on regional scales ([Frumhoff 2007](#)).

Ocean acidification is a relatively new field that is examining the oceans vulnerability to anthropogenic carbon emissions. Ocean pH levels have decreased by 0.1 units over the last century and will continue to decrease ([Doney et al 2009](#)), impacting essential biological functions such as photosynthesis, respiration, growth, reproduction, recruitment and calcification rates of some or all life history stages of marine species ([Subcommittee on Ocean Acidification 2009](#)). Over time, all of these factors are expected to alter important predator – prey interactions, influence species migration patterns, change primary and secondary productivity, and increase the vulnerability of resident marine species populations to diseases and invasive species invasions ([Hayhoe et al 2007](#)). These changes will have substantial long-term fisheries management implications.

Marine Fisheries is confronted with several key climate related fisheries management challenges. These include:

- Alterations to species distributions, migration patterns, productivity, and species interactions resulting from changes in temperature, weather patterns and ocean current circulations
- Near-shore habitat loss resulting from sea level rise
- Ocean acidification and its impacts on important commercial and recreational shellfish populations
- Impacts to shellfish closures resulting from shifting spatial patterns of precipitation and changes in the frequency and intensity of storm events across the region
- Frequency, duration, and intensity of harmful algal blooms (HABs)
- Exacerbation and facilitation of known diseases and the emergence of new diseases and the potential implications to marine resources

Addressing these concerns requires ensuring the continuation of ongoing time-series data collection efforts, expanding these efforts to include additional relevant data, and developing new monitoring programs to address identified data needs in response to potential climate impacts with fisheries management implications.

***Marine Fisheries* role in providing climate information, tools and services**

Agency projects collect and maintain long-term data sets for monitoring water quality, habitat loss, harmful algal bloom frequency, duration, and intensity, species abundance and diversity, and fishing effort. Information is disseminated to the public through data analysis, outreach efforts, public meetings, the development of technical reports, and the fulfillment of data requests. This information has many benefits for addressing impacts to commercial and recreational fisheries and for establishing collaborative efforts to ensure resource sustainability in the face of climate change. These include:

- Raising industry awareness of climate change and ocean acidification and the potential for future social and economic consequences
- Establishing efforts with other agencies and research institutions to monitor climate associated impacts to marine resources and habitats
- Focusing research efforts on regional fisheries management needs
- Identifying vulnerabilities to communities with harbors and other infrastructure important to the fishing industry

- Justifying important fisheries management decisions

Participation in the development of fishery management plans through the New England Fishery Management Council (NEFMC) and interstate fisheries management through the Atlantic States Marine Fisheries Commission (ASMFC) continues to be significant to *Marine Fisheries* mission to manage marine resources for the Commonwealth. Regional consequences of climate change and ocean acidification will elevate the importance of several ongoing regional fisheries management efforts to address these impacts. The ASMFC and NEFMC will play several key roles in this process. These include:

- Updating fishery management plans to accommodate biological, economic and social variation resulting from the effects of climate change and ocean acidification
- Conducting workshops examining climate change implications for fisheries and aquaculture on a regional scale
- Acting as a conduit for identifying regional climate related issues and outlining regional policies and adaptation strategies
- Developing a structured approach to addressing climate change impacts through fisheries management
- Establishing quota management strategies for addressing shifts in species ranges
- Providing cross boundary governance necessary for fisheries impacted by climate change

Current Programmatic Activities

Marine Fisheries has long recognized the importance of time-series monitoring and data collection for the development of policies governing the use and protection of fisheries resources. Several agency programs currently monitor key meteorological, oceanic, and biotic parameters that may be useful in determining trends resulting from climate change and ocean acidification, or in augmenting existing climate related data sources. Project specific efforts include:

Recreational and Diadromous Fisheries

Four diadromous fish projects maintain continuous data sets for several river systems along the coast.

American eel young-of-year (YOY) monitoring stations were established on the Parker River (Newbury) in 2004, the Jones River (Kingston) in 2005, the Saugus River (Saugus) in 2007, and the Wankinco River (Wareham) in 2010 to collect temperature data year round. Beginning in 2010 additional long-term monitoring stations were established on Pilgrim Lake (Orleans) and Grass Pond / Cold Brook (Harwich) to collect temperature data for 16 weeks during the eel migration season (early March – late June).

Rainbow smelt population monitoring using fyke nets occurs annually on eight rivers. This project began collecting temperature data year round on the Crane River (Danvers), the North River (Peabody), and the Fore River (Braintree) in 2002. The project expanded to include the Parker River (Newbury) in 2004, the Jones River (Kingston) in 2005, the Saugus River (Saugus) in 2007, and the Weweantic (Wareham) and Westport (Westport) Rivers in 2008. During the 11 week smelt spawning season (early march to mid-May) three grab samples per week are collected using a YSI 6920 multi-parameter logger to record pH, specific conductivity, turbidity, dissolved oxygen, and temperature at all stations. Continuous YSI loggers have been deployed in the Jones and Fore rivers from March-June since 2005.

A rainbow smelt habitat eutrophication study conducted from 2002 – 2003 also collected seasonal (early March to late June) temperature data in the Ipswich River (Ipswich) and Charles River (Watertown) from 2003 - 2008, the Neponset River (Milton) from 2002 – 2008, and the Mill River (Rowley) from 2002 – 2009.

Seasonal (March - June) temperature data is also collected during annual river herring migration counts. There are eight active monitoring stations. Monitoring on the Monument River (Bourne) began in 1984. The project expanded to include the Nemasket (Middleboro) and Mattapoisett Rivers in 1995, the Back River (Weymouth) in 2003, the Essex River, Town Brook (Plymouth), and Mystic River in 2004, and the Mystic River in 2004. In addition to these eight active programs, data was also collected for the Charles River (1984-1992, 1997), Jones River Kingston (1992-1995), Mill Creek Sandwich (1992-2001) and the Agawam River (1993-1994, 2005).

Data collection efforts follow an approved Quality Assurance Program Plan ([Chase 2010](#)) developed by *Marine Fisheries* and approved by DEP. Other water quality and water chemistry data is collected at select locations. Most of this data resides on project dedicated network drives, however older data (pre 1997) are archived in paper records and are on file at *Marine Fisheries* South Coast Field Station in New Bedford.

Ocean Bottom Temperature Monitoring conducted by the Lobster Investigations Project

Bottom temperature monitoring began in 1986 at Cleveland's Ledge in Buzzards Bay. To increase spatial coverage, additional bottom temperature monitors have been deployed in state waters near Manomet and Plymouth (1988), at the mouth of Buzzards Bay, the mouth Boston Harbor, and the mouth of Plymouth Harbor (1989), Beverly Harbor (1996), Brace Rock, Gloucester (1999), and Sippiwisset Rocks and Scorton's Ledge (2001). Bottom temperature readings are recorded every 2 hours at all locations. Data resides on project dedicated network drive and is readily available upon request in Excel spreadsheet format. A map of site locations is also available. Data is used to corroborate long-term lobster settlement and migration trends.

Resource Assessment

Project collects and maintains fisheries independent data on the distribution, abundance, size and age composition of finfish and select crustaceans and mollusks in state waters. Monitoring began in 1978 and is the longest ongoing inshore survey on the U.S. east coast. Data includes commercially and recreationally important targeted species and non-targeted species as well as select hydrographic data and is essential for monitoring potential changes in the migratory patterns of fish. Data resides in an Oracle database at the Northeast Fisheries Science Center.

Shellfish

The Shellfish Project has been collecting water samples to classify shellfish areas in coastal waters at over 2300 stations statewide at varying frequencies since 1988. Data set contains over 150,000 individual temperature, salinity, rainfall amount and fecal coliform records collected under specific protocols used for classifying shellfish areas. Data resides in a dedicated in-house Oracle database.

The PSP monitoring program has been monitoring biotoxin levels in shellfish since 1972. Data set contains weekly samples collected from 15 primary stations from April through November. Data set includes temperature, salinity, and biotoxin level records collected under specific protocols used for monitoring biotoxins in select shellfish species. Data resides on project dedicated network drive and is readily available upon request in Excel spreadsheet format.

The shellfish stock enhancement project in collaboration with Dr. Mark Green, a professor of environmental science at Saint Joseph's College in Maine began collecting sediment pH data at 103 test plots across six shellfish restoration sites in Boston Harbor in 2009. This activity is expected to continue for the next several years to develop baseline information that will be used to relate clam growth, survival, and recruitment to pH sediment levels. Data resides on project dedicated network drive.

Fisheries Habitat

The Eelgrass project has monitored eelgrass in Salem Sound since 2007. Project collects time-series temperature, light penetration, density, canopy height and percent cover data from three stationary transect locations in Salem Sound as part of the global SeagrassNet program. Data is entered into a global database and is accessible via an online database.

The artificial reef project has conducted annual monitoring of a *Marine Fisheries* constructed cobble enhancement reef in Boston Harbor since 2006. Project collects time-series temperature, light penetration, species density and diversity data using transect sampling conducted by divers. Data resides on Lobster project dedicated network drive and is readily available upon request in Excel spreadsheet format. Data is used to corroborate long-term succession trends of benthic communities. Annual monitoring is expected to continue indefinitely.

Habitat mapping is an ongoing effort to collect critical baseline information on the spatial extent of habitat types in coastal waters. This data is critical for monitoring long-term changes to fisheries habitats and has direct implications to fisheries management. Select information resides on project-dedicated hard drives and is available upon request.

Management Information Systems and Fisheries Statistics

Project collects and maintains fisheries dependent data in the form of annual and recent trip level catch reports for quota-managed species. This data is critical for monitoring long-term catch, effort, and economic data for important commercial and recreational marine species. Historical landings data for quota-managed species from 2002 to present is available via the *Marine Fisheries* website. Long-term data sets such as the history of the *Loligo* squid fishery, striped bass, and lobster fisheries are available via the *Marine Fisheries* technical report series. Other historical information such as the southern Cape Cod weir fishery is contained in older archived reports in paper form. These reports provide valuable fishery performance records and may be useful in documenting changes to species distributions over time resulting from several factors, including climate change. A major initiative in 2010 to begin licensing salt-water recreational fishing will be critical to improving stock assessments and identifying trends in recreational fishing efforts.

Several other projects have collected short-term time-series temperature data including annual studies of cod aggregations in Massachusetts Bay and striped bass temperature preference monitoring studies. These short term efforts are designed to answer specific project related questions regarding the migratory patterns of select marine species, however may have value in augmenting future efforts specific to climate change.

Outside sources used to obtain climate information

The primary sources of outside information used by agency projects for climate specific data are the National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS), and the Northeastern Regional Association of Coastal Ocean Observing System (NERACOOS). Several projects utilize datasets maintained by the National Weather Service (NWS) including sea surface temperature, hourly rainfall amounts, and advanced hydrologic

prediction services. These products contain readily available long-term data sources that support management decisions for shellfish, lobster, and diadromous fish projects. Stream flow monitoring data collected at select locations throughout the region by USGS are utilized by the shellfish project for managing the classification of shellfish growing areas and by the diadromous fish project for monitoring stream flow in systems where diadromous fish runs are monitored. NERACOOS operates a series of weather monitoring arrays in the Gulf of Maine (also known as the Gulf of Maine Ocean Observing System (GoMOOS)) that provide real time information via satellite on sea surface temperature, air temperature, wind direction, wind speed, and other select meteorological parameters. In addition, other NERACOOS regional ocean observing programs with relevant climate information include the Martha's Vineyard Coastal Observatory (MVCO) and the University of New Hampshire's Coastal Ocean Observing Center (COOA). This information is used by several projects to supplement other data collection efforts and to assist in the scheduling and execution of field data collection activities. In addition to providing valuable information for fisheries scientists and managers, these products are also utilized by our constituents and are critical in providing information essential to their safety and well being at sea. As these data sources are critical to several data collection efforts, *Marine Fisheries* will continue to champion these efforts.

Collaborative efforts

Collaborative efforts have begun to address fisheries management and data concerns specific to climate change and ocean acidification. Agency personnel contributed to the Commonwealth Coastal Zone and Ocean ([CZO 2009](#)) Subcommittee of the Massachusetts Climate Change Adaptation Advisory Committee (CCAAC), established under the Global Warming Solutions Act of 2008 by Secretary Bowles to advise EOEEA to study and make recommendations on strategies for adapting to climate change. Establishing research and policy partnerships should be an agency priority. Efforts should include:

- Partnering with government agencies and research institutions to identify climate change related impacts and to identify and establish additional long term time-series monitoring efforts
- Participating in initiatives to identify and address resource vulnerabilities, identify funding opportunities, and to develop adaptation strategies
- Identifying and working with climate change researchers to obtain funding to collect data applicable to identified fisheries management needs

Coastal climate change impacts will affect coastal development, water and wastewater management, commercial port development, hazard mitigation, and other land-based activities requiring input from resource managers, planners and local governments. In order to collect and analyze appropriate climate data, develop management priorities, and avoid duplication of effort, partnerships with government agencies, academia, research institutions and the fishing industry should be an agency priority.

Improving future data collection

Specific impacts to important marine resources and habitats resulting from climate change and ocean acidification are not well known. High-resolution time series information of important meteorological, oceanic, and biotic parameters is essential to the development of informed fisheries management decisions. *Marine Fisheries* can implement several key long-term improvements for future data collection efforts. These include:

- Ensuring the continuance of existing long term monitoring efforts

- Expanding select monitoring efforts (eelgrass, artificial reefs, shellfish restoration, lobster EBP sampling, resource assessment surveys, time series temperature monitoring, GIS habitat mapping) to develop more robust baseline information in anticipation of potential environmental changes that may impact the management of marine resources
- Supporting long-term ocean acidification monitoring efforts and seeking to expand efforts to include strategically based near-shore stations through collaborative efforts or new funding opportunities
- Collaborating with regional partners to model the effects of changing primary and secondary productivity resulting from changing temperature and ocean currents
- Researching relevant technology development and remote sensing applications
- Standardizing measurement protocols and data reporting guidelines

Strategies to address future needs

Future fisheries management decisions will require better information and more collaboration between *Marine Fisheries*, academia, and our commercial and recreational constituents to address the affects of climate change and ocean acidification. There are several services that *Marine Fisheries* should develop to address future climate change and ocean acidification impacts to marine resources. These include:

- Identifying specific habitat types or environmentally sensitive areas that are particularly vulnerable to climate change and require specific fisheries management strategies
- Identifying specific resource vulnerabilities (i.e. temp and salinity tolerances of species, species ranges, species seasonality)
- Developing a cumulative impact assessment identifying significant resource impacts resulting from man-made coastal alterations and accelerated loss of critical fisheries habitat from climate change
- Developing a standardized approach to long term climate related data collection
- Seeking funding opportunities for collaborative research efforts with the commercial fishing industry to explore the potential for shellfish and finfish aquaculture to offset potential economic losses
- Working with the shellfish industry and research institutions to develop predictive warning systems for harmful algal blooms (HABs).
- Examining the potential of the depuration plant for maintaining the viability of commercially important shellfish areas impacted by climate change
- Researching the “living shoreline” concept as a means to provide greater resiliency of important marine resources to adapt to climate change
- Supporting restoration efforts that enhance the resiliency of marine ecosystems and expand habitat connectivity
- Identifying and participating in regional programs and partnerships to address future fisheries management needs
- Developing a centralized database application to fully utilize all climate and associated biological data

Marine Fisheries recognizes that climate change is a serious challenge that requires a comprehensive response to address significant impacts to Massachusetts’ coastal and ocean resources and recreational and commercial fisheries based economies. Addressing these impacts will require focused research efforts and translation of research results into useable information for policymakers to make critical fisheries management decisions. Science, including long term monitoring will be crucial to our understanding of and adapting to climate change in the decades ahead.

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