

The School for Marine Science and Technology

Framework for Formulating the Mt. Hope Bay Natural Laboratory: A Synthesis and Summary

Rodney Rountree, Dave Borkman, Wendell Brown, Yalin Fan, Lou Goodman, Brian Howes, Brian Rothschild, Miles Sundermeyer, and Jefferson Turner

(FINAL DRAFT)

May 22, 2003

SMAST Technical Report No. SMAST-03-0501

The School for Marine Science and Technology University of Massachusetts Dartmouth 706 South Rodney French Boulevard New Bedford, MA 02744-1221 508.999.8193 www.smast.umassd.edu

Framework for Formulating the Mt. Hope Bay Natural Laboratory: A Synthesis and Summary

Rodney Rountree, Dave Borkman, Wendell Brown, Yalin Fan, L. Goodman,

Brian Howes, Brian Rothschild, Miles Sundermeyer, and Jefferson Turner

Table of Contents

List of Tables	iii
List of Figures	iv
Chapter 1 . Introduction (Rodney Rountree)	. 1
Chapter 2 . Physical Environment (Yalin Fan & Wendell Brown)	13
Chapter 3 . Habitats and Habitat Quality (Brian Howes & Miles Sundermeyer)	57
Chapter 4 . Plankton (David Borkman & Jefferson Turner)9	98
Chapter 5. Nekton (Dave Borkman, Jefferson Turner and Rodney Rountree) 12	26
Chapter 6. Modeling Efforts (Miles A. Sundermeyer & Yalin Fan)	62
Chapter 7. Summary and Conclusions (Rodney Rountree)	90
Literature Cited and Selected Bibliography	07
Appendix A. ASA's WQMAP	92
Appendix B. Selected Web Pages Related to MHB	00

List of Tables

Table 2.1. Narragansett Bay PORTS station data products
Table 2.2. Available historical and real-time PORTS information for the Narragansett Bayarea. Status indicates which versions of the different variables are available online,including historical data (H), real time data (RT), and information (X).19
Table 2.3. Station information for Taunton, Blackstone, Woonasquatucket and Pawtuxet Rivers USGS gauge stations
Table 2.4. Tidal harmonic constants for the important tidal constituents at several sites in the Narragansett Bay system, including Providence, Conimicut Light, Fall River, Quonset Point, and Newport. Tidal phases are in Greenwich epoch degrees
Table 3.1. Summary of estuarine and marine habitat acreages for Narragansett Bay in 1996.(Adapted from Huber 1999.)
Table 3.2. Discharges from municipal wastewater treatment facilities during 1997. (Data from Save the Bay 1997.)
Table 3.3. Land-use within the upper and lower watersheds to Mt. Hope Bay. (Data from MassGIS.) 80
Table 3.4. Benthic infaunal species and numbers within upper and mid- Mt. Hope Bay at Stations C, F, and I#4, March 1997-February 1998. (Adapted from MRI 1999.)
Table 4.1. Mt. Hope Bay phytoplankton identified in MRI 1997-1998 surveys (MRI 1999).Note Toner (1981) refers to 230 species or categories of phytoplankton in Mt. Hope Bayin 1972-1979
Table 4.2. Mt. Hope Bay zooplankton identified in 1997-1998 MRI surveys (MRI 1999) 118
Table 5.1. Adult winter flounder thermal tolerance data. 149
Table 6.1. EPA model calibration guidelines (McCutcheon et al. 1990)
Table 6.2. Factors potentially affecting the survival of winter flounder in Narragansett Bay.(From Collie and DeLong, 2001.).183

List of Figures

Figure 1.1. Schematic of the Mt. Hope Bay Natural Laboratory operations (see text) Arrows represent information flow and feedback loops.). P. 4
Figure 1.2. Diagram of selected sources of variation affecting Mt. Hope Bay fish stoc annual, decadal and longer-term time scales.	ks over P. 7
Figure 2.1. The bathymetry of the Narragansett Bay region, including Mt. Hope Bay defined by the contour lines for 5, 10, 15, 20, 30 and 40 m. The red box outline Hope Bay/Taunton River region shown in Figure 2.2. The Hicks (1959c) water property measurement transects and the Weisberg (1976) moored current met location (red square in Providence River) are also shown.	s the Mt.
Figure 2.2. Mt. Hope Bay with distribution of the 31 ASA thermistor strings during February 1999 thermal mapping study. Circles indicate the locations of moorin bottom sensors (Swanson et al. 1999). The Spaulding and White (1990) moore current meter locations (red squares) are shown.	ngs with
Figure 2.3. The NOAA PORTS sites in the Narragansett Bay region.	P. 18
Figure 2.4. Annual cycle of monthly mean wind speeds at T.F. Green State Airport i Warwick, RI. The data are averaged over the years 1964 to 1987, inclusive (Pi 1991).	
Figure 2.5. Annual cycle of bimonthly circular frequency histograms of wind vector Green State Airport in Warwick, RI. These histograms were formed by vector averaging winds in 10° sectors. The scale indicates the number of years (in the 1986 interval of observations) that the vector-averaged wind blew from the ind direction in that particular bimonthly period. (Reprinted from Pilson 1991.)	r- e 1964 to licated
Figure 2.6. Daily wind vectors from PORTS stations at Providence, Conimicut Light Prudence Island, Quonset Point and Newport between 31 October 2000 and 31 October 2001. The actual wind observations are hourly at Providence, Conimic Light, Quonset Point, and Newport; every six minutes at Prudence Island.	
Figure 2.7. Taunton, Blackstone, Woonasquatucket and Pawtuxet River discharge r from 30 September 1999 to 30 September 2000. (See Table 2 for details of data information.)	
Figure 2.8. Upper panel: Cross correlation between Taunton River discharge and Bl River discharge; middle panel: Taunton River annual discharge (the red line w showing measurement, and the blue line with stars showing estimated results); panel: Blackstone River annual discharge.	vith stars
Figure 2.9. Sea level record at the Fall River PORTS station for October 2001.	P. 28
Figure 2.10. Co-amplitude (solid – m) and co-phase (dash – °Greenwich) lines for M hours) semidiurnal tide.	₂ (12.42 P. 31
Figure 2.11 A) Ebb tidal currents (knots) in the Narragansett Bay system three hour high water at Newport, Rhode Island. B) Flood tidal currents (knots) nine hou	

high water at Newport, Rhode Island. The red square on the map indicates the

location of the Brayton Point Power Plant. (Adapted from Spaulding and Swanson 1984.) P. 33

- Figure 2.12. Observed (solid) surface (upper panel) and bottom (lower panel) temperature series at Brayton Point mooring station (Station 9 in Figure 2.2) for August 1997. Model temperatures are the dashed lines. (From Spaulding et al. 1999a.) P. 34
- Figure 2.13. Surface (solid) and bottom (dashed) temperature (°C) distributions along A) axes of Providence River-East Passage channels and B) axes of Mt. Hope Bay-Sakonnet River channels (see Figure 2.1) at ±1hour of slack water before ebb during February, April, June, and August, 1956, respectively. The locations are given in minutes of latitude relative to 41°N. The arrow on the panels shows the latitude at which Narragansett Bay connects to Mt. Hope Bay. (Data from Hicks 1959c.) P. 35
- Figure 2.14. Water column average temperature (°C) distribution at ±1hour of slack water before ebb along axes of the (above) Mt. Hope Bay-Sakonnet River and (below)
 Providence River-East Passage channels (Figure 2.1) during February, April, June, and August, 1956, respectively. The locations are given in minutes of latitude relative to 41°N. The orange arrow on the lower panel shows the latitude at which Narragansett Bay connects to Mt. Hope Bay. (Data from Hicks 1959c.)
- Figure 2.15. Horizontal distributions of surface (solid) and bottom (dashed) temperature (°F) distributions at ±1 hour of slack water before ebb for 6-10 August 1956. (Data from Hicks 1959c.) P. 40
- Figure 2.16. Study areas within Mt. Hope Bay. Segments 1-4 defined by 1.4-km radius from Brayton Point Power Station (Carney 1997). P. 41
- Figure 2.17. Seasonal temperature signals of Mt. Hope Bay sections (see Figure 2.15) distributions derived from Landsat (TM Band 6) satellite infrared images with a spatial resolution of 120 m. The upper Narragansett Bay temperatures are given for comparison. Note that the main body of Mt. Hope Bay (sections 1-4) is warmer than upper Narragansett Bay from February through December (Carney 1997). P. 42
- Figure 2.18. Series mean temperatures at 5 different depths at different stations (Figure 2.2) in Mt. Hope Bay during February 1999. The Brayton Point Power Plant cooling water outlet is located at about 41° 43' (Swanson et al. 1999). P. 43
- Figure 2.19. Salinity records in Mt. Hope Bay during February-March 1999; near-surface and bottom at Brayton Point (station 9; Figure 2.2) and near-bottom at the Borden Flats (station 31; Figure 2.2) (from Swanson et al. 1999). P. 44
- Figure 2.20. Surface and bottom salinity (‰) distribution at slack before ebb ±1 hour along A) axes of Mt. Hope Bay-Sakonnet River channel and B) axes of the Providence River-East Passage channel (see Figure 2.1) during February, April, June, and August, 1956. The locations are given in minutes of latitude relative to 41°N. The arrow on the panels shows the latitude at which Narragansett Bay connects to Mt. Hope Bay. (Data from Hicks 1959c.) P. 45
- Figure 2.21. Water column average salinity (‰) distribution at slack before ebb ±1 hour along axes of channels (Figure 2.1) during February, April, June, and August, 1956. The locations are given in minutes of latitude relative to 41°N. The arrow on the upper panel shows the latitude at which Narragansett Bay connects to Mt. Hope Bay. (Data from Hicks 1959c.) P. 46

- Figure 2.22. Horizontal salinity (‰) distribution at slack before ebb ±1 hour during cruise 19 (6-10 August 1956). Surface – solid lines and large numerals; bottom – dashed lines and small numerals. (Reprinted from Hicks 1959c.) P. 48
- Figure 2.23. Water column vertical stability distribution in terms of buoyancy frequency at slack before ebb ±1 hour along axes of channels (Figure 2.1) during February, April, June, and August, 1956. The arrow on the upper panel shows the latitude at which Narragansett Bay connects to Mt. Hope Bay. (Data from Hicks 1959c.) P. 49
- Figure 3.1. Historical distribution of eelgrass beds in Narragansett and Mt. Hope Bays. (Reprinted from Kopp et al. 1995.) P. 60
- Figure 3.2. Eelgrass distribution in Mt. Hope Bay and upper Narragansett Bay. Eelgrass, shown in yellow, is absent from Mt. Hope Bay and is confined to shallow marginal areas within the lower western portions of Narragansett Bay. This system-wide distribution is typical of estuaries receiving significant nutrient inputs to the upper tributaries. Mt. Hope Bay has high turbidity and periodic low dissolved oxygen during summer, conditions not supportive of eelgrass beds. (Data provided by RIDEM-the Rhode Island Department of Natural Resources and Environmental Management.) P. 61
- Figure 3.3. Evidence of the impact of nutrient loading and pollution on habitats and ecosystems depicted by closure of shellfish areas. (From www.state.ri.us/dem/maps/static/shellnar.jpg.) P. 64
- Figure 3.4. Although a species can be distributed across many types of habitats, variation in the habitat quality as measured by mortality, growth, fecundity, spawning success, etc., likely vary strongly among the habitats, such that some can be considered of higher "quality" than others. P. 65
- Figure 3.5. Habitat quality or suitability can shift among reproductive stages so that habitats optimal for spawning may not be optimal for other periods. P. 66
- Figure 3.6. Estuarine habitats are trophically linked by nekton movements in a variety of ways, including ontogenetic, seasonal, tidal and diel migrations. (Adapted from Rountree 1992) P. 67
- Figure 3.7. Primary and secondary production in saltmarshes and other shallow estuarine habitats supports secondary production in other habitats, sometimes far removed from them, through the migration of nursery species. (Reprinted from Deegan et al. 2000; permission pending.) P. 68
- Figure 3.8. Saltmarshes and other shallow tidal habitats support secondary production in deeper subtidal estuarine habitats through tidal and diel foraging movements of nekton. (Reprinted from Deegan et al. 2000; permission pending.) P. 69
- Figure 3.9. Saltmarsh and other shallow estuaries support open bay and coastal marine ecosystems through a chain of migration of nekton species resulting in the trophic relay of energy and materials. (Adapted from Deegan et al. 2000; permission pending.) P. 69
- Figure 3.10. Land area contributing freshwater and nutrient to Mt. Hope Bay. The Bay's watershed is the second largest in Massachusetts. (Adapted from MassGIS and the Massachusetts Watershed Initiative; http://:www.state.ma.us/mgis/.) P. 72

- Figure 3.11. Map of the watershed contributing to Mt. Hope Bay via direct discharge or indirectly through the Tauton River. Major surface water sub-watersheds and freshwater streams and rivers are shown. (Map adapted from MassGIS; http://:www.state.ma.us/mgis/.) P. 73
- Figure 3.12. Upper watershed to Mt. Hope Bay showing sub-watersheds which contribute nutrients to the Bay via surface water discharges to the Tauton River. The Tauton River is the major freshwater source discharging to the Bay and the major conduit for the transport of nutrients from the upper watershed. (Map adapted from MassGIS; http://:www.state.ma.us/mgis/.) P. 75
- Figure 3.13. Lower watershed to Mt. Hope Bay showing sub-watersheds which contribute nutrients directly to the Bay via small tributary streams or direct groundwater discharges. (Map adapted from MassGIS; http://:www.state.ma.us/mgis/.) P. 75
- Figure 3.14. Population growth in the Mt. Hope Bay region between 1960 and 2000. Regional population has generally grown 30%-60% over this interval, while the urban (sewered) area has experienced a slight population decline. (Data from MassGIS and SRPEDD.) P. 77
- Figure 3.15. Distribution of land-uses within the upper watershed to Mt. Hope Bay (see Figure 3.12). Total land area is 115,300 hectares. (Data from MassGIS.) P. 80
- Figure 3.16. Distribution of land-uses within the lower watershed to Mt. Hope Bay (see Figure 3.13). Total land area is 35,300 hectares. (Data from MassGIS.) P. 81
- Figure 3.17. Long-term record (1880-1999) of flow in the upper region of the Tauton River as recorded by USGS. Note the 3-fold variation over the record and the frequent 2fold variation in flow in consecutive years. P. 83
- Figure 3.18. Average annual flow in the upper region of the Tauton River as recorded by USGS from 1880-1999 (see Figure 3.17). Note the strong annual cycle resulting from the annual distribution of rainfall and evapotranspiration within the watershed.
 - **P. 84**
- Figure 3.19. Key water quality data collected during mid-summer 2001 at the SMAST mooring near the channel at mid-Bay. (Data collection in collaboration with Narragansett Bay Commission and MCZM under EPA EMPACT Program.) P. 87
- Figure 3.20. SMAST mooring in Mt. Hope Bay during mid-summer 2001. The oxygen levels at the surface are generally above and the bottomwater generally below atmospheric equilibration. This is indicative of eutrophic conditions where sufficient ecosystem oxygen consumption is present to exceed oxygen production through photosynthesis and ventillation. (Data collection in collaboration with Narragansett Bay Commission and MCZM under EPA EMPACT Program.) P. 87
- Figure 3.21. Bottom water dissolved oxygen levels and associated levels if at atmospheric equilibration for data interval in Figure 3.20. P. 88
- Figure 3.22. Salinity of surface and bottom waters at the SMAST mooring during midsummer 2001. Note the strong salinity stratification that is consistent with the low dissolved oxygen observed during this interval. (Data collection in collaboration with Narragansett Bay Commission and MCZM under EPA EMPACT Program.) P. 89

Figure 3.23. Location of benthic sampling (MRI 1999). P. 91

- Figure 3.24. Annual variations in median densities of total benthos at stations F and C and annual log mean densities plus and minus 2 S.E. (MRI 1999). P. 93
- Figure 3.25. Annual variations in median densities of *Ampelisca abdita* (right panels), *Nucula annulata* (middle) and *Mediomastus ambiseta* (right) at stations F and C and annual log mean densities plus and minus 2 S.E. (MRI 1999). P. 94
- Figure 4.1. 1997-1998 dinoflagellate abundance (heavy line) compared to 1972-1985 mean ±1 standard error dinoflagellate abundance (dashed line) at four Mt. Hope Bay monitoring stations. Panel A shows pattern at Mt. Hope Bay station 'I', panel B shows station 'C', panel C shows station 'F' and panel D shows station 'A'' 1997-1998 and 1972-1985 mean dinoflagellate abundance annual cycles. (From data in MRI 1999.) P. 108
- Figure 4.2. Monthly change in Mt. Hope Bay chlorophyll concentration compared between 1972-1985 (dashed line is mean ±1 S.E.) and the 1997-1998 sample year (solid line). (Adapted from Figure P-23, MRI 1999.) P. 109
- Figure 4.3. 1997-1998 zooplankton abundance (heavy line) compared to 1972-1985 mean ±1 standard error zooplankton abundance (dashed line) at four Mt. Hope Bay monitoring stations. Panel A shows pattern at Mt. Hope Bay station 'I', panel B shows station 'C', panel C shows station 'F', and panel D shows station 'A'' 1997-1998 and 1972-1985 mean zooplankton abundance annual cycles. (Adapted from data in MRI 1999.) P. 111
- Figure 4.4. Seasonal pattern of *Acartia hudsonica* abundance in Mt. Hope Bay compared between the 1972-1985 (dashed line is mean ±1 S.E.) and the 1997-1998 sampling year (solid line). (Adapted from Figure Z-25 in MRI 1999.) P. 112
- Figure 4.5. Abundance of larval winter flounder collected at the BPPS from 1973-2000. (Reprinted from USGen 2001.) P. 122

Figure 5.1. Location of MRI, RIDEM and URIGSO standard trawl sampling. P. 127

- Figure 5.2. Comparison of annual totals of mean monthly trawl catches for demersal fishes in Narragansett Bay and Rhode Island Sound from 1966-1982. Note different scales among y-axes. (Reprinted from Jeffries and Terceiro 1985.) Note different scales among y-axes. P. 129
- Figure 5.3. Power curve for relation of total annual abundance of Narragansett Bay winter flounder and total migrant species abundance. (After Figure 6 of Jeffries and Terceiro 1985.) P. 129
- Figure 5.4. Shift in dominance of groundfish species to elasmobranch and pelagic fishes observed in the NW Atlantic. (Reprinted from Sinclair and Murawski 1997.) P. 132
- Figure 5.5. Rhode Island (RI) and southern New England/Mid-Atlantic (SNE) winter flounder landings time series. (Rhode Island data after DeAlteris et al. 2000; southern New England data is after NMFS data summarized by Nitschke et al. 2000.) P. 137
- Figure 5.6. Rhode Island (RI) and Gulf of Maine (GOM) winter flounder landings time series. (Rhode Island landing data after that of DeAlteris et al. 2000; GOM landings are NMFS data after Nitschke et al. 2000.) P. 138

- Figure 5.7. Rhode Island (RI) and Georges Bank (GB) winter flounder landings time series. (Rhode Island data after DeAlteris et al. 2000; Georges Bank data is after NMFS data summarized by Nitschke et al. 2000.) P. 138
- Figure 5.8. Rhode Island (RI) winter flounder landings (filled circles, after DeAlteris et al. 2000) and Mt. Hope Bay winter flounder catch per unit effort (CPUE; filled diamonds). (CPUE data is based on MRI trawl surveys as analyzed and presented by T. Englert at the October 2001 Mt. Hope Bay Workshop.) P. 139
- Figure 5.9. Habitat delineation of juvenile winter flounder habitat as determined by the BBPP (USGen 2001). P. 147
- Figure 5.10. Schematic of the life history pattern of winter flounder. Movement patterns of adults are shown separately at the top for clarity. (See text for explanation.) P. 154
- Figure 6.1. Model grid used for simulations in Mt. Hope Bay. The gridded area extends into substantial portions of Narragansett Bay to more accurately reflect conditions at the entrance to Mt. Hope Bay. P. 166
- Figure 6.2. ASA WQMAP model error for Mt. Hope Bay simulations: (left panel) relative mean error (rme) and (right panel) root mean square error (rms) between model predictions and observations for the surface (0.25 m) thermister locations. (From Spaulding et al. 1999b.) P. 174