Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-42

Quality Assurance Program Plan (QAPP) for Water Quality Measurements Conducted for Diadromous Fish Habitat Monitoring Version 1.0, 2008-2012

B. C. Chase

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Department of Fish and Game
Massachusetts Division of Marine Fisheries

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Massachusetts Division of Marine Fisheries Technical Report Series

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Quality Assurance Program Plan (QAPP) for Water Quality Measurements for Diadromous Fish Habitat Monitoring Version 1.0, 2008-2012

Bradford C. Chase

Massachusetts Division of Marine Fisheries
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May, 2010

Commonwealth of Massachusetts
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Executive Office of Energy and Environmental Affairs
Ian Bowles, Secretary
Department of Fish and Game
Mary B. Griffin, Commissioner
Massachusetts Division of Marine Fisheries
Paul Diodati, Director

Title: Quality Assurance Program Plan for Water Quality Measurements conducted for Diadromous Fish Monitoring (Version 1.0)

Date: November 2009 *(Final Draft)*

Program Participant: Massachusetts Division of Marine Fisheries

Prepared By: _____ 11/17/09 Date

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Abstract: Diadromous fish migrate between freshwater and marine habitats to complete essential life history stages. New England diadromous species include anadromous fish such as river herring that mature in the ocean and spawn in freshwater, and a single catadromous fish, the American eel, which spawns at sea and its young migrate to freshwater habitat for juvenile growth and maturation. Most anadromous species possess a demersal egg that requires clean substrate for incubation and survival. The success of the anadromous reproductive strategy is dependent on elevated flows and suitable water and habitat quality occurring after the spring freshet. Diadromous fish populations on the Atlantic coast of North America have declined in recent decades, with watershed alterations, harvest mortality, and passage impediments known to be negative influences in some regions. Interest in diadromous fish restoration has increased recently among constituents and government agencies; however, the majority of restoration efforts have focused on migratory impediments with less attention on water and habitat quality. In order to improve the traceability and reliability of water quality data collected during diadromous fish monitoring and to provide guidance to diadromous fish restoration efforts, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) developed a quality assurance program plan (QAPP) of standardized water and habitat sampling protocols. Standard Operating Procedures (SOP) are provided for routine measurements and multi-project applications for water temperature and chemistry loggers and for river herring and rainbow smelt habitat assessments. The QAPP was designed to also coordinate sampling efforts to produce data that is acceptable for Waterbody Assessments (Clean Water Act , Section 305 (b)) conducted by the Massachusetts Department of Environmental Protection (*Mass*DEP), and to relate species life history to habitat criteria.

INTRODUCTION

This quality assurance program plan (QAPP) addresses water quality measurements and analysis for monitoring projects conducted by the Massachusetts Division of Marine Fisheries (*MarineFisheries*) and program partners. Standard Operating Procedures (SOP) are provided for routine measurements and multi-project applications for water temperature and chemistry loggers, and also for diadromous fish habitat assessments. The document serves two primary purposes for *MarineFisheries* and program partners. The first objective is to provide standardized and consistent sampling protocols to improve the traceability and reliability of water quality data. The second objective is to guide sampling efforts to produce data that is acceptable for Waterbody Assessments [Clean Water Act (CWA), Section 305 (b)] conducted by the Division of Water Management, Massachusetts Department of Environmental Protection (*Mass*DEP).

The *MarineFisheries* water quality monitoring for diadromous fish habitat QAPP adopts the standardized approach recommended by the U.S. Environmental Protection Agency (US EPA) and *Mass*DEP and described in Godrey et al. (2001). This approach contains 24 elements necessary to construct a successful and consistent QAPP. These 24 elements are listed below and follow the formatting and terminology described in Godfrey et al. (2001) and *Mass*DEP (2005). The remainder of this QAPP is comprised of four SOPs that provide specific direction for water quality monitoring related to Water Temperature Loggers (Section 1.0), YSI 6-Series Probe Sondes, (Section 2.0), Rainbow Smelt Spawning Habitat Assessment (Section 3.0), and River Herring Spawning and Nursery Habitat Assessment (Section 4.0). The 24 elements in this **Introduction** provide common and consistent structure to data collections and management for each SOP.

1. QAPP Version. The present QAPP version 1.0 was developed during 2006-2009 while recording data using draft SOPs. These pilot efforts facilitated the development of data forms, quality assurance and quality control (QA/QC) protocols and criteria. SOP 3.0 protocols originated from a rainbow smelt eutrophication study conducted by *Marine Fisheries* in 2002-2003. It is expected that QAPP versions will need to be updated every 3-5 years depending on changes to methodologies and applications, program objectives, and principal staff.

2. Equipment Disclaimer. References to commercial products and manufacturers do not indicate the endorsement of any products or companies by the Massachusetts Division of Marine Fisheries or program partners. It is necessary to specifically name each piece of equipment so that QA/QC protocols can be developed around each product's specifications. SOP 2.0 on water chemistry loggers is directed to the use of Yellow Springs Incorporated (YSI) water quality sondes because all participating *MarineFisheries* projects use this equipment. However, the 24 elements of the Introduction are not dependent on specific sampling instruments. The SOPs can be readily modified by program participants in appendices to match the equipment specifications of items not listed in this version to water quality criteria.

3. Distribution List.

Massachusetts Division of Marine Fisheries Project Staff:

Program Manager -- Michael Armstrong
Monitoring Coordinator -- Bradford Chase
Project QA/QC Analyst -- Bradford Chase
Project Field Coordinator -- Matthew Ayer
Project Database Manager -- Scott Elzey

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Program Participants:

The following agency staff may utilize one or more of the SOPs under this QAPP. Additional staff and seasonal employees may be added following training.

MA Division of Fish & Wildlife	Caleb Slater
MA Division of Fish & Wildlife	Steve Hurley
MA MarineFisheries	Phillips Brady
MA MarineFisheries	John Boardman
MA MarineFisheries	Katie L'Heureux
MA MarineFisheries	John Sheppard
NH Dept. Fish and Game	Kathy Mills
NH Dept. Fish and Game	Jessica Fischer
ME Dept. Marine Resources	Claire Enterline

4. Project Organization. The *MarineFisheries* project staff that will administer this document are within the Recreational and Diadromous Fisheries Program. It is anticipated that future QAPP versions will include participants from other *MarineFisheries* programs and partner organizations. Program participants from the Maine Department of Marine Resources and the New Hampshire Department of Fish and Game will apply SOP Sections 1.0-3.0 during 2008-2011 as part of a National Oceanic and Atmospheric Administration (NOAA) grant to develop a conservation plan for rainbow smelt for the three states. SOP 4.0 will be used by watershed organizations in partnership with *MarineFisheries* to assess river herring habitat.

5. Program Background. The Massachusetts Division of Marine Fisheries is responsible for managing diadromous fish resources in the coastal waters of Massachusetts and shares this

Project Organization

Program Manager: Michael Armstrong, *Marine Fisheries.* Reviews and approves all project proposals and project reports using the QAPP.
Monitoring Coordinator: Bradford Chase, *Marine Fisheries.* Developed the four SOPs and will continue to provide oversight for the projects and share regional instrument calibration and maintenance responsibilities with the Field Coordinator. Will evaluate field, laboratory and data management activities and maintain related communications with the Field Coordinator and Database Manager.
QA/QC Analyst: Bradford Chase, *Marine Fisheries.* Will review data collected under the QAPP and assign data status criteria. Will train other *MarineFisheries* staff to serve as future QA/QC analysts for specific projects.
Field Coordinator: Matthew Ayer, *Marine Fisheries.* Will coordinate the deployment of temperature loggers and YSI sondes on the North Shore. Will share regional instrument calibration and maintenance responsibilities with the Monitoring Coordinator. Will be responsible for data processing for Onset temperature loggers, and will be trained to collect data for all SOPs.
Database Manager: Scott Elzey, *Marine Fisheries.* Will maintain databases for the QAPP and be trained to collect data for all SOPs. Will be responsible for processing data from YSI sondes.
Project Participant: John Sheppard, *Marine Fisheries.* Will collect and process data under SOP Sections 1.0 and 2.0.
Project Participant: Kathy Mills, NH Dept. Fish and Game. Will lead NH DFG efforts to collect and process data under SOP Sections 1.0, 2.0, and 3.0.
Project Participant: Claire Enterline, ME Dept. of Mar. Resources. Will lead ME DMR efforts to collect and process data under SOP Sections 1.0, 2.0, and 3.0.

responsibility with the Division of Fisheries and Wildlife in inland waters. There is long history of *MarineFisheries* recording water quality data to accompany fisheries monitoring and research projects. Data management for past projects has been done on a project-specific basis potentially reducing the comparability of the data for intra- and inter-agency uses. Improved electronic logger technology during the last two decades allows the attainment of high accuracy and precision during water chemistry sampling if consistent QA/QC procedures are applied. The projects outlined in this QAPP and future efforts will benefit from the application of standardized water quality sampling and data processing protocols. In addition, *Mass*DEP's Waterbody Assessments are a powerful tool to identify and initiate remediation for water quality problems that influence the health of aquatic life. A *Mass*DEP-approved QAPP will allow *MarineFisheries* data to contribute to the Waterbody Assessment process.

The effort to adopt standard protocols originated from *MarineFisheries* efforts in 2002 and 2003 to relate water quality and watershed influences to rainbow smelt spawning habitat. This project deployed continuous water temperature loggers in rivers with smelt spawning habitat and collected water quality data related to eutrophication impacts on spawning habitat. This project and the increasing utility of the electronic loggers for aquatic habitat monitoring prompted the interest in standardized sampling and QAPP protocols. Interest also came from the NOAA grant partnership between the states of Massachusetts, New Hampshire and Maine tasked with developing a conservation plan for rainbow smelt. The partnership conducts smelt habitat monitoring that will also benefit from QAPP guidance.

6. Program Objectives. The primary program objective is to develop standardized data collection and processing protocols for water quality monitoring related to specific diadromous fish monitoring projects. The following four SOPs will serve ongoing projects that were developed with the objective of producing comparable and reliable water quality data:

Section 1.0-- Water Temperature Logger
Section 2.0-- YSI 6-Series Multi-Probe Sondes
Section 3.0--Rainbow Smelt Spawning Habitat Assessment
Section 4.0--River Herring Spawning and Nursery Habitat Assessment

It is expected that Sections 1.0 and 2.0 will become templates for a wider range of users within DMF. Section 3.0 will focus on nutrient and periphyton measurements at smelt spawning habitat and will be used by the MA/NH/ME smelt conservation partnership. Section 4.0 will produce a tool for assisting the assessment and prioritization of diadromous fish restoration projects. More specific details on project objectives and the target watersheds are presented in the individual SOPs. An important secondary objective is to provide data that can contribute to *Mass*DEP's programmatic objectives of assessing the ability of water bodies to support designated uses (CWA, Section 305(b)) and remediating pollutant loads (CWA, Section 303 (d) under their Watershed Assessment process (*Mass*DEP 2005).

7. Data Quality Objectives. Parameter-specific data quality objectives will be provided in each SOP. The QAPP's basis for data quality control and assurance will be criteria established for the data quality indicators of precision, accuracy, completeness, comparability and representativeness (*Mass*DEP 2005).

Precision. Precision is a measure of the proportion of agreement among replicate measurements. For most parameters in the four SOPs, precision will be sampled and evaluated by criteria established for the relative percent difference (RPD) of duplicate samples. Acceptable RPDs will be typically 5-10% for laboratory and multi-probe water chemistry sonde measurements and ≤35% for nutrient and productivity measurements.

Accuracy. Accuracy is the degree to which a recorded measurement varies from a true or expected value. Accuracy for multi-probe water chemistry sonde measurements will be assessed comparing pre and post-calibration results to specifications established for standard solutions. Accuracy for temperature sensors will be checked against NIST-certified thermometers (National Institute of Standards and Technology). Where appropriate, the SOPs will outline the use of laboratory and trip blanks to contribute to assessments of accuracy. Accuracy warning and control limits will be established using standard

deviation criteria on the departure from seasonal and station means for specific parameters.

Representativeness. Data representativeness refers to the extent to which measurements actually represent the true environmental condition. This attribute is addressed through site selection criteria in "Station Selection" sections for each SOP. For example, rainbow smelt spawning habitat stations are selected from a state-wide list of known smelt spawning riffles where river flow is well-mixed and does not routinely receive saline water from the salt wedge.

Completeness. Data completeness refers to the amount of valid data collected as a proportion to the targeted sampling frequency. Weather, instrument failure and other conditions can result in incomplete or failed measurements in the course of a sampling season. The range of acceptable completeness for targeted measurements will be 75-100% for all SOPs.

Comparability. Data comparability refers to the extent to which data from one study are comparable to data collected for similar parameters during previous studies or from other areas. The documentation of sampling methods, data processing and QA/QC reviews will be used to determine data comparability over time. It is an important objective of the QAPP to improve and document data comparability for future surveys and resource management decisions.

8. Training Requirements. Program participants must become familiar with all aspects of the QAPP, SOPs and instrument manuals that guide sampling. Training sessions will be conducted by the Monitoring Coordinator under each SOP for program participants. SOP 4.0 may include unsupervised volunteer efforts in the future. In these cases, the Monitoring Coordinator will conduct training sessions and initial trips with SOP 4.0 partners. It is expected that most SOP 4.0 trips will be lead by agency staff trained as program participants. Following training in 2008-2009, the Field Coordinators will be prepared to conduct training for program participants to collect field data for all SOPs.

9. Documentation and Records. Standardized field and laboratory calibration forms will be used for all data collection covered within the QAPP. Templates of data forms are provided in each SOP and electronic templates are available for distribution from the Monitoring Coordinator (brad.chase@state.ma.us). Field forms are constructed from Excel spreadsheets and are relational to spreadsheets where data will be entered and stored. Program participants will be trained to use field forms, calibration forms and enter data to spreadsheets. The Program Field Coordinator and Database Manager will process field and calibration data, and the program QA/QC Analyst will review and classify data files. Following review and final data classification, annual data files will be saved as read-only files in a common server folder that all participants can access. Back-up annual files will be saved in a different server by the Database Manager and QA/QC Analyst. Sampling stations will be documented with photographs and by recording the GPS location. The station documentation will be stored in an adjoining common server folder.

10. Sampling Process.

Sampling Safety. Sampling under Sections 1.0-3.0 will occur in coastal rivers during spring. These conditions can be challenging, dangerous, and may compromise sampling methods when river flows are elevated. Field coordinators should monitor precipitation forecasts, stream flow gauge stations (when available) and use their best professional judgment (BPJ) when making decisions on river deployments. Field trips should be made with at least two staff. Exceptions can occur in small streams, primarily under SOP 1.0. Field staff should notify their supervisors of their plans before each field trip. Waders should be used for most in-stream work, although hip boots or knee boots are suitable for smaller streams and during the summer when low flows are prevalent. Waders should be worn with a chest belt to reduce inadvertent flooding of water into the waders. SOP 4.0 will be conducted from small boats in most cases. Staff should wear Coast Guard-approved life vests during boat trips. All boat deployments should be accompanied with an extra life vest, paddle, anchor, and cell phone or VHF radio.

Design Considerations. Water quality sampling under this program targets specific river and lake locations used by diadromous fish for spawning, nursery and migratory habitat. Therefore, the approach to monitoring under Sections 1.0-4.0 is to select fixed stations that can be monitored by *MarineFisheries* during critical life-stage periods on an annual basis. Probability based designs which

are most suitable for watershed basin or state-wide water quality assessments (*Mass*DEP 2005; and DeSimone et al. 2001) were judged impractical for retrieving detailed information on specific habitats used by individual diadromous fish runs.

The four SOPs have independent features that reduce the utility of using a uniform sampling design. For QAPP Version 1.0, SOP 1.0 and 2.0 are related to river sampling of smelt spawning habitat and lake sampling of river herring habitat. Site selection for the smelt spawning habitat stations depended on a previous *MarineFisheries* spawning habitat survey (Chase 2006). Six of the smelt habitat monitoring stations also serves as fyke net locations where spring smelt catches are recorded for annual population monitoring. These stations were selected to provide ranges of smelt population size, watershed drainage area, and watershed usage. In these rivers, temperature logger and YSI sonde deployments will be made upstream of the fyke net location in the freshwater zone. The water quality data collected in the smelt runs will be associated with fyke net catches and used to categorize the river systems in relation to *Mass*DEP surface water quality standards.

SOP 3.0 will provide guidelines for delineating smelt spawning habitat and monitoring biotic and abiotic characteristics of the spawning habitat. SOP 4.0 sampling will be conducted in the spring and summer at river herring spawning and nursery habitats. Unlike the previous sections, SOP 4.0 will focus on lake sampling; however, water quality data processing and quality assurance will be similar. Site selection and sampling designs will depend on previous *MarineFisheries* river herring surveys (Belding 1921; Reback and DiCarlo 1972; and Reback et al. 2004). The river herring habitat SOP is designed to provide status assessments on the suitability of water bodies to support river herring migrations, spawning, and juvenile rearing. Site selection for SOP 4.0 projects will be made on a case-by-case basis to provide information needed for resource management, habitat restoration, and population restoration. It is expected that future *MarineFisheries* applications for SOP 1.0 and 2.0 will be developed independently of the present smelt and river herring monitoring projects.

11. Sampling Method Requirements. Sampling methods for each program project are described in the corresponding SOP sections.

12. Sample Handling and Custody Requirements. Laboratory analyses for SOP Sections 1.0, 2.0 and 4.0 are limited to instrument calibration. Calibration procedures are outlined in each SOP. SOP 3.0 will involve the field collection and laboratory analysis of surface water nutrient samples and periphyton biomass parameters. These handling procedures will be described and a chain of custody form will be supplied in SOP 3.0. For all field and laboratory processes, the date and names of the sampling crew must be recorded on data forms. Sample labeling and numbering will be synchronized among the program participants. Both water quality and biological data samples will be assigned an alphanumeric label that denotes, in order: State (text, 2 letters), year (2 numbers), sample week (2 numbers), location (text, 2-4 letters), sample type (text, 1-3 letters), replicate (numbers, 1-3). For example, a single total phosphorus sample collected in the Parker River, MA during the second week of 2008 sampling would appear as: MA0802PR-TP1.

13. Analytical Methods Requirements. The reporting of laboratory analytical methods applies to SOP 3.0. The analytical methods, holding times and parameter specifications for the analytical laboratory are described with citations in SOP 3.0.

14. Quality Control Procedures. Quality control procedures will be outlined in each SOP section. The following three main components of quality control will be applied in each SOP where applicable: pre and post-deployment instrument calibrations with accuracy and precision checks, analysis on the similarity of replicates, and outlier review using specified flags related to deviations from seasonal and station mean data. For projects where different crews are applying the same methods (primarily SOP 3.0), an annual QA/QC meeting should be held to discuss sampling methods and review quality control results. At these meetings, side-by-side measurements of the same model instruments can be made, if QA/QC reviews identified questions for a sensor or parameter. The comparability of these measurements can help isolate quality control problems.

15. Instrumentation/Equipment Inspection and Testing. Instrument testing and maintenance will be outlined in each SOP section and recorded on sampling forms during each calibration. Laboratory balances used for supporting wet and dry chemistry applications are inspected and

calibrated annually at *MarineFisheries*' Annisquam River Marine Fisheries Station and New Bedford bacteriological laboratory by a certified vendor, with test documents maintained on file at the laboratories.

16. Instrumentation Calibration and Frequency. Instrument calibration information is outlined in each SOP section. With a few exceptions, the YSI water chemistry sonde will be the only instrument calibrated for QAPP applications. The YSI sonde calibration procedures are provided in SOP 2.0. Specific project applications for water chemistry sondes are outlined in SOP's 3.0 and 4.0.

17. Inspection of Supplies. Field and laboratory data forms were designed by the Monitoring Coordinator and will be consistently used by all program participants. The data forms will be inspected at the start of each field season for completeness and applicability. Program participants will inspect all calibration solution standards to ensure they have not expired. Expired standards may be used for calibrations for up to six months after the expiration date, after which they can only be used as a pre-calibration wash solution. Coolers and other carrying containers for field instruments and samples will be thoroughly cleaned at the start or end of each week during the sampling season. Specific procedures for handling supplies for nutrient and biomass sampling will be outlined in SOP 3.0.

18. Data Acquisition Requirements. Annual requests will be made to the U.S. Geological Survey (USGS) for discharge data from sampled rivers with stream flow gage stations. Secondly, annual requests will be made to the National Climatic Data Center (NCDC) for air temperature and precipitation data from weather stations near river sampling stations. In both cases, real-time values of some parameters are available on the agency's web sites. The real-time data should not be used for this QAPP. USGS and NCDC data undergo a QA/QC review and classification by each agency. This could result in changes to real-time data. It is presently more efficient and prudent to wait until the sampling season is over and retrieve all data needs for the calendar year following agency classification. These data will be processed and included in water chemistry data files as daily records for each sampling season.

19. Data Management. All laboratory calibrations and field data collections will be recorded on approved forms listed in Table I. All form templates are stored in the *MarineFisheries* shared computer drives (W:\) under the "QAPP" folder. Field and calibration forms should be filled out on the day that project activity occurred and stored in individual hard copy files by the program participant during the sampling season. All forms should be inspected for completeness, initialed and dated by the project participant. At the end of a sampling season, all forms for a given project should be inspected by the Field Coordinator or QA/QC Analyst to flag errors or missing fields. Any identified problems should be discussed with the field collector and corrections should be documented. Following this activity, the data will be ready for entry into Excel datasheets.

Following data entry, the QA/QC Analyst or Database Manager (if the Database Manager did not enter data) will audit the Excel data files by visual comparison with field forms. The audit will cover 100% of entered data. Discovered errors will be corrected and a tally of field sheet, keypunch, and other errors will be recorded in a QA/QC review worksheet in each annual data file. Once the audit is complete, the auditor will indicate the QA/QC status on the data file and enter his/her name and the month/year.

The QA/QC Analyst should review the data and classify the QA/QC status and data status using the classes listed below. The QA/QC status refers to the review stage for the entire data file. When all QA is finished the QA/QC Analyst will mark the QA status box as *Complete* and enter the month and year. The data status classes refer to the status of data when the QA review is completed. Data will be stored in the *MarineFisheries* shared computer drives (W:\) with back-ups in the personal (P:\) drives of the Database Manager or QA/QC Analyst. Once a data file has been validated by the QA/QC Analyst it will be saved as a read-only file in the W:\ drive and backed up in the P:\ drive.

QA/QC Status

1. Draft. Data processing is in progress, and QA/QC has not been conducted.

2. Preliminary. Data processing is complete, but QA/QC is not complete. Data can be used for internal project summaries.

3. Complete. All data processing and QA/QC review is completed.

Data Status

1. Preliminary. Data have been entered from field sheets or downloaded but QA/QC review is not complete.

2. Censored. Data are eliminated because of instrument failure or QA/QC performance.

3. Conditional. Data are fully audited and QA is complete, but have deficiencies that are documented and may limit use.

4. Final. Data are fully audited, checked and acceptable.

Censored data cells will be shaded with a red color code in the Preliminary datasheets and empty in Final Worksheets. Conditional data cells will be shaded with a yellow color code in both Preliminary and Final datasheets.

20. Assessment and Response Actions. The evaluation of field, laboratory and data management activities for all SOP sections will be overseen by the QA/QC Analyst and will involve in-season and post-season communication with program participants and a series of validation checks at key junctions during data collection and processing. The *MarineFisheries* field activities for SOPs 1.0-3.0 will involve only a few trained staff. In-season and post-season communication among project staff will be a routine process to ensure project protocols are being followed and project objectives are met. Raw data form checks and data file audits are important validation steps that will identify minor errors and result in corrective action for systematic errors. The data file audit will include a tally of errors by type and data entry staff. A meeting will be held at the conclusion of each annual project audit to discuss data quality and identify recurring errors. We have experienced consistently low frequency of data entry error of typically <3% (No. of errors per 100 keypunched cells) for similar water quality data files. Error rates above 3% will prompt specific discussions on correcting the data entry errors. All QA/QC decisions and corrections will be recorded in the QA/QC Review worksheet adjoined to each annual data file.

21. Reports. Project reports will be written for each specific project conducted under SOP 3.0 and 4.0 and include a discussion on QA/QC. Data collected under SOP 1.0 and 2.0 will be used in the

List of Data Forms
(Contact the author for Forms 3.1 through 3.5)

Title	Type	SOP	Purpose
Form 1.1	Water Temperature Logger	1.0	Temperature logger deployment and QA
Form 2.1	YSI Sonde Calibration	2.0	YSI sonde calibration: long-term
Form 2.2	YSI Sonde Calibration Review	2.0	Compare calibration to SOP specifications
Form 2.3	YSI Sonde QA/QC	2.0	QA/QC review and data status
Form 2.4	YSI Sonde Calibration	2.0	YSI sonde calibration: grab samples
Form 3.1	Field Water Chemistry and Flow	3.0	Periphyton field station water data
Form 3.2	Nutrient Data	3.0	Periphyton field station nutrient data
Form 3.3	Periphyton Tile Collection	3.0	Periphyton tile collection records
Form 3.4	AFDW Biomass Measurements	3.0	Periphyton Ash-Free-Dry-weight
Form 3.5	Periphyton Identification	3.0	Taxonomic identification of periphyton
Form 4.1	River Herring Habitat Assessment	4.0	Documentation of field habitat assessments

project reports on smelt and river herring habitat assessments, and smelt population monitoring. In addition, all validated data files will be shared with program partners and available as public property to any interested party. The schedule and detail of written summary reports will depend on the objective of each SOP and in response to varied requests to meet *MarineFisheries* management needs, to assist environmental permit review, to meet environmental permit enforcement requests and other external requests. Deviations from the QAPP and SOPs will be documented in the project reports.

22. Data Review. Common methods and terminology will be used for documenting the QA/ QC review and data status in each SOP Section of this QAPP (see No. 19. Data Management).

23. Validation and Verification Procedures & Requirements. Specific processes for validating data are provided in each SOP, including parameter specific validation criteria tables. Following entry of field data into the corresponding data files, each annual data file will be reviewed by the following four steps (where applicable):

1. ***Data Audit***. Data are compared to field sheets (100% visual audit for keypunched data) to identify entry errors, remove pre- and post-deployment data and flag potential outliers.

2. ***Calibration Review*****.** For YSI sondes and a few other applications, the pre- and post-deployment calibration data will be evaluated following specific performance criteria on accuracy related to standard solutions and manufacturer's specifications.

3. ***Replicate Analysis*****.** The similarity of replicates will be reviewed in relation to performance criteria on sampling precision.

4. ***Outlier Review*****.** Outliers flagged during auditing shall be graphed and compared to deviations from the parameter means and medians for both seasonal and station data series. Outliers that exceed warning (±2 SD) and control (±3 SD) limits will be subject to classification responses outlined in each SOP.

24. Reconciliation with Data Quality Objectives. The final status of sampled data will depend on the data classification criteria described in Data Management (see No. 19 Data Management). Decisions on data classification are dependent on the calibration performance of each sensor as assessed by accuracy and precision tests. For the water quality data, corrective actions will be made on units of data from individual deployments (or between calibrations). Within deployments, classifications and corrective actions will be specific for each sensor or parameter. For example, it will be possible for an entire annual (or seasonal) column of specific conductivity data to be classified as *Final* while the DO data in the same file carries classifications of *Final, Conditional or Censored* for different deployments in the same data file. Parameter specifications and validation criteria are provided in each SOP along with direction for corrective actions and guidance for data classification.

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NOTES AND UPDATES

Optional Methods. Included in the methods sections for each SOP are *options* for field methods, QA/QC, and data processing. The options are suggestions for different approaches to an operating procedure or to troubleshoot problems. In all cases, the options are not requirements of this QAPP and the required procedures should be first attempted and documented. It is expected that technologies and methodologies for using these electronic instruments will be periodically updated. These changes will result in modifications to some current standard operating procedures. The application of the optional methods may help identify better approaches for water quality monitoring and will assist the improvement of future versions of this QAPP.

ACRONYMS

AFDW	Ash Free Dry Weight
BPJ	best professional judgment
cfs	cubic feet per second
CWA	Clean Water Act
DDW	deionized-distilled water
DEP	Department of Environmental Protection
DFG	Mass. Department of Fish and Game
DO	dissolved oxygen
GPS	Global Positioning System
MA	Massachusetts
*Mass*DEP	Mass. Department of Environmental Protection
MarineFisheries	Mass. Division of Marine Fisheries
MassWildlife	Mass. Division of Fish and Wildlife
ME	Maine
NCDC	National Climatic Data Center
NH	New Hampshire
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration.
NTU	Nephelometric Turbidity Units
QAPP	quality assurance program plan
QA/QC	quality assurance/quality control
RPD	relative percent difference
RSD	relative standard deviation
SD	standard deviation
SOP	standard operating procedures
SWQS	surface water quality standards-*Mass*DEP
TN	total nitrogen
TP	total phosphorus
UNH	University of New Hampshire
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
YSI	Yellow Springs Incorporated

CONVERSIONS

Multiply U.S. Customary Units	By	To Obtain Metric Units
inch (in.)	2.54	centimeters (cm)
foot (ft.)	0.3048	meters (m)
mile (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
acre (A)	0.004047	square kilometers (km^2)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
Gallons (gal)	3.785	liters (L)
Temperature Conversion		
Celsius degrees (^oC)	1.80*(^oC) +32	Fahrenheit degrees (^oF)
Fahrenheit degrees (^oF)	0.5556*(^oF-32)	Celsius degrees (^oC)

EQUATIONS

Relative Percent Difference (RPD)

A measure of precision for duplicate samples (X_1 and X_2)

$$RPD = [(X_1 - X_2)/ ((X_1 + X_2)/2)] * 100$$

Relative Standard Deviation (RSD)

A measure of precision for three or more replicates (X_1, X_2, and X_3)

$$RSD = [SD/ ((X_1 + X_2 + X_3)/3)] * 100$$

STANDARD OPERATING PROCEDURES

Section 1.0 Water Temperature Loggers

Scope and Application

Monitoring Objective. Metabolic and reproductive processes in ectothermic fish have evolved in response to natural temperature patterns. Natural and anthropogenic disruptions to water temperature can have acute and chronic consequences to individual fish and fish populations. Water temperature is an important environmental cue for different stages of river herring life history (Loesch 1987). Electronic data loggers will be deployed to record high quality, continuous water temperature data. The water temperature data will provide seasonal and annual trends that can be related to diadromous fish life history and habitat requirements.

Data Quality Objective. The accuracy of data loggers must be ± 0.3 ºC of the true temperature value and must be confirmed with the accuracy checks described below. The precision of the data loggers must be at least 95% (≤5 % relative percent difference, RPD) as determined from duplicate recordings at the same time and space.

Instruments

A variety of instruments are available to accurately record continuous water temperature for river and marine deployments. The loggers with a listed accuracy of ±0.3 ºC over the range of 0 to 25 ºC and battery capacity to conduct annual deployments are preferred. Table 1.1 lists the loggers approved and presently used for this program with specifications (in water).

Table 1.1. Temperature loggers approved for use in Standard Operating Procedure 1.0.

Logger	Ryan Tempmen-tor	Onset Water Pro	Onset Water Temp Pro V2
Resolution	0.10 ºC	0.02 ºC	0.02 ºC
Accuracy (at 0 to 50 ° C)	±0.3 ºC	±0.2 ºC	±0.2 ºC
Range	-32 ºC to 70 ºC	-20 ºC to 70 ºC	-20 ºC to 70 ºC

Deployment

Pre-Deployment Procedures

Time Check. Compare instrument time and date to PC or cell phone time and date. Adjust if needed using the logger's launch/readout software.

Battery Check. Record battery strength; annual deployments should not have less than 90% capacity, and shorter term (spring) deployments should not have less than 80%.

Accuracy Check. Two acceptable methods are available to check logger accuracy. The preferred method is to compare the logger to a thermometer traceable to National Institute of Standards and Technology (NIST) standards and accurate to ±0.2 ºC. Fill a bucket of water and allow the bucket to sit ≥2 hours at constant room temperature (20 °C ±5 °C). Record logger and NIST-traceable thermometer temperatures at the same bucket depth. The logger tested will be acceptable if its measurement is within ± 0.3 ºC of the NIST-traceable thermometer.

If a certified thermometer is not available, use a bucket of crushed ice with distilled water to check logger accuracy. Allow the ice and water to acclimate for 20 minutes and immerse logger. The logger is acceptable if the measurement is 0 ºC ±0.3 ºC. Loggers that fail these tests should be tested again and not be deployed following two failures. If accuracy check results cannot be reviewed until logger retrieval (as with all Ryan and some Onset applications), then evaluate both the pre-and post-deployment accuracy checks during the post-deployment review.

Precision Check. Test the logger precision by recording duplicate temperature measurements separated by two minutes at the same time as the bucket accuracy check. Calculate the RPD of the two samples. Back-up Logger *Option:* when deploying a back-up logger, simultaneous measurements from each logger placed side-by-side in the water bath can be used to check precision and comparability among loggers. Loggers with RPD ≤5% are acceptable for deployment. Loggers that exceed this level of precision should be tested again in the water bath at two temperature ranges in order to isolate possible causes for lower precision. Loggers with RPD ≤5% at both temperature ranges

are acceptable and those with RPD >5% should not be deployed.

Ryan TempMentor. Ryan TempMentor loggers have o-rings that should be carefully cleaned with each deployment and receive a thin coating of silicone grease. A thin-width, tie-wrap should be attached as a lock to the o-ring clamp to provide extra security.

Deployment Procedures

Logger Set-up. Back-up loggers should be activated to begin logging at the same time and date as the primary loggers. If practical, use a common time stamp for loggers at multiple sites.

Location Selection. Pick river locations that have noticeable landmarks and shelter from full sunlight and visibility. The flow at the site should have good mixing and provide at least 0.2 m of depth over the logger. Record GPS coordinates and landmarks. Loggers used in diadromous fish runs should be deployed upstream of the salt wedge (determined by existing salinity data, or the presence of barnacles and shellfish) in order to record freshwater temperature. Marine locations accessed by scuba diving should be associated with visible underwater landmarks and not be subject to disruption from fishing gear or other scuba divers.

Schedule. The minimum deployment period for loggers in diadromous fish runs is March 1st –June 30th. For this deployment period loggers should go out by the end of February. Marine loggers are deployed and retrieved on one date per year. Therefore, scheduling can be flexible as long as battery life is considered. Scheduling scuba visits during warmer months is usually preferred. For most river projects, the loggers will be deployed annually. In these cases, the deployment period can also be flexible allowing for a midseason check (Recovery Procedures).

Record Keeping. Record logger serial number, deployment history, location, and all other fields listed on Water Temperature Logger Deployment Form 1.1.

Recovery Procedures

Schedule. Loggers used for spring diadromous fish runs should be recovered or checked after June 30th. This allows a complete record for March 1st – June 30th fish runs. Consideration should be given to checking loggers following large rain events (>2 in.). River stations designated for annual coverage to capture juvenile emigration periods should be visited for a midseason check (after June 30th) to download data and check battery. Marine stations visited only by scuba diving will have single, annual recovery/deployment visits.

Post-Deployment Procedures

Quality Assurance. Repeat instructions listed under "Pre-deployment Procedures". Loggers that fail accuracy tests should be tested again. Data from loggers that had an acceptable pre-deployment quality control checks yet failed two post-deployment accuracy tests (and the difference from NIST-traceable thermometer is <1.0 ºC) should be classified as *Conditional*, and the loggers should be returned to manufacturer for service before deploying again. Data from loggers that fail two post-calibration checks by ≥1.0 ºC should be *Censored*, as this level of error is considered unacceptable and associated with logger failure. Transfer logger data to an Excel data file and check start and end times to confirm the accuracy of transcription. No additional visual audit of logger data is needed for loggers that had acceptable pre and post-deployment quality control checks. The user should complete all fields on Logger Deployment Form 1.1.

Calculation of Daily Mean Temperature. Daily mean water temperature will be calculated in the Excel spreadsheet from the raw data. The measurements included in a calculation of a daily mean should begin after midnight (≥0001) and end at 2400 for a given calendar day. In the case of Ryan loggers set at two hour intervals, daily mean calculations will include 12 measurements starting at 0200 and ending at 2400.

Data Calculations (*Option*)**.** Users can select to process daily mean temperature data into annual tables that calculate monthly mean, minimum and maximum temperature, and histograms that illustrate the number of days that the daily mean temperature occurred within 1 ºC bins. When information is available on thermal requirements for specific fish, data can be processed as daily maxima to compare to acute thermal criteria and weekly average maxima for comparisons to chronic criteria (Todd et al. 2008). Daily maximum temperature is the highest 2-hour average temperature during a 24-hour period. Weekly average maximum temperature

is evaluated by comparing the 7-day means of daily mean temperatures to chronic thermal requirements for each fish species.

Logger Cleaning. Loggers should be soaked in soapy water to loosen dirt and attached marine life. Onset loggers deployed in freshwater require only moderate scrubbing with a scour pad, except the optical port should only be cleaned with a sponge. Ryan loggers deployed in marine waters require cleaning with a scour pad to remove attached organisms. The o-ring should be cleaned with water and a sponge. A single annual cleaning when loggers are retrieved from the field has been sufficient to maintain Ryan and Onset temperature loggers for ongoing projects.

Data Classification. Use the Excel temperature logger template to review raw data and quality control checks. The final Excel data file should have three attached worksheets labeled: *Raw*, *Mean*, and *Form 1.1*. The QA/QC Analyst should review the data and classify the QA/QC review status and data status using the classes listed below. The QA/QC status refers to the review stage for the entire data file. When all QA/QC is finished the QA/QC Analyst will check the QA/QC status box as *Complete* and enter the month and year. The data status refers to the status of data when the QA/QC review is completed.

QA/QC Status

1. ***Draft.*** Data processing is in progress, and QA/QC has not been conducted.

2. ***Preliminary.*** Data processing is complete, but QA/QC is not complete. Data can be used for internal project summaries.

3. ***Complete.*** All data processing and QA/QC review is completed.

Data Status

1. ***Preliminary.*** Data have been entered from field sheets or downloaded but QA/QC review is not complete.

2. ***Censored.*** Data are eliminated because of instrument failure or QA/QC performance.

3. ***Conditional.*** Data are fully audited and QA is complete, but have deficiencies that are documented and may limit use.

4. ***Final.*** Data are fully audited, checked and acceptable.

Data Storage. Each location will have an annual Excel data file that is named by river and year (ex. Parker River-2005). All Excel approved data files should be stored as read-only files on the *MarineFisheries* shared drive (W:\) with back-ups saved in the Database Managers' personal drive (P:\). Logger stations with five years or more of *Complete* data should also be posted on the *MarineFisheries* web site.

Back-up Loggers. Back-up loggers should be deployed at marine stations with over five years of records. Back-up loggers are not required for river stations where annual loggers receive mid-season checks. The start times should be synchronized for the primary and back-up loggers. Back-up loggers should be subject to the same quality assurance as primary loggers, although documentation can be included on the same logger Excel data file by adding a *Back-up* worksheet. The records of two deployed loggers can be compared by evaluating the percent agreement of daily mean temperatures. Given the high accuracy of these instruments, agreements near 100% are expected and have been observed to date. Data from back-up loggers should be stored as a worksheet in the same Excel file holding data from the primary logger. *Option:* the user can elect to process data from the logger with the best performance during the post-deployment accuracy check. This approach is acceptable if the primary and back-up loggers had common time and date stamps and the RPD of daily mean temperatures is ≤5%.

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MASSACHUSETTS DIVISION OF MARINE FISHERIES

Water Temperature Logger Deployment and QA/QC. **Form 1.1**

Location: *(place, Town)*
Start: *(date, time)*
Deployment: *(date, time)*
Recovery: *(date, time)*

GPS Position: *(Latitude/Longitude)*
Logger: *(model/serial number)*
Instrument Accuracy: *(± ºC at specified range)*
Deployment History: *(purchase date and No.)*
QA/QC Analyst: *(name)*
QA Status: (*Draft, Preliminary, Final*)

Pre-Deployment Check

			ACCURACY			*PRECISION*			
Date	**Time**	**Logger** (SE#)	**Logger** (ºC)	**Cert. Therm.** (ºC)	**Deviation** (ºC)	**RPD (1)**	**RPD (2)**	**RPD (%)**	**Notes**
									(*Accept, Reject, Cond.*)

Primary Logger Battery: *(% or V)*
Back-up Logger Battery: *(% or V)* **Back-up Logger:** *(model/serial no.)*
Internal Clock: *(check with cellphone and note adjustment or mark "correct")*

Post-Deployment Check

			ACCURACY			*PRECISION*			
Date	**Time**	**Logger** (SE#)	**Logger** (ºC)	**Cert. Therm.** (ºC)	**Deviation** (ºC)	**RPD (1)**	**RPD (2)**	**RPD (%)**	**Notes**

Primary Logger Battery: *(% or V)* **Internal Clock:** *(note adjustment or mark "correct")*
Back-up Logger Battery: *(% or V)* **Daylight Savings Time:** *(note if adjusted for DST)*
Record of Deployment Start: *(compare time data to deployment notes)*
Record of Deployment End: *(compare time data to deployment notes)*
Back-up Comparison: *(comment on timing agreement and certified thermometer check)*
Back-up Daily Mean: *(comment on % agreement)*

Data Status: *(QA reviewer approves QA records and assigns data status)*

Notes: *(general)*

Section 2.0 YSI 6-Series Multi-Probe Sondes

Scope and Application

Section 2.0 of the QAPP's Standard Operating Procedures (SOP) is intended to standardize instrument handling, calibration, deployment, post-deployment procedures and maintenance for multi-probe water chemistry sondes. Standardized protocols are necessary to improve the traceability and reliability of the data. These procedures are required for all deployments of YSI 6-Series (6920, 6820, and 6600) sondes. Separate protocols are provided for unattended logging and grab samples. The SOP was developed using YSI 6-Series Operations Manual (YSI 2006) and the 2005 YSI technical note, "Deployment and Data Quality Assurance", and over 10 years of experience using YSI products. The SOP should be revisited and updated periodically to account for changing technologies and improving application knowledge. This document does not cover all aspects of instrument calibration and operation. It is important that users of YSI 6-Series sondes become familiar with the YSI operations manual and follow the manual's instructions. The SOP protocols offer additional points of clarification on YSI manual instructions and quality control and assurance procedures specific to our applications monitoring diadromous fish habitat.

Monitoring Objectives. Electronic multi-probe sondes will be deployed to record both grab samples and continuous water chemistry data within coastal river systems monitored for diadromous fish resources. The recorded data will assist ongoing fisheries sampling programs and interagency efforts to manage aquatic resources.

Instruments

Section 2.0 applies only to YSI 6-Series multi-probe sondes that are presently used for diadromous fish and marine waters monitoring. Program participants with other instruments can use the SOP's QA/QC guidelines while modifying the SOP with an attachment to account for different sondes or sensors. Table 2.1 should contain the current roster of instruments available for deployment for each program participant.

Specifications

Sensor resolution, range, and accuracy are provided by the manufacturer for each measured parameter Table 2.2. These specifications represent a baseline of expected performance and criteria for evaluating calibration results. It is our experience that properly functioning and calibrated sondes will provide results within these specifications, with few exceptions.

Data Quality Objectives. Water quality data within the accuracy range specified by YSI for each parameter probe should be attainable with accurate and consistent calibration. The acceptable SOP accuracy differs slightly from YSI specifications for temperature, dissolved oxygen (DO), and specific

Table 2.1. Roster of instruments used by program participants.

Program Participant:	**Massachusetts Division of Marine Fisheries**				
MAKE	**MODEL**	**SERIAL NO.**	**YEAR**	**STATION**	**SENSORS**
YSI	6820	97AO362AB	1997	Gloucester	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920	02EO838AD	2002	New Bedford	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920	02EO838AA	2002	Gloucester	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920 V2	06E1965AA	2006	Gloucester	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920 V2	07B11200AA	2007	Gloucester	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920 V2	07B11200AD	2007	New Bedford	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920 V2	08A100952	2008	New Bedford	Temp., Sp. Cond., DO, pH, Turbidity
YSI	6920 V2	08A100953	2008	Gloucester	Temp., Sp. Cond., DO, pH, Turbidity

Table 2.2. Sensor resolution, range and accuracy are provided by the manufacturer for each measured parameter. These specifications represent a baseline of expected performance and criteria for evaluating calibration results. An asterisk (*) in the ACCURACY columns denotes "whichever is greatest" relative to the concentration of calibration standard.

PARAMETER (Units apply to columns 1-4)	RESOLUTION and RANGE	YSI ACCURACY (±)	SOP ACCURACY CRITERIA (±)	SOP PRECISION CRITERIA (RPD)
Temperature (ºC)	0.01 -5 to 45	0.15	0.3	5%
Depth (m)	0.001 0 to 61	0.12	0.12	5%
pH (standard units)	0.01 0 to 14	0.2	0.2	5%
DO (mg/l)	0.01 0 to 50	0.2 or 2% of standard*	0.5 or 5% of standard*	5%
DO (% saturation)	0.1 0 to 500	2% of standard	5% of standard	5%
Specific conductance (mS/cm)	0.001 0 to 100	0.5% of standard (+0.001 mS/cm)	2% of standard	5%
Salinity (ppt, derived)	0.01 0 to 70	0.1 or 1.0% of standard*	0.5 or 2% of standard*	5%
Turbidity (NTU)	0.1 0 to 1000	2.0 or 5% of standard*	2.0 or 5% of standard*	5%

conductivity. It is our experience that the YSI accuracy listed for these parameters provides little margin for slight deviations. Therefore, we have adopted higher criteria for acceptable accuracy. These accuracy objectives can be monitored by conducting and reviewing pre-deployment and post-deployment calibrations. The precision of sensor measurements is monitored in the laboratory during each calibration by recording the relative percent difference (RPD = (difference of two consecutive readings/ average of two consecutive readings) x100).

Precision Check. Allow a bucket of tap water to acclimate to room temperature (minimum of 2 hours). Place the sonde in the bucket and allow sensors to equilibrate to water temperature for at least 10 minutes. Once the sonde has equilibrated, record water chemistry on Form 2.1 and repeat measurements after two minutes. At this time, also check the temperature probe against a National Institute of Standards and Technology (NIST) traceable thermometer.

Long-Term Deployments

Site Selection.

Rainbow Smelt. Sondes should be deployed to record freshwater chemistry data in close proximity to smelt spawning habitat. The presence of the salt wedge is not desired because it will confound the interpretation of the freshwater chemistry that influences adult fish attraction and egg survival. Ideally, a site above the influence of tide at an active spawning riffle should be selected. The site should have well-mixed flow and adequate depth to cover the sonde at all times and conceal the sonde from detection. Depths greater than 1 m should be avoided because retrieval can be difficult with high flows. Sites near the fresh and saltwater interface that experience the backing up of freshwater during high tide can be selected, but may require enhanced data management to account for the salt wedge. Avoid high pedestrian traffic locations where the risk of vandalism increases. Record location in latitude and longitude with GPS unit.

River Herring. See Section 4.0 on river herring spawning and nursery habitat.

Pre-Deployment Procedures.

Calibration. Calibrations should be done in the laboratory at room temperature using a PC or laptop with EcoWatch software or with a YSI 650 MDS Display. The depth sensor is the one exception that can be calibrated in the field or laboratory. The calibration should occur within 24 hours of the deployment. Begin the calibration process with DO and continue with each parameter as described in the YSI manual. Record the calibration process on Calibration Form 2.1.

Calibration Rinses. Clean unexpired calibration standards should be used for each calibration. Previously used standards should be used to rinse probes, but cannot be used for calibration. Before each calibration step with a standard solution, the probes should be rinsed once with deionized-distilled water (DDW) followed by a rinse with a previously used standard. A second rinse of DDW should be made prior to 0.0 NTU turbidity and specific conductivity calibrations. The sonde should be shaken lightly prior to using the final standard to remove excess liquid from the probes. The previously used standards should be discarded after one rinse.

DO Calibration (6562 sensor).

Sensor Membrane. Our long-term sonde deployments are routinely for 2-4 weeks. Because the DO membranes are unstable following installation, the membrane should be changed the day before or at least 6 hours before each deployment. If this is not possible, conduct a membrane "burn-in" in Discrete Run mode. Set the sonde to record DO at 4-second intervals in Discrete Mode. Allow sonde to run in this mode for 15 minutes to electrically stabilize membrane and probe. After 15 minutes, confirm that the 4-second measurements have stabilized and check DO charge and gain to confirm they are within the acceptable ranges (see *DO Troubleshootin*g). Because the KCL electrolyte is corrosive to connectors and o-rings all sensors and sonde ports should be protected from the KCL electrolyte with paper towels.

Calibration Cup. Use YSI calibration cup with 1 inch of water. Do not let the DO probe membrane rest in water. Screw the calibration cup to the sonde for only 1-2 threads: air space is needed to vent with the atmosphere. Allow sonde to rest on its side for at least 10 minutes.

Pre-Calibration Test. Turn on sonde in Discrete mode after sonde has acclimated with calibration cup. After 10 minutes, record % saturation (pre-calibration value for Calibration Form 2.1) and DO charge. Percent saturation should be near 100% and DO charge should be in range of 25-75. Proceed to calibrate if correct or to troubleshooting if not (see Technical Notes for an alternative DO calibration).

Calibrate DO. In the Advanced Menu set the Auto Sleep RS-232 option to "ON" for unattended logging and "OFF" for grab sampling. Conduct DO calibration in % saturation mode. If using a YSI 650 display or computer without barometer, enter barometric pressure (mm Hg) from laboratory barometer. If a barometer is not available available, refer to YSI manual for using uncorrected barometer pressure measurements.

DO Optical Sensor 6150. The new optical DO sensor 6150 may soon replace 6562. The optical sensor has no Teflon membrane and requires less maintenance. The water-saturated air calibration for the 6150 sensor follows the same process as the 6562 sensor. YSI recommends that calibration error can be reduced by calibrating the 6150 sensor in saturated water using a bucket and air pump. Saturated water calibration is not recommended for QAPP Version 1.0 because of concerns over consistency among program participants. Refer to the YSI manual for optional calibration instructions and further technical comments on the optical DO sensor.

DO Troubleshooting (#6562). DO charge and gain readings are diagnostic tools for evaluating DO probe performance. The gain of a properly calibrated DO probe should be in the range of -0.7 to +1.4. This can be checked under "Cal Constants" in the sonde's Advanced Menu if there is doubt over probe performance or the acceptability of a calibration. DO charge should be in the range of 25-75. Values below this range can be caused by low concentration electrolyte or a tear in the membrane. Values above this range may be caused by anode oxidation or a failed probe. If DO gain or charge is out of range, inspect the integrity of the membrane. Secondly, inspect the probe anodes for oxidation. If the anode is tarnished or gray, recondition with YSI kit 6035. Thirdly, remove the DO probe from sonde

and check the DO charge: a reading of -0.8 to 1.2 indicates that the sonde is functioning correctly and the problem is likely a failed probe.

Temperature Check. The 6560 temperature probe is reported to not require calibration and there is no mechanism available to calibrate or adjust temperature performance. Our experience has found the probe to be reliable for many years of service. Despite this, confirming temperature probe performance is essential because all other probe measurements are temperature compensated. Pre and post-deployment checks should be made with a NIST traceable thermometer (accurate to ±0.2 ºC). Fill a bucket of water in the laboratory and allow the bucket to sit for at least 2 hours. Record temperature with the YSI probe and certified thermometer at the same bucket depth. The YSI probe is acceptable if the measurement is within ± 0.3 ºC of the certified thermometer. If a certified thermometer is not available, use a bucket of crushed ice in distilled water to check temperature accuracy. Allow the ice and water to acclimate for 20 minutes and immerse sonde. The probe is acceptable if the measurement is 0 ºC ±0.3.

Temperature Troubleshooting. Contamination (typically grit or water) on the temperature port connector can cause poor temperature sensor performance. This has been observed when dirt on the connector causes an unusually high temperature reading. This error can be confirmed by removing the probe from the sonde and checking the temperature display. Any reading other than -9.99 ° C indicates that connector contamination or a circuit failure has occurred.

Pressure/Depth Calibration. The sonde should be set on laboratory bench (not immersed in water), or held at the river surface at the field deployment site, and placed at the expected deployment orientation. Enter a calibration value of 0.00 m and calibrate. No additional calibration procedures are needed for the depth sensor module used in freshwater applications. See the YSI manual for barometric pressure and salinity considerations when seeking high accuracy depth measurements for marine applications.

pH Calibration.

Calibration. Conduct a two-point calibration using pH buffer standards that are certified traceable to NIST with an accuracy of ± 0.05 pH. Always use 7.00 pH for the first standard during calibration and select 4.00 or 10.00 depending on the expected pH range of water at your station. Allow at least one minute of temperature equilibration for each buffer. Record pre and post calibration values for both buffers and pH mV at 7.00 pH. The YSI recommended mV range for YSI 6561 pH probes in 7.00 buffer is ±50.

pH Troubleshooting. It is not uncommon to see the YSI 6565 pH probe produce mV readings >50 mV in 7.00 pH while maintaining calibration within specified data quality objectives. New probes tend to track near 0 mV and with age they range higher. With each calibration, record mV at 7.00 pH and watch for unstable readings. When mV measurements first exceed ±50 at 7.00 pH, or when fluctuations are first noticed, calculate the sensor's slope by also recording pH mV in the 4.00 or 10.00 buffers. The difference (absolute value) between the two mV readings is the sensor slope and the acceptable range is 165-180. Sensors that are out-of -range for pH 7.00 mV or slope can be reconditioned by soaking the probe overnight in 2 M KCL solution or 1 hr in 1M HCL followed by 1 hr in tap water. Probes that are stable, maintain calibration and are within diagnostic ranges can continue to be used. Probes that do not respond to cleaning and continue to have an unacceptable slope should be retired.

Specific Conductivity

Calibration. The conductivity probe is reported by YSI to be linear for the specified range of 0-100 mS/cm. Therefore, only a single point calibration is needed with a standard in the range of the sampling station's specific conductivity. Standard solutions should be traceable to NIST standards and have a stated accuracy of ≤1% of the standard concentration. An acceptable alternative to commercial standards is to prepare your own standard starting with a stock 1.0 M KCL solution. If preparing a KCL standard, the user should follow instructions from *Mass*DEP's SOP on Water Quality Multi-probes (*Mass*DEP 2005) and must have access to high quality deionized water. Acceptable standards for freshwater sampling range from 1.0 mS/cm for freshwater to 50 mS/cm for marine waters. However, due to high linearity, YSI has recently recommended a single mid-point standard (10 mS/cm) for all calibrations.

Conductivity Troubleshooting. The YSI conductivity probe has proven to be reliable and consistently holds calibration for long deployments. To minimize temperature compensation error, calibrations should be conducted at stable room temperature near 25 ºC. Be aware of incorrect readings during calibration caused by air bubbles trapped in the conductivity cell or from having too little standard solution to cover the entire cell. Add more solution or gently move the probes up and down to remove the bubbles. If calibration or field measurement errors are suspected, the conductivity cell constant can be checked in the Advanced Menu under "Cal Constants". The acceptable range is 5 ± 0.45. Values outside this range point towards a problem with the probe or calibration solution. The probe can be further checked by removing it from the sonde and reviewing the conductivity reading. Values of 0.00 ± 3 uS/cm are acceptable and values outside this range indicate that probe or port connectors are contaminated and must be cleaned. Soapy warm water is used to clean the probe and connectors. For severe contamination, soak the probe in hot, soapy tap water for one hour; followed by DDW rinses and air drying.

Salinity. Salinity readings are derived from the YSI's measurements of conductivity and temperature. No calibration is required for salinity measurements. However, the user should recognize that the algorithm for deriving salinity is linear for all measurements of conductivity. Therefore, salinity concentrations will be assigned for low levels of conductivity even when sampling is conducted in freshwater with no saline water present. This feature may require the attention of users when deployments are near the salt and freshwater interface. The response in these cases could be to require data corrections for false low salinity readings or to ignore the parameter in freshwater.

Turbidity.

Calibration Standard. A two-point calibration is recommended by YSI using DDW as the 0.0 NTU standard and 123.0 NTU polymer-based standard manufactured by YSI (Item 6073). Other commercial turbidity standards are available, but not recommended at this time. The DDW should come from a high quality laboratory system documented in Section 2.0 Technical Notes. Turbidity standards should be stored away from direct light in a constant temperature setting. *Option:* although 123.0 NTU is preferred and recommended as the second standard, because of the high cost, 123 NTU standard can be reduce volumetrically the 123 NTU standard to a 10 NTU or 20 NTU standard using DDW water.

Calibration. First, run a wiper cleaning cycle to be sure the wiper does not park on the optic port. Next, the two-point calibration should be conducted using the black bottomed, extended calibration cup with the cup resting on the laboratory bench and the sonde clamped to a laboratory stand with the probes pointing downward into the cup. The sonde bulkhead should rest on the top thread of the calibration cup. If the probe is less than three inches from the bottom of the cup (as with a standard calibration cup), field readings of turbidity can be slightly negative (about -0.5 NTU) from actual reading. Start the calibration with the 0.0 NTU standard and be sure to make an extra rinse with DI water before and after this calibration. Be aware of bubbles or the wiper blocking the turbidity sensor and causing an erroneously high reading during calibration. Conduct the second point of calibration with 123.0 NTU.

The recent transition from the 6026 turbidity sensor to the more accurate 6136 sensor and from single optical port sondes to the dual optical port 6920 V2 has created calibration concerns. The problem may only become evident when the sampling of clear water produces negative turbidity measurements. However, this error must be addressed for all 6920 V2 applications. There are two processes that introduce error into 0.0 NTU calibrations. First, the new optical sensor is better at detecting low levels of contamination that are introduced to the 0.0 NTU standard from the calibration cup and sensors. Secondly, the change from a single, centered optical sensors to two off-centered optical sensors in the 6920 V2 contributes interference from the bottom of the calibration cup. These sources of error will create a positive offset of about 0.2 to 0.8 NTU. YSI recommends (Mike Lizzote, YSI, *pers. comm*. Nov. 2008) two methods for correcting the offset at 0.0 NTU for 6920 V2s following the two-point calibration.

1.) Place the sonde with sensor guard attached into a 3-5 g bucket of DDW that has settled for two hours. Once the turbidity value has settled (it may be slightly negative), conduct a one-point calibration for 0.0 NTU. This process accounts for

both the calibration cup and contamination error and is the preferred offset method.

2.) Repeat the 0.0 NTU calibration in the calibration cup as a one-point calibration. Assign the YSI recommended value of +0.5 NTU to offset the positive error. This process is less time consuming than the first but less accurate. It is recommended that the first offset method be conducted at least once per season.

Turbidity Troubleshooting. The YSI turbidity probes have not demonstrated longevity within our applications. Probe failure during the second season of use has been common. Probe failure is usually first indicated by poor or failed post-calibration performance. There are few diagnostic checks available to the user to evaluate the turbidity probe. You can cover the turbidity sensor with your finger and should see a reading of 1000-1400 NTU. If the sensor does not respond to your finger, the probe has failed and must be returned to YSI for reconditioning or discarded. The 1000-1400 NTU range is also a signal during post-deployment QA/QC that the sensor was probably blocked by debris while recording data. *Option:* if available, a laboratory bench-top turbidity meter can be used to check YSI probe performance with standard solutions.

When using 6136 turbidity sensors with 6920 sondes, be sure to that the sonde and 650 display firmware are upgrades to Version 3.06. For unattended sampling, the turbidity time constant should be increased from the factory setting of 12 seconds to 30 seconds (menu: Advanced/Data Filter/Time Constant). This will improve the sensor's stability at low turbidity measurements. For all uses of 6136 sensors, be sure to use black-colored turbidity wiper mounts or blacken white wipers with paint or markers. Users of 6600 sondes should consult with the YSI manual to account for the different calibration cup size from the 6920 sonde.

Deployment Procedures.

Initiate Unattended Logging. Once calibration is complete, follow YSI manual instructions to initiate unattended logging. Logging sampling frequency is dependent on project, and typically 15, 30, or 60 minutes. Specific projects should select a consistent sampling frequency. The logging interval is dependent on battery capacity, sampling frequency and sensor performance. Deployments of 3-4 weeks are suitable for most projects. Intervals that exceed 5-6 weeks run the risk of losing power or DO membrane failure. Assign a file name for each deployment that has a three-digit year/ deployment code (ex. Jones071). Verify correct date and local standard time, parameter setup, and start logging. Be sure to activate pH mV and DO charge in Report Set-up. In Advanced Set-up, activate Auto sleep RS232 and SDI-12 functions with a 60 second interval for DO warm-up.

Sonde Preparation and Deployment. The sonde anchor should be streamline and allow the sonde to sit parallel to flow without high visibility. The anchor should allow the sensors to sit at least two inches above the substrate to avoid interactions with sediment. A 20-40 lb. section of railroad track is a good platform to use as an anchor. The sonde can be attached to the anchor with black tie-wraps and duct tape to reduce visibility. Wrap the sonde with a cloth rag before applying duct tape. Insert a business card or agency ID in waterproof sleeve into the exterior wraps of duct tape. The sonde and anchor should have low visibility once sitting on the stream bed. Orient the sonde so the sensors face downstream to avoid catching debris on the sensor guard.

Post-Deployment Procedures. Following every retrieval of sondes, QA/QC checks and post-deployment calibration must be conducted in the laboratory with the sonde acclimated to room temperature. If the sonde will be redeployed and has a 6562 DO sensor, then planning must allow for a DO membrane change. In this case, the best approach to avoid losing chemistry readings for a calendar day is to retrieve the sonde in the afternoon and conduct the precision checks, DO and turbidity post-deployment checks, and membrane change that afternoon. The remaining post-deployment calibration can be conducted the next morning before redeployment.

Download Data. Download data to YSI 650 display or PC. Briefly view field data to confirm a successful deployment and to flag compromised data or probes that have potentially failed.

DO Post-Deployment Check. The DO 6562 probe performance should be checked before cleaning or changing the membrane. Repeat the pre-deployment test for DO. This reading will serve as the post-deployment check for DO. Following the

test, the DO membrane should be changed. The following morning the DO probe should be calibrated again to set the calibration for the new membrane. For sondes with the optical DO probe, only a single calibration is needed and can be done in sequence with the other parameters.

Turbidity Post-Calibration Check. Inspect the sensor face to identify and record any evidence of biological fouling near the optics. Remove wiper and thoroughly clean all sensors. Reinstall the wiper and verify that it is parking correctly. Prior to the two-point calibration, conduct an "after cleaning" check with DDW. This value will be recorded as an indicator of sensor drift.

Post-Deployment Calibration. This step is crucial because it will provide the information needed to evaluate the quality of the logged data and serve as the pre-deployment calibration for the next deployment. Proceed with the calibration using the same protocols as during pre-deployment. Conduct additional sensor and sonde bulkhead cleaning if there is evidence that the sensors are not residue-free following the initial cleaning and two DI rinses.

Battery Changes. In most cases, batteries will be replaced with each deployment. Batteries can be redeployed if voltage is >11.5 V for deployments in warmer weather. Decisions on changing batteries should consider temperature, sampling frequency and deployment duration.

Quality Control and Assurance

There are two processes for reviewing and validating YSI multi-probe water chemistry data. The first process is to export YSI EcoWatch data to Excel and review the raw data to flag potential outliers and trim "out-of-water" data. Secondly, the pre and post-deployment calibration data are reviewed to identify if the data are within acceptable ranges of accuracy and precision. Once these protocols are completed, the data can be adjusted where needed and classified.

Data Documentation. Raw water chemistry data are saved in an annual Excel data file that is named after the river sampled and year (e.g., Parker River-2005). The following three worksheets in this file contain water chemistry data: *raw data*, *final data*, and *daily mean*. The Excel data file also contains three additional worksheets used for calibration and QA/QC review. The first form, Calibration Form 2.1 will be a printed form used in the laboratory while conducting calibrations. The user can keep a paper file for Form 2.1 or elect to enter data into the worksheet Form 2.1. Data from Form 2.1 is next transcribed to Form 2.2 which is used to review all calibrations for that season. The third form is Form 2.3, which summarizes all calibration and QA/QC procedures for the sampling season and classifies the data. Forms 2.2 and 2.3 will be maintained as electronic files.

Database Management. Data files will be saved on the common server (W:\) and back-up files will be saved on the primary server (P:\) of the Database Manager. The data classification will be updated by the QA/QC Analyst and care should be made to ensure the back-ups are consistent with the primary files. Once all possible review is completed and data has received the final classification, the annual river data file will be saved as read-only files in both the common and primary servers.

Data file Review.

Deployment Schedule. The *raw data* worksheet in the annual Excel data file should be reviewed to confirm that deployment time, retrieval time, and the sondes internal clock are consistent with Form 2.1 records. Make notes in the *raw data* worksheet to indicate the start and end of each deployment. Copy *raw data* to the worksheet named *final data* and trim data that were recorded before or after the sonde was placed in the river.

Outlier Review. Scan the data for each deployment in the *raw data* worksheet for outliers and evidence of failed probes. Make notes on obvious problems. The most common errors we have found are failing DO probes (usually membrane damage) and debris blocking the turbidity sensor. Highlight potential outliers and return to these questionable data once you have summarized the calibration. With the exception of salt wedge influence on conductivity, and debris blocking turbidity optics, most outliers are caused by probe failure and will be flagged during post-deployment calibration.

Turbidity Outlier Troubleshooting. Some data outliers are easily flagged and others are measurements that could occur naturally without clear indication that these marginal values should be censored. Debris covering the turbidity sensor will

produce a high turbidity reading near the sensor maximum (1000-1400 NTU). If a single reading in that high range occurs with base flow turbidity on either side of the measurement, this outlier should be eliminated (*Censored*) from the *final data* worksheet. The difficulty comes with random spikes over 100 NTU during rain events. Some of these higher readings could be a partially blocked sensor. It is recommended that turbidity data from all annual deployments in a river are reviewed at the same time to develop an understanding of base flow conditions. A calculation should be made of each river's mean turbidity during base flow (no precipitation) for each season. Base flow values that are 3x the value of the nearest value and ≥3 SD of the mean base flow should be classified as *Conditional* and scrutinized as potential outliers. This approach can be confounded by low turbidity water and poor resolution of precipitation data. It is acknowledged that the QA/QC response to turbidity outliers has limitations in this SOP and more experience is needed to refine appropriate validation criteria.

DO Outlier Troubleshooting. In the case of DO, a breached membrane will cause a slow, but apparent reduction of DO charge and concentration. The post-deployment calibration will confirm the membrane has failed. The QA/QC Analyst must then review the data stream to decide at what time the membrane failed and strike these data.

Calibration Review. The QA/QC Analyst should complete the Calibration Review Form 2.2 and assign a preliminary status for each parameter on the basis of the calibration results. Calibration results for each parameter in Form 2.2 will be classified as *Accept*, *Conditional*, or *Censor*. Following a review of the *raw data* worksheet, the QA/QC Analyst summarizes calibration results and other deployment checks on Form 2.3 in order to classify all river data for the season.

If a probe passed the pre-deployment and post-deployment calibration (allowable deviations for accuracy and precision) and outliers were resolved, then the data can be accepted as *Final*. Data that exceed the allowable deviations up to twice the specification should be reviewed further to confirm the raw data are within expected baseline conditions for that river. Any potential causes for reduced accuracy or precision should be noted and the data should be classified as *Conditional* (shade cells yellow in *final data*). Calibration data that exceed the allowable deviation by more than twice the specification should be evaluated as a candidate to be *Censored*. Form 2.3 should document causal factors for deviations and outliers and provide concluding comments on the decision to *Censor* the data or keep it as *Conditional*. Censored data should be shaded red in the *final data* worksheet and not transferred to the *daily mean* worksheet. Future SOP versions will include warning and control limits based on parameter deviations from seasonal mean values. Overall, with the exception of the turbidity sensor, *Censored* data will most often be associated with a failed probe. Violations of turbidity accuracy specifications are not uncommon and the turbidity measurements will have a higher proportion of outliers than other parameters.

Data file Classification. The QA/QC Analyst should review the data and classify the QA/QC review status and data status using the classes listed below. The QA/QC status classes refer to the review stage for the entire data file. The data status classes refer to the status of data under the QA/QC review. This data file classification is consistent for all four SOPs in this QAPP.

QA/QC Status

1. ***Draft.*** Data processing is in progress, and QA/QC has not been conducted.

2. ***Preliminary.*** Data processing is complete, but QA/QC is not complete. Data can be used for internal project summaries.

3. ***Complete.*** All data processing and QA/QC review is completed.

Data Status

1. ***Preliminary.*** Data have been entered from field sheets or downloaded but QA/QC review is not complete.

2. ***Censored.*** Data are eliminated because of instrument failure or QA/QC performance.

3. ***Conditional.*** Data are fully audited and QA is complete, but have deficiencies that are documented and may limit use.

4. ***Final.*** Data are fully audited, checked and acceptable.

Linear Adjustment of Data. The YSI operation manual does not offer suggestions for adjusting data following the identification of QA/QC problems. In some cases, you will not be able to identify a causal factor for a probe failing calibration or for outliers. When a successful pre-deployment calibration is followed with poor post-deployment calibration there may be evidence of an error in post-calibration procedures or steady directional drift in measurements. For example, during post-deployment calibration the turbidity sensor could measure 4.0 NTU lower than the 0.0 NTU standard and the raw data consistently has base flow values lower than expected and some negative values. In this situation, linear adjustment may be appropriate if a calibration error can be identified. These data would remain *Conditional* but could be used for daily mean data. For this SOP version, linear adjustment will only be permissible when a clearly identified calibration error influenced a probe's performance in a linear manner for an entire deployment. More review and guidance is needed on the use of linear adjustment for YSI data in future QAPP versions.

Field Precision Measurements. For QAPP Version 1.0, there will be no requirements to assess the precision of replicate measurements in the field for long-term deployments. Parameter precision will be measured with each pre-deployment and post-deployment calibration in the laboratory. This decision has been made because of the very high precision observed to date with program laboratory measurements and because sondes are programmed at 15-60 minute intervals and attached to anchors before heading out in the field. *Option:* if questions develop over the precision of field measurements, the sonde can be activated for long-term deployment after recording 2-3 replicate measures at two minute intervals at the sampling station. Another option is to record replicate measurements for two or more program sondes placed side-by-side at the sampling station before and/or after each deployment. The acceptable RPD and RSD for these replicates is $\leq 5\%$.

Single Point Measurements

The YSI sondes are also used to collect individual, single point measurements or grab samples at various river, lake and marine sampling stations. The collection of grab samples requires the user to follow all sampling and calibration protocols applicable from the YSI operations manual. The user should also follow all calibration, deployment and storage procedures from the Long-Term Deployment section of this SOP with the following single point exceptions.

Calibration.

Calibration Frequency. When possible, calibrate the sonde on the day of sampling. This is not always practical or necessary for some applications. At a minimum, calibration should be conducted on the first day of sampling during a given work week and continue during the sampling season on a weekly basis. We have calibrated YSI sondes on a daily basis for many years and found this high calibration frequency was not necessary to maintain probe performance specifications. *Option:* if post-deployment calibrations identify concerns with weekly calibrations, program participants can increase the calibration frequency. This approach has been recommended in past YSI manuals for DO measurements.

DO Sensor. Make sure the AutoSleep RS-232 function has been turned off for grab sampling. This function is found by following the sonde's Setup Menu to Advanced Menu. *Option:* YSI presently recommends conducting an on-site pre-deployment check for DO #6562 probes by wrapping the sonde in a wet towel soaked in tap water. In this condition the sonde is run for 10 minutes to confirm that the DO value is within specifications. If the reading is out of tolerance, then simply recalibrate on site. This check is an option for the #6562 probe and not needed for the optical sensor because vibrations and temperature swings can affect the Teflon membrane and cause sensor drift. This is only an option and not a recommendation because with careful treatment of the instrument, we have not experienced frequent post-calibration drift while grab sampling with weekly calibrations.

Temperature Check. The accuracy check on the temperature sensor should be conducted at least monthly during laboratory bucket precision checks. Weekly checks are not necessary.

Sample Collection.

Sample Location. A sample location should be designated and recorded in GPS at each river station, and consistently used. The location should have an identifiable landmark and receive mixed

flow from the stream channel. Most sampling under this SOP will be in the spring. It is possible that the sampling location within a river will need a slight adjustment when sampling in the summer at lower flows.

Water Column. The water column depth where measurements are recorded should be standardized for each monitoring project. Surface measurements for rivers and lakes should be recorded at a depth that exposes the sonde cable connector to air and places the probes at a depth of approximately 0.3 m. In shallow streams (<0.3 m) the sonde can be rested horizontally on the bottom when hard substrate is present or tilted at an angle with the probe guard on the bottom and the cable connector resting on the sampler's boots or a designated rock.

Acclimation Time. The acclimation time for probes to settle to accurate values is primarily dependent on temperature. To be consistent, for the first sample at a given station, allow at least 10 minutes of acclimation time for all grab measurements when water temperature ≥5 °C. Changes in water pH and DO between stations can also influence response time for those probes, especially in cold water. The acclimation time should be increased to 15 minutes for water temperature <5 °C. A 10-minute acclimation time may appear too conservative for summer sampling; however, stratification in lakes can slow probe response while changing sample depth. Additional measurements at a station (primarily water column sampling in lakes) can be taken after a 5-minute acclimation period, providing that the sonde did not pass through the thermocline to reach the next sample. In all cases, monitor the display to determine when the probes have stabilized. Sondes that rested in a warm car for a long drive may need a few extra minutes to acclimate in cold water.

Multiple Samples. For QA/QC purposes, replicate measurements will be made to assess sampling precision. All river station measurements should be made in triplicate at two minute intervals. For lakes, where multiple water column measurements are made, a duplicate measurement is sufficient to check field sampling precision. The duplicate should be made of a surface sample at a two minute interval only for one station per lake.

Quality Assurance. The review of sonde calibrations and precision checks will follow the same process as for unattended logging. Deviations from accuracy specifications and parameter RPDs >5% will result in classifying sensor data as *Conditional*. The warning limit for turbidity RPD is set higher at 25% because of the common occurrence of deviations from equilibrium for low turbidity concentrations in a flowing stream.

Data Recording. Field data should be recorded to the YSI 650 display to a file designated for the given river and year. The file can be downloaded at the end of the season to Ecowatch. It is an option for each participant and user to also transcribe the data to a field sampling sheet (not supplied in QAPP) as a safeguard against data loss. With experience and careful attention, we have found that paper records as back-ups have not been necessary. Secondly, the advent of replicate sampling to assess precision created an onerous transcription effort.

Data Documentation. Raw data should be transcribed or downloaded to an annual Excel data file that contains data for all river stations. Grab sample calibrations are documented on Form 2.4 and QA/QC is evaluated by transcribing weekly calibration data to Form 2.2. Form 2.3 will not be necessary for grab sample data.

Database Management. Use the same procedures as with Long-Term Deployments.

Storage and Transportation

During the sampling season, instruments should be transported and stored in a carrying case. The case should be cushioned to prevent movement of the sonde during transport. The calibration cup should cover the probes with a third volume of tap water. After each use, the sonde (with calibration cup on) and display unit should be allowed to air-dry. After each marine deployment, all components should be cleaned with tap water. The carrying case should be set to dry out on a weekly basis.

Maintenance

With-in Season. It should not typically be necessary to remove probes from sonde during with -in season maintenance for freshwater deployments. A test-tube brush or toothbrush is suitable for dislodging sediment and organic deposits. The probes can be soaked briefly in warm, soapy water or white vinegar prior to cleaning. With each cleaning between long-term deployments inspect conductivity ports, DO anodes, and the glass bubble

of pH probe and refer to YSI operational manual for specific cleaning instructions. The turbidity wiper pad should be removed and cleaned (or replaced) following each long-term deployment.

Sonde, Probe, and Cable Connectors. Be careful not to drop the disconnected cable connectors into dirt or hard surfaces. With careful use, the cables will perform well for many years. The problems associated with small amounts of contamination on the connectors are easily avoided. Very high or low readings can often be associated with dirt or water on the connections. If this occurs, the connectors can be cleaned with warm soapy water applied from a squirt bottle. Following cleaning, dry the connectors thoroughly with air pressure or a hair dryer.

Annual Maintenance. At the end of the sampling season, remove all probes and clean o-rings. Probes should be cleaned and stored dry, except the DO probe should be fitted with a new membrane and stored in tap water, and the pH probe is stored in 2 M KCL. The pH probes can be stored for a month or less in tap water, but never in distilled water and should not be allowed to dry out. Replace any o-ring that shows the slightest sign of wear. When probes are re-installed for the start of the sampling season, lubricate all o-rings with a light application of silicon grease.

Technical Notes

YSI Calibration Tips. Mike Lizotte of YSI produced a document in 2009 with up-to-date tips on calibrating YSI 6-Series sondes (Lizotte 2009). This document is a valuable supplement to YSI manuals. Users of this QAPP should obtain a copy and become familiar with the tips. It is expected that Mike will upgrade the document periodically and make it available soon on the YSI website. The document provides valuable support for troubleshooting under this QAPP.

Distilled Water. Distilled water can be used for standard preparations if the laboratory distiller provides high grade distilled deionized water. The distiller and deionizer should be listed in the SOP with specifications for resistivity and annual maintenance. If high grade DDW can be achieved and maintained, then the DDW can be used to prepare pH buffers, 0.0 NTU standard, and to prepare turbidity standard dilutions. The conductivity of DDW water should be recorded during each laboratory precision check.

Anniquam River Marine Fisheries Station Distiller and Deionizer. At the *MarineFisheries* Gloucester facility we have Barnstead Fistreem Glass Still (Model# A56220-857) purchased in 1999. The deionizer is a Barnstead Mega-Pure Automatic Deionizer (Model# D440046) purchased in 1996. The deionizer has been preset to a resistivity of 50K ohm-cm with a signal light prompt to indicate that resistivity is greater than 50K ohm-cm and the water is properly deionized. Both systems are serviced annually by a commercial vendor and as of 2009 have not failed to meet factory specifications.

Specific Conductivity. The conductivity accuracy specifications stated for YSI probes (2002 and 2005 manuals) are ± 0.5% plus 0.001 mS/cm of reading when properly calibrated. Our experience has found this probe to be one of the most consistent and durable YSI probes; however, a quality control problem exists since slight deviations from low concentration standard solutions will exceed the accuracy level. Post-deployment calibration violations are more likely for freshwater applications than marine. These specifications have changed over time, as evident from the 1997 YSI 6820 manual that reported a sensor accuracy of ±5% from standard solutions. For this project, we will adopt a ±2% deviation from standard solutions as acceptable accuracy for *Final Data*. Deviations from ±2-5% will result in a *Conditional* classification for data, and data that exceed ±5% will be *Censored* unless a calibration error provides justification for linear adjustment.

The remaining three categories in Technical Notes are not SOP recommendations. They are references on evolving alternative methods that can be applied by project partners in a troubleshooting mode or considered for future QAPP versions.

Dissolved Oxygen. The YSI protocols for calibrating DO probe #6562 have been tuned over the years with increasing experience. Recent suggestions allow for pre and post-deployment calibration of the DO probe while the sonde is in logging mode with a sample frequency of 15 minutes or less. This option is an acceptable alternative to the protocols in the **Long Term Deployments** section under DO Calibration (6562 sensor). To calibrate while logging, allow the

sonde to record data for 2 hours before deployment with the calibration cup set for DO calibration. After 2 hours, calibrate the DO probe. With this process, you will have water-saturated air data recorded. The post-deployment check is done in the same manner while the sonde is still logging. This approach provides a longer record of data to evaluate DO sensor drift which may benefit some applications. Recent YSI suggestions have also reduced the waiting time from 3 to 6 hours following membrane change to calibrate. In most cases, this will still equate to waiting overnight after the membrane change.

Air-Saturated Water. Recently YSI recommended using air-saturated water as an alternative method for calibrating DO sensors. Allow a 5 g bucket of water to aerate for at least 1 hour with an aquarium air pump and air stone. Place the sonde with sensor guard attached into the bucket to acclimate for 10-minutes and calibrate to 100% saturation. The air-saturated water calibration requires more time than the water-saturated air calibration but is reported to create less opportunity for error. Both methods can produce the same results if done correctly. This method is not recommended as the primary approach for DO calibration for this SOP due to of concerns over consistency among program participants that could result in calibration saturation values that are under or over 100%.

Zero DO Standard. *Mass*DEP recommends the application of zero DO standard checks when low DO values are expected in the field (*Mass*DEP 2005). *Mass*DEP began using the zero DO standard prepared with DI water and sodium sulfate in 2006.

Low Ionic Standard. *Mass*DEP recommends a protocol for using a quality control standard for pH and conductivity when sampling low ionic waters (*Mass*DEP 2005). A low-ionic phosphate standard stock solution can be prepared to confirm sensor performance.

Literature Cited

Lizotte, M. 2009. Calibration tips for YSI 6-Series Sondes & Sensors. January 2009, Yellow Springs Incorporated, Yellow Springs, Ohio.

*Mass*DEP. 2005. Standard Operating Procedures for Water Quality Multi-probes. CN: 004.21. Mass. Dept. of Environ. Protection, Div. of Watershed Mgt., Worcester, MA.

YSI. 2006. 6-Series Multiparameter Water Quality Sondes User Manual. Revision D, October 2006, Yellow Springs Incorporated, Yellow Springs, Ohio.

YSI 6-Series Sonde -- Calibration Form 2.1

STEP 1: PRE-CLEANING CHECK

LOCATION:
SONDE ID:
DATE: TIME: INITIALS:

Parameter	Pre-Cal Reading	Post-Cal Reading
DO Sat%		
DO Charge (6562 only)		
Turbidity (0.0 NTU)		

Time (in): _____
Time (out): _____
Clock Check: _____
(correct/DST)

STEP 2: PRE (or POST)-DEPLOYMENT CALIBRATION

DATE: TIME:

Parameter	Pre-Cal Reading	Standard Used	Post-Cal Reading	RPD (1)	RPD (2)	RPD (%)
Temperature (ºC)						
Sp. Cond. (mS/cm)						
DO Sat% (new mem.)						
pH (1)						
pH (2)						
Turb. (1) (NTU)						
Turb. (2) (NTU)						
Depth (m)						
pH mV (for pH7)		**Battery Charge (V)**	**pre/post change:**			
DO Charge (new mem.)			**Wiper Service:**			
mmHg			**New Filename:**			

NOTES:

STEP 1: PRE-CLEANING CHECK

LOCATION:
SONDE ID:
DATE: TIME: INITIALS:

Parameter	Pre-Cal Reading	Post-Cal Reading
DO Sat%		
DO Charge (6562 only)		
Turbidity (0.0 NTU)		

Time (in): _____
Time (out): _____
Clock Check: _____
(correct?/DST)

STEP 2: POST-DEPLOYMENT CALIBRATION

DATE: TIME:

Parameter	Pre-Cal Reading	Standard Used	Post-Cal Reading	RPD (1)	RPD (2)	RPD (%)
Temperature (ºC)						
Sp. Cond. (mS/cm)						
DO Sat% (new mem.)						
pH (1)						
pH (2)						
Turb. (1) (NTU)						
Turb. (2) (NTU)						
Depth (m)						
pH mV (for pH7)		**Battery Charge (V)**	**pre/post change:**			
DO Charge (new mem.)			**Wiper Service:**			
mmHg			**New Filename:**			

NOTES:

MASSACHUSETTS DIVISION OF MARINE FISHERIES

YSI 6920 Deployment: **River:** **File Type:** Calibration Form 2.2
Year: **Data Status:**
QA/QC Analyst:
Sonde ID:
QA Status:

Pre-Deployment

Parameter	Units	SOP Specs. (±)	Pre-Calibration	Standard	Post-Calibration	Notes
(1) **Date**						
Temp.	*(ºC)*	0.3				
DO	*(% sat.)*	5%				
Sp. Cond.	*(mS/cm)*	2%				
pH (1)		0.2				
pH (2)		0.2				
Turbidity (1)	*(NTU)*	2.0 or 5%				
Turbidity (2)	*(NTU)*	2.0 or 5%				
7.0 pH mV		(-30 to +30)				
DO charge		<75				

Summary:

Post-Calibration

Parameter	Units	SOP Specs. (±)	Pre-Calibration	Standard	Post-Calibration	Deviation from Spec.	Allowable Deviation (±)	Status
(1) **Date**								
Temp.	*(ºC)*	0.3						*(Accept/Cond./Reject)*
DO (pre)	*(% sat.)*	5%						
DO (post)	*(% sat.)*	5%						
Sp. Cond.	*(mS/cm)*	2%						
pH (1)		0.2						
pH (2)		0.2						
Turbidity (1)	*(NTU)*	2.0 or 5%						
Turbidity (2)	*(NTU)*	2.0 or 5%						
7.0 pH mV		(-30 to +30)						
DO charge		<75						

Summary:

Notes: 1.) Add extra tables for each post-calibration.
2.) Remove "DO (post)" and "DO charge" rows for calibrations with optical DO probe (no probe membrane).
3.) Classify each parameter as *Accept, Conditional* or *Reject*. This is a preliminary status for each parameter based only on the calibration results.

MASSACHUSETTS DIVISION OF MARINE FISHERIES

YSI 6920 Deployment: **River:** **File Type:** QA/QC Form 2.3

Dates: **Sonde ID:**

QA/QC Analyst:

Deployment History: **QA Status:**

Maintenance:

Review Note:

PRE-DEPLOYMENT

Calibration

	Status	Notes
WaterTemp.		
DO		
Sp. Cond.		
pH (1)		
pH (2)		
Turb. (1)		
Turb. (2)		
7.0 pH mv		
DO charge		
Battery *(V)*		
Internal Clock		

Summary:

POST-DEPLOYMENT

Time and Battery Check

	Calibration No. 1	Calibration No. 2	Calibration No. 3
Deployment Time:			
Retrieval Time:			
Internal Clock Time:			
Battery (pre/post V):			
Notes:			

QA Review

	Pre-Deployment Calibration			Calibration No. 1			Calibration No. 2		
	Accuracy Spec. Dev.	***Precision*** RPD (%)	***Data*** **Status**	***Accuracy*** Spec. Dev.	***Precision*** RPD (%)	***Data*** **Status**	***Accuracy*** Spec. Dev.	***Precision*** RPD (%)	***Data*** **Status**
Temp. *(ºC)*									
DO *(% sat.)*									
Sp. Cond. *(mS/cm)*									
pH (1)									
pH (2)									
Turb. (1) *(NTU)*									
Turb. (2) *(NTU)*									
7.0 pH mv									
DO charge									

Outlier Review			
Data Adjustments			

Data Completeness:

Summary:

YSI 6-Series Sonde -- Calibration Form 2.4

DATE: **TIME:** **INITIALS:**

PROJECT: **QA STATUS:**

				Relative Percent Difference		
Variable	**Pre-Cal Reading**	**Standard Used**	**Post-Cal Reading**	**RPD (1)**	**RPD (2)**	**RPD (%)**
Temperature (ºC)			NA			
Sp. Cond. (mS/cm)						
DO Sat.%						
pH (1)						
pH (2)						
Turb. (1) (NTU)						
Turb. (2) (NTU)						
pH mV (for pH7)						
DO Charge						
mmHg:						

Sonde ID:

DO Membrane Change? (Y/N):

NOTES:

DATE: **TIME:** **INITIALS:**

PROJECT: **QA STATUS:**

				Relative Percent Difference		
Variable	**Pre-Cal Reading**	**Standard Used**	**Post-Cal Reading**	**RPD (1)**	**RPD (2)**	**RPD (%)**
Temperature (ºC)			NA			
Sp. Cond. (mS/cm)						
DO Sat.%						
pH (1)						
pH (2)						
Turb. (1) (NTU)						
Turb. (2) (NTU)						
pH mV (for pH7)						
DO Charge						
mmHg:						

Sonde ID:

DO Membrane Change? (Y/N):

NOTES:

Section 3.0 Rainbow Smelt Spawning Habitat Assessment

Scope and Application

Rainbow smelt (*Osmerus mordax*) are an anadromous fish native to the Atlantic coast of North America. Smelt are an important forage fish for many species of wildlife and supported traditional commercial and recreational fisheries in New England that have declined in recent decades. The declining fisheries trend and reduced presence in Southern New England prompted the National Marine Fisheries Service (NMFS) to designate smelt a "Species of Concern" in 2004 under their review process for the Endangered Species Act. Currently, the states of Maine, Massachusetts, and New Hampshire are working cooperatively under a grant from the NMFS Protected Species Division to develop a conservation plan to prevent further reductions in New England smelt populations.

Smelt spawning in New England occurs during the spring freshet in March-June. Spawning habitat is typically found at gravel and cobble riffles upstream of the tidal interface. Smelt deposit demersal, adhesive eggs that incubate in spawning riffles for 1-3 weeks, depending on water temperature. The reproductive strategy of depositing an adhesive egg for a long incubation is susceptible to reduced success if the spawning habitat is degraded. Land use and hydrology alterations in urban areas have left streams vulnerable to impacts from nutrient enrichment, reduced, shading and riparian buffer, and non-point source pollutants. Watershed alterations in Massachusetts have contributed to spawning habitat degradation from physical alterations, reduced flow, sedimentation, eutrophication, and acidification (Chase 2006). Eutrophication may be the primary source of degradation in urban watersheds by causing excessive periphyton growth in spawning riffles. These concerns have also been raised for smelt runs in tributaries to the St. Lawrence River in less urban regions of Quebec (Lapierre et al. 1999). Field observations in Massachusetts indicate that high periphyton growth at spawning riffles causes reduced smelt egg survival (Chase 2006). However, relationships between water quality, smelt spawning habitat degradation, and smelt populations have not been assessed. More information is needed on the condition of smelt spawning habitat in New England and influences on habitat quality.

The influence of nutrient pollution on water and habitat quality in rivers and lakes is a growing concern in the United States (US EPA 1998; Mitchell et al. 2003). The trophic state of a river is influenced most by light, carbon sources, nutrients, hydrology and food web structure (Dodds 2007). Among these influences in developed watersheds, nutrient enrichment is most dependent on human activity and may be most amenable to remediation efforts. The US EPA recommends that States develop nutrient water quality criteria that can be used to protect specific designated uses of aquatic habitat under Clean Water Act (CWA) assessment and remediation processes (US EPA 2000a). This approach depends on setting criteria or reference conditions for causal and response variables that can act as thresholds for protecting designated uses. The reference conditions will represent minimally impaired water quality and are based on the lower 25^{th} percentile of a statistical distribution of causal and response variables. Section 3.0 adopts the US EPA recommended approach for developing water quality criteria for smelt spawning habitat with the goal of producing an assessment tool that can contribute to Clean Water Act processes and protect smelt spawning habitat throughout the species range. Smelt spawning habitat will be assessed with three approaches in Section 3.0: spawning habitat delineation, field measurements of water quality and primary productivity, and the application of water quality criteria.

Monitoring Objectives. The main purpose of Section 3.0 is to provide standardized protocols for delineating and assessing smelt spawning habitat and to develop habitat assessment tools within the framework of US EPA and *Mass*DEP CWA guidelines. The following objectives should improve our understanding of the negative and positive influences on water and habitat quality at smelt spawning habitat and provide valuable information for the resource management goals of protecting and restoring anadromous fish habitat and enhancing smelt populations.

1. Delineate and document river and stream locations where smelt spawning occurs.

2. Select fixed sampling stations at smelt spawning habitat where biotic and abiotic parameters related to spawning habitat will be measured. Identify water and habitat quality

deficiencies at each station using physical, chemical and biotic criteria.

3. Develop reference condition thresholds and relationships between abiotic conditions and measures of primary productivity.

4. Incorporate monitoring results into CWA processes for protecting designated habitat uses and make recommendations for improving and protecting specific habitat locations.

Reference Conditions.

Nutrients. The US EPA's Nutrient Criteria Technical Guidance Manual for rivers and streams (US EPA 2000a) recommends several statistical approaches for developing nutrient criteria for total phosphorus (TP), total nitrogen (TN) and chlorophyll *a* (chl *a*). In the absence of data on reference conditions for protecting designated uses, US EPA recommends using the 25th percentile of the distribution of measured variables from a population of rivers within a region. The 25th percentile serves as a threshold between degraded locations and minimally impacted reference locations. The US EPA has generated reference conditions using the median of the four seasonal 25th percentiles for all rivers sampled in the Northeastern Coastal Zone (Ecoregion 14, sub-region 59; US EPA 2000b). Nutrient data collected under this SOP will be compared to these thresholds during the assessment of the trophic status of each sampling station. In addition, independent reference conditions will be calculated from the 25th percentile of data collected during the smelt spawning season for TN and TP. These data will contribute to habitat assessments and the development of designated use criteria for smelt spawning habitat.

Physico-Chemical. The US EPA recommendations for nutrient criteria do not include criteria for water chemistry response variables such as dissolved oxygen and pH. Thresholds for designations of suitable spawning habitat will be adopted from *Mass*DEP's Surface Water Quality Standards (SWQS) for temperature, DO, and pH. These thresholds along with physical thresholds for spawning habitat will be refined as the smelt Species of Concern project is implemented by the ME/NH/MA partnership. All reference criteria are presented in Table 3.1.

Algal Biomass. Periphyton (also referred to as benthic algae) biomass is a useful indicator of water quality because it is sessile, fast growing and relies on the water column for uptake of nutrients and minerals. The US EPA nutrient recommendations include reference conditions for phytoplankton chl *a* but not for algal biomass in the stream bed. Although there is less guidance for algal biomass, the percentile distribution approach used for nutrients can also be applied to algal biomass. Riskin et al. (2003) used a median concentration for periphyton biomass of 21 mg/m^2 as a mesotrophic (moderately enriched) threshold for New England streams. The value was derived from a summary of published studies on nutrient and periphyton relations (Biggs 1996). The 50th percentile of algal biomass data collected under this SOP can be evaluated as the mesotrophic threshold. Furthermore, the 25th percentile can be evaluated as a threshold for reference streams and the 75th percentile can be evaluated as a threshold for impaired streams.

Hypothesis. Smelt spawning habitat monitoring in Massachusetts resulted in a hypothesis that states a primary threat to smelt populations is the degradation of spawning habitat from watershed pollution (nutrient, sediments, contaminants) and alterations (flood control and transportation structures, land development, and dams) (Chase 2006). Specific to eutrophication, it is hypothesized that elevated nutrient concentrations have degraded spawning habitats by enhancing periphyton growth and reducing the suitability of spawning substrate for egg survival.

Watershed Classification. All sampling stations are located in coastal watershed basins on the Gulf of Maine coast in the subecoregion 59 of the Northeastern Coastal Zone (US EPA 2000a). The stations should be initially classified by the following three watershed categories (US EPA (2000a).

1. Non-assigned streams (not assessed by State waterbody assessments).
2. Impacted streams (on States 303(d) list or designated as impaired in 305(b) reports).
3. Reference stream that area minimally impacted; with the following three conditions: a.) watersheds with <5% impervious surface cover; b.) watersheds with <5% agricultural use and <5% of disturbed riparian buffer; c.) watersheds with population densities <20 people per square mile.

Artificial Substrates. Artificial substrates have been used extensively in water quality monitoring to relate periphyton growth and species composition to ambient water quality, although concerns remain over the reliability of measurements (Weitzel 1979; and Lowe and Pan 1996). When using artificial substrate to collect periphyton for this application, three assumptions are made: (1) all substrates deployed have equal colonization and development of periphyton, (2) sample replicates are exposed to identical conditions, (3) changing water chemistry is the only variable influencing periphyton growth and species composition at the different sampling locations. If these conditions can be met, substrata can be sampled for indirect measures of periphyton productivity (ash-free dry weight (AFDW), biovolume, and chlorophyll) and species community. Clearly, natural variations in the conditions of water velocity, depth, shading, grazing, scouring and solar incidence can challenge these assumptions. The careful development of sampling design, site selection, and application of QA/QC procedures are essential to successfully relate periphyton sampling to water and habitat quality.

Table 3.1 Physical, Chemical, and Biotic Criteria for Smelt Spawning Habitat. The water chemistry parameters relate to Massachusetts SWQS for protecting aquatic life at Class B Inland Waters (*Mass*DEP 2007), and US EPA reference conditions for the Northeast Coastal Zone sub-Ecoregion (US EPA 2000b). Additional criteria will be developed during the application of smelt spawning habitat monitoring under Section 3.0.

Variables	**Suitable** (SWQC or BPJ)	**Minimally Impacted** (25^{th} percentile)	**Notes/Source**
CHEMICAL			
Temperature (ºC)	≤ 28.3		Maximum limit (*Mass*DEP 2007)
Temperature (ºC)	≤ 20.0		7-day mean of daily max. (*Mass*DEP 2007)
pH	≥ 6.5 to ≤ 8.3		(*Mass*DEP 2007)
DO (mg/L)	≥ 6.0		(*Mass*DEP 2007)
Turbidity (NTU)		≤ 1.7	EPA Ecoregion 14, sub-59 (US EPA 2000b)
TN (mg/L)		≤ 0.57	EPA Ecoregion 14, sub-59 (US EPA 2000b)
TP (ug/L)		≤ 23.75	EPA Ecoregion 14, sub-59 (US EPA 2000b)
PHYSICAL			
Substrate Size (Ave. mm)	>2.0		Chase (2006)
Water Velocity (Ave. m/s)	>0.3		Chase (2006)
Slope (%)	0.5 to 1.0		Chase (Pers. obsv.)
Riffle	Presence/Absence		Best Professional Judgment (BPJ)
Canopy			BPJ based on percent open canopy
BIOTIC			
Aquatic Moss	Presence/Absence		BPJ
Periphyton Biomass (g/ m^2/d)			Current project will establish thresholds
Phytoplankton Chlorophyll (ug/L)		≤ 0.44	EPA Ecoregion 14, sub-59 (US EPA 2000b)

Data Quality Objectives. Parameter-specific data quality objectives are presented in Table 3.2. For water chemistry parameters measured with YSI sondes, these objectives are provided and discussed in SOP Section 2.0 and adopted for all projects under the QAPP. The primary data quality objectives are based on accuracy and precision. Accuracy objectives are derived from the manufacturer's sensor specifications and are monitored by conducting and reviewing pre-deployment and post-deployment calibrations. The precision of sensor measurements is monitored in the field and laboratory by recording the relative percent difference (RPD) of two consecutive readings or relative standard deviation (RSD) of three or more consecutive readings.

Nutrient and periphyton biomass data objectives are specific to SOP Section 3.0. Additional details, including laboratory specifications for each parameter are provided in the QA/QC section of this SOP. In addition to specific warning limits for accuracy and precision, data quality objectives are provided for reviewing outliers in the QA/QC section. Several biotic and physical parameters listed in Table 3.1 are not included in Table 3.2 because the existing information on smelt spawning habitat is too limited for defining numeric criteria. The present application of Section 3.0 will provide more information on this topic for future QAPP versions.

Materials

Artificial Substrate. Unglazed ceramic tiles will be used as artificial substrate for periphyton collection. We have had success using the "Mayflower Red" flat quarry tile and recommend this type. The tiles are purchased as 6x6 inch squares (15x15 cm or 0.0225 m^2). When cut into

Table 3.2. Data Quality Objectives for Water Quality Monitoring under SOP Section 2.0. The values in the Accuracy column are the acceptable deviation from a certified standard or instrument. An asterisk (*) denotes "whichever is greatest" relative to the reading of calibration standards.

Analyte	Units	Resolution	Range	Accuracy (±)	Precision (RPD / RSD)	Achievable Laboratory MDL	Achievable Laboratory RDL
Temperature	ºC	0.01	-5 to 45	0.3	5%	NA	NA
DO	mg/l	0.01	0 to 50	0.5 or 5%*	5%	NA	NA
pH	SU	0.01	0 to 14	0.2	5%	NA	NA
Specific conductance	mS/cm	0.001	0 to 100	2%	5%	NA	NA
Turbidity	NTU	0.1	0 to 1000	2.0 or 5%*	25%	NA	NA
Total Nitrogen	mg/l	0.01	0 to 200	85-115% recovery of lab. fortified sample matrix	35% field 15% lab.	0.01	0.05
Total Phosphorus	ug/l	0.1	0 to 500	85-115% recovery of lab. fortified sample matrix	35% field 15% lab.	0.8	2.0
Periphyton Biomass	AFDW (g/m^2/d)	0.001	NA	0.0005 g ave. for sample blanks	35%	NA	NA

four squares, the tile area is 7.4x7.4 cm (0.00548 m^2). A copper wire ring will be attached with marine epoxy to the bottom of each tile to hold a hooked metal rod as a substrate anchor.

Drying Ovens. A laboratory drying oven capable of maintaining a constant temperature of 105 ºC is needed for drying periphyton samples and a muffle furnace capable of constant temperatures ≥500 ºC is needed to ash periphyton samples.

Analytical Balance. A high quality balance is needed to weigh AFDW samples. The balance should be readable to 0.0001 g and calibrated annually to maintain an accuracy of ±0.0005 g.

Aluminum Weigh Boats. Aluminum weigh boats should be used for holding the periphyton samples during the drying process and should be specified to tolerate temperatures >500 ºC.

Desiccator. A glass desiccator capable of holding up to 35 aluminum weight boats will be needed for holding periphyton samples prior to weighing.

Water Chemistry Equipment. A multi-probe water chemistry sonde is needed for continuous logging or grab samples at the tile stations. The sonde should be listed in Section 2.0 and meet the SOP specifications.

Water Velocity Meter. A stream flow velocity meter is needed for weekly flow and depth measurements at the tile station. The meter should operate over a velocity range of 0.1 to 3.0 m/s and have a resolution of 0.01 m/s. A meter stick is needed to measure water depth (cm).

Scraping Tool. A flexible, synthetic scraping tool should be used to remove periphyton from tiles. These tools are commonly sold for marine fiberglass application. The scraper width should cover the tile width (at least 7.4 cm). The scrapers should be purchased in bulk for all project partners, and be replaced when the blade becomes worn (maximum of 50 samples).

Smelt Egg Scoop. A stainless steel autoclave basket (approximately 12x12 cm) attached with hose clamps to a solid wood broom pole. This egg scoop is well-suited for checking gravel in riffles for the presence of smelt eggs.

Global Positional System (GPS). A hand-held, battery-operated GPS unit is needed for recording smelt spawning habitat and sampling station locations.

Delineation of Spawning Habitat

The level of effort needed for delineating smelt spawning habitat and selecting spawning habitat sampling stations will depend on existing knowledge in each region. Observations of deposited eggs formed the basis for documenting smelt spawning habitat. Smelt migrate during evening high tides to freshwater riffle habitat where they deposit demersal, adhesive eggs. In relatively large smelt runs, deposited smelt eggs are readily found at the first freshwater riffle upstream of the tidal interface. In rivers where smelt spawning habitat has been documented, additional effort on mapping spawning habitat may not be necessary and the program participant can proceed to site selection in the following section on Tile Deployment.

In rivers where information is lacking on the spatial extent of smelt spawning habitat, it is recommended that the following methods from Chase (2006) are used to confirm the presence of smelt spawning and to document spatial and temporal spawning habitat use. In the target watershed, all freshwater drainages should be surveyed for potential smelt spawning habitat. Locations that contain suitable freshwater riffles can be selected for routine monitoring. Smelt spawning habitat is defined as the river water and substrate where smelt egg deposition was observed. Potential smelt spawning habitat is defined as habitat that possessed suitable riffles to attract smelt spawning but either was not previously know to be occupied by spawning smelt or no egg deposition was observed during study monitoring. The physical and chemical conditions that provide suitable spawning habitat are not well documented. Table 3.1 contains a list of parameters that are important for the attraction of spawning adults and smelt egg survival. It is expected that the application of this SOP will contribute to better definition of the parameters in Table 3.1.

Each selected monitoring station should be visited at least twice a week for the entire duration of the smelt spawning period to inspect stream substrata for the presence of smelt eggs. Cobble

should be inspected by hand to look for smelt eggs and a smelt egg scoop can be used to inspect gravel. Egg monitoring should initially focus on the first riffle found upstream of tidal influence.

The identification of the first riffle typical requires several reconnaissance visits to the location at low and high tide stages. Once egg deposition is identified, monitoring should expand to nearby riffles until the upstream and downstream limits of egg deposition is recorded. A monitoring log should be maintained with each station visit to record qualitative observations and GPS locations on the spatial extent of spawning locations. Eggs are identified on the basis of size, oil globule, and seasonal comparison with other species (Cooper 1978; Elliot and Jimenez 1981). Depending on the smelt run size and spatial extent of spawning habitat, the delineation may require 1-3 seasons. One season of monitoring should be sufficient to allow the selection of a riffle station for habitat assessments under this SOP. Customized monitoring strategies will be needed for rivers that are not safely wadeable. Very few smelt spawning runs in Massachusetts are not wadeable. The few exceptions were monitored with additional methods such as setting ichthyoplankton nets and deploying egg collection platforms attached to anchors and buoys (Chase 2006).

Tile Deployment

Site Selection. Site selection will be critical for meaningful comparisons and will take careful consideration because of the natural variation found in riverine habitats and the common presence of tidal influence. All sampling stations should be active smelt spawning riffles that were previously identified or delineated. Channel width should be close to 20 m (± 10 m) to allow wadeable access and have similar conditions of depth (0.5 m, ± 0.3 m), water velocity (0.5 m/s, ± 0.3 m/s) and canopy (no vertical cover bank-to-bank March-April). It is recommended that all stations be located in the freshwater zone in close proximity (<0.5 km) to the freshwater/saltwater interface. However, some rivers have dams near the tidal interface that cause greater fluctuations in depth and velocity and prevent smelt from passing further upstream. To account for this, each station should be ranked as either freshwater zone (no tidal influence during spring), tidal interface (moderate changes in depth/ velocity with no salt wedge) or tidal zone (substantial changes in depth/velocity and salt wedge presence). Samples collected in freshwater zones have the highest likelihood of producing periphyton growth that can be related to environmental and water quality conditions. Samples from the tidal zone will be exposed to greater changes in physical habitat, but in some cases may represent the only viable spawning habitat in the river system and water quality will still be dominated by freshwater discharge for most of the tidal cycle. The presence of USGS stream flow gage stations and previous or ongoing water chemistry sampling elevate the value of candidate stations. Once stations have been selected, the station characteristics should be recorded in Table 3.4 at the end of this section.

Tile Sampling.

Tile Placement. Once a spawning riffle has been selected based on physical criteria, the precise placement of tiles depends on finding a level surface that receives fully mixed river flow. This approach lends towards mid-channel locations and avoids the river edge. All tiles should sit level on the river bottom. It is appropriate to groom a patch of bottom with a rake to ensure the bottom is level. Tiles should be placed in two rows running parallel to flow. Adjacent tiles should not influence each other. This can be achieved with level placement and a space of 1-2 cm between tiles. The tiles should be inspected during weekly visit between deployment and retrieval, and disrupted tiles no longer suitable for sampling should be removed.

Tile Replicates. The number of tile replicates should exceed the total number of needed samples by approximately 50%. The higher number of tiles deployed than tiles needed allows the collection of a random sample and provides back-ups in case some tiles are disrupted.

Duration and Frequency. The deployment of tiles should coincide with the spawning period of smelt. Weitzel (1979) recommends two-week durations for tile deployments. We have had successful deployments for both two and three weeks. With three week deployments, the threat of scouring and grazing increases. For smelt habitat applications, two weeks is often too brief when low growth persists in early spring. For present applications, the target duration will be three weeks with the option to pull the tiles after two weeks if an impending storm threatens to scour the tiles. Four deployments should be made during the period of March through June. The onset of tile deployments

will depend on ice conditions and the spawning period of smelt in a given region. Each participant's schedule should be recorded in Table 3.5 at the end of this section.

Tile Retrieval. The tiles selected for AFDW, periphyton identification and benthic chlorophyll will be selected randomly before retrieval. Generate random numbers to match with numbers marked on the tiles and include several alternative numbers in case the selected tiles are disrupted. The tiles must be carefully removed from the substrate to avoid disruption of periphyton. In shallow or warm waters, retrieval by bare hand is the best approach. It may be necessary to use arm-length gloves in deep or cold water. Retrieve all needed tiles and place them in a transport tray with a cover to avoid sunlight. Carefully transfer periphyton from the tiles to sample containers in the field immediately.

Periphyton Sample Processing.

Ash Free Dry Weights. Five tiles will be sampled for AFDW in each river per sampling period. Tiles will be scraped in the field through a funnel into plastic storage containers with sealing lids. First, discard all periphyton from the tile edge facing the container. Next, make three uniform sweeps across the tile with the scraper, pushing periphyton from the tile surface into the container. Finally, use distilled water from a squirt bottle to rinse periphyton from scraper and funnel into the container and to clean materials between samples.

The containers will be placed on ice until processing later that day. Upon returning to the laboratory, the boats will be dried overnight at 105° C and weighed to a constant weight (weighed on three separate days with storage in desiccators). Once dry weights are measured, store samples in a freezer until ashing at a later date. Samples will be ashed for 1 hour at 500° C in a pre-heated muffle furnace and then re-wetted with distilled water and dried again at 105° C and weighed to a constant weight (APHA 1989). The analysis units will be AFDW g/m^2 and g/m^2/day. *Option:* samples can be frozen on the sample day for subsequent dry weight processing.

Periphyton Identification. One tile will be collected in each river per sample period for periphyton identification. These samples will be transferred from the tiles directly into 125 ml jars containing 90 ml of distilled water and 3 ml of "M^3" preservative (APHA 1989; see Technical Notes). Tile samples will be scraped into the jars with 10 ml of distilled water from a syringe to assist the transfer. Samples will be stored in the dark until processed for periphyton identification to the lowest possible genera. A single duplicate tile will be collected randomly per trip for QA/QC analysis.

Natural Substrate Sampling. In addition to tile sampling, periphyton will be collected from natural substrate to identify standing algal communities. Select five rocks that are representative of the riffle substrate within 10 m of the tile transect. Follow the methods of ME DEP for Natural Substrate Sampling (Danielson 2006). The rock samples will be processed the same as tile samples with the exception of using a ½ inch metal scraper and a 1 inch diameter neoprene washer to outline the scraping surface.

Periphyton Chlorophyll a (Option). Samples of benthic chlorophyll growth on tiles provide a measurement of photosynthetic periphyton and allow the estimate of an autotrophic index when related to AFDW. One tile can be collected in each river per sample period for chlorophyll *a* analysis. The sample will be scraped directly into 50 ml centrifuge tubes with chilled 90% acetone and stored in the dark on ice until filtering later that day. Filtering should occur in near-dark conditions and the filter paper should be rolled into a small glass jar, covered with tin foil, and placed in the freezer. Chlorophyll samples should be run within three weeks of freezing.

Periphyton Identification.

Microscope Analysis. Periphyton samples in 125 ml jars should be vigorously shaken and an aliquot should be drawn immediately with an eye dropper. Place a single drop of sample on a glass microscope slide and cover with slide cover. Using a research grade, light microscope, scan the viewing field with necessary magnification (10X, 20X, 40X and 100 X objective lenses) to become familiar with the taxa present. The sampler should develop an understanding of algae identification using the guides of Smith (1950), Prescott (1978) and Wehr and Sheath (2003). Begin counting diatoms and algae cells at the right middle margin of the slide cover and record by genera or taxa groups. Follow a parallel transect line across the slide until filling the targeted number of cells.

Cell Counting. Each algal filament or diatom cell is counted as one. This includes cells that are in the process of dividing and strings of colonial diatoms. This approach can be applied consistently and requires less judgment among samplers. Counting each observed cell or filament as one will under-represent filamentous algae, but the alternative of assessing biovolume is labor intensive. *Option:* more information can be gained on filamentous algae by recording average cells per filament from a sub-sample of observed filaments.

Target Number of Cell Counts. Rarefaction curves were plotted by *MarineFisheries* during pilot species identification efforts to determine an appropriate number of cell counts (Krebs 1989). The "short-count" method of Weitzal et al. (1979) was used to count 500 cells from a sample with tallies recorded at 50 cell increments. The rarefaction curves plotted from these data identify 350 as the count when 90% of all genera and groups that occur in a 500 count are present. Based on these results, we have selected 350 as the target number of cell counts.

Taxa Grouping. Most algae and many diatom specimens will be seen in sufficient detail to identify genera. In some cases, especially for diatoms in girdle view, it will not be possible to separate genera. The most common grouping will be "unidentified pennate diatom" (Chetelat et al. 1999). Secondly, colonial diatoms that can have rectangular shape in girdle view, such as *Eunotia, Fragillaria, Tabillaria and Synedra,* are often difficult to separate, particularly in degraded samples. These diatoms will be grouped as "unidentified colonial diatom". *Option:* if applicable, pennate-shaped diatoms can be further divided into two sub-groups of "Naviculoid-shaped diatom" and "girdle view diatom"

Counting with Image Analysis Pro Software. When using Image Analysis software, snap photograph frames (10X) along transect line. The selection of frames to snap should not be biased by visual observations. To avoid this bias, frames should be taken from the border of the previous frame or selected while moving the objective along the slide cover without viewing the PC monitor. The number of frames taken will depend on cell density. Count cells with the manual count feature and export data to a standard Excel file. Once reaching the target count of 350, finish counting and identifying all remaining cells in the last frame.

Counting through Microscope. If imagery software is not available, cell counting should be done through the microscope by counting all cells in the viewing field and proceeding to the next field along the transect. Care must be taken to line up viewing fields at the border of the previous field. Counts will be tallied on a laboratory sheet. Once reaching the target count of 350, finish counting and identifying all remaining cells in the last frame.

Environmental Data

Basic water chemistry, water flow, and nutrient data will be collected weekly during tile deployments. Because periphyton biomass growth will be evaluated in terms of weight/day, the data among deployments will be most comparable if the same day of the week is selected for sampling throughout the season. The sampling schedule for a three-week tile deployment would result in measurements on the day of tile deployment, the day of tile retrieval and twice during the two weeks between these events. Table 3.5 provides estimates of sample numbers. It is acknowledged that the QAPP would benefit from separate field SOPs for the sampling of light intensity, water flow, and nutrients. The utility of separate field SOPs will be addressed in future QAPP versions. Presently, detailed instruction on field sampling for the following environmental data will be provided during annual training sessions for all program participants.

Water Chemistry. Follow Section 2.0 procedures for calibration and QA/QC for grab samples with YSI 6-Series sondes. Measure the following parameters during each weekly visit to sample stations: water temperature (°C), DO (mg/l), DO saturation (%), specific conductivity (mS/cm), pH, and turbidity (NTU). Three measurements will be made immediately downstream of the rows of periphyton tiles (within 0.5 m) at a depth of 10-20 cm from the substrate. The 1st measurement should be made between the two-tile rows after a minimum of 10 minutes acclimation time. Dissolved oxygen and pH values should be monitored to be sure the sensors have stabilized after 10 minutes. The 2nd and 3rd measurements should be taken at two-minute intervals on both sides of a 0.5 m wide transect in which the 1st measurement marks the middle. The three measurements will be used for QA/QC evaluations and averaged for reporting.

Light Intensity. Nutrient concentrations and light availability can be the most important factors influencing primary production in shallow streams. Site selection protocols were designed to provide a standard canopy among stations. The approach supports the assumption that tiles at all stations receive similar solar incidence. However, variations in riparian tree canopy and water depth and color could cause differences in the amount of light reaching the tiles. Therefore, each station must record light intensity at the tile transect. Hobo Pendant light loggers are a suitable option for acquiring light data (lumens/m^2). Hobo Pendants should be activated at 15-minute intervals for monthly deployments and anchored to the substrate within 1 m upstream or downstream of the tile station. Periphyton will grow on the deployed Pendants and obscure the light measurements. The Pendants should be wiped clean of algae during each weekly visit. In addition, the percentage of open canopy can provide a second measure to compare light at each tile station. At each tile retrieval date, measure the left and right canopy angles with a handheld clinometer at the tile station to calculate the percentage of open canopy.

Water Velocity. A measurement of water velocity (m/s) over the tiles should be made with a professional grade current meter. Current meters are factory calibrated and cannot be readily recalibrated during field use. The current meter selected should have manufacturer's specifications for confirming acceptable operation and these steps should be stated in the following QA/QC section. Water velocity should be measured at the same sampling frequency as water chemistry and at the same location relative to tiles. Three water velocity measurements should be made 10-20 cm from the bottom along with total depth (cm) at the same tile transect used for water chemistry sampling. Do not use automatic readings for instantaneous measurements of flow; instead record average velocity over a 40 second interval.

Discharge (Option). Discharge measurements (m^3/s) are recommended when no USGS gauge station is present near the tile station. Discharge will be measured at a flow transect with uniform dimensions in close proximity to the sample station. The midsection method of the USGS (Buchanan and Somers 1969) should be followed. Under this method a minimum of 20 vertical measurements (40 seconds each) will be made along the cross-section at six-tenths of water depth. Conducting discharge measurements with each site visit will be time-consuming and may not be compatible with all river stations. An alternative method is to relate water stage height to discharge by developing a depth rating curve at a river station. The rating curve is made by taking 6-8 discharge measurements across a range of flows and recording a relative staff gage height. Once the rating curve is established, the staff gage height or depth can be recorded with each station visit and related to discharge.

Water Nutrient Measurements. Water samples for TN and TP will be collected at the same sampling frequency as flow and water chemistry. Nutrient samples will be collected at the tile deployment stations when no tidal influence is present. Collect samples in 60 ml HPDE collection bottles. The bottles should be dipped downstream of the tiles at the mid-transect point and draw water at 10-20 cm from the bottom. The bottles should be half-filled, shaken vigorously and rinsed three times before drawing a sample of 50 ml. The samples should be stored on ice in the dark until freezing later that day (<8 hours after collection).

All sample bottles and associated glassware used for nutrient sampling should be first washed with phosphorus-free detergent (ex. Liqui-Nox) and rinsed with tap water before sitting overnight in a 10% HCL bath. Upon removal from the acid bath, glassware should be rinsed five times with DDW water. *Option*-- the collection of water column chlorophyll *a* would be a valuable addition to nutrient sampling. Chlorophyll *a* samples will require shorter holding times and specific handing procedures. If Chlorophyll *a* is collected, the sampling specifications must be outlined in an appendix to Section 3.0.

Nutrient Analytical Procedures.

Total Nitrogen. Total nitrogen will be analyzed under contract with the Water Quality Analysis Laboratory of the Department of Natural Resources, University of New Hampshire, Durham, NH. Total nitrogen is measured by alkaline-persulfate digestion followed by colormetric analysis on a Smartchem autoanalyzer using methods from the USGS Water-Resources Investigations Report 03-4174 (USGS 2003). The WQ Analysis Laboratory does not have a holding time specification for TN because of its long-term stability when frozen. Projects should synchronize TN sample holding and

laboratory delivery with TP samples. Nutrient QA/QC is reported in the following section.

Total Phosphorus. Total phosphorus will be analyzed under contract with the Lakes Lay Monitoring Laboratory of the University of New Hampshire, Durham NH. Total phosphorus is measured using the manual ascorbic acid method (Standard Method, 4500-P.E.; APHA 1989) with a Milton Roy Spectronic spectrophotometer. The maximum holding time (collection date to laboratory analysis while frozen) for TP at the Lakes Lay Monitoring Program is 90 days.

Expression of Data Concentrations. Water chemistry data should be expressed to the decimal place indicated by the parameter resolution under Specifications in Section 2.0. Velocity and flow measurements should be expressed as 0.001 m/s and 0.001 m^3/s, respectively, or to two decimal places when using US customary units. Nutrient measurements will be expressed to the significant figures specified by laboratory method detection limits. Nutrient analyte concentrations will be reported as mg/L or ug/L. Reporting data files will contain conversion tables for uM concentrations.

USGS Discharge Data. No instream discharge measurements are needed for tile stations with nearby USGS stream flow gage stations. Discharge data can be retrieved from USGS at their website (http://waterdata.usgs.go). The daily discharge values used for analyses will be the average of all daily mean discharge measurements for each day the tiles were deployed. Water velocity must still be measured in the field because gage stations do not provide velocity data.

Weather Data. After the conclusion of the field season, average daily air temperature and total daily precipitation should be recorded from a nearby weather station reported by the NOAA's National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.htm).

Weather Classification. Sample collection dates will not be random or target designated weather. This is because weekly sampling depends on the tile deployment schedule and occurs during the specific spawning season of smelt. It is assumed that weekly measurements will capture typical weather and run-off conditions experienced during the smelt spawning season. We will characterize all sample dates by the amount of recent precipitation using criteria for dry (<0.125 in), wet, (≥ 0.125 to 2.0 in) and flood (>2.0 in) weather for intervals of both 1-day (day of sampling) and 3-days (including the day of sampling). Record the presence of rain on Form 3.1 at the time of station visits to assist subsequent adjustments for cases when rain begins after the time of sampling.

Quality Assurance and Control

Quality assurance and control protocols will be applied for each of the following data collections: basic water chemistry, water flow, water nutrients, and periphyton. The QA/QC review depends on three main components of performance criteria that target data quality indicators of accuracy and precision. The analysis of pre and post-deployment calibration data is used to evaluate accuracy, but only pertains to basic water chemistry measurements. The analysis of the similarity of replicates (laboratory, field and blanks), and outlier review will be conducted on each of the data collections outlined below.

Water Chemistry.

Basic Water Chemistry. All instrument handling, calibration, and calibration data review procedures are outlined in Section 2.0. Once the calibration analysis has been conducted, the following criteria can be applied to classify field data. When the field season is complete, RSD will be calculated for all triplicate parameter measurements. All triplicates that have a RSD ≤5% will be accepted and the triplicate average will be used for the daily parameter measurement. A seasonal mean will be calculated for each river from all parameter measurements with RSD ≤5% . A warning limit of ±3 SD from the seasonal mean will be used to flag potential outliers. All triplicates with RSD >5% will be classified as *Conditional* data and reviewed for outliers. Individual replicates should be *Censored* when they are identified graphically as outliers by exceeding the seasonal mean by 3 SD and when removed from their corresponding triplicates cause the remaining duplicates to have a RPD of ≤5%. The seasonal mean data for each river should be cumulative when multiple sampling seasons are available.

Turbidity Exception. Turbidity measurements are subject to interference from suspended objects, will show natural variation in stream flow, and base flows often have low NTU values. Minor differences of low values can cause high RSDs.

This is a function of proportional statistics and not necessarily related to precision. Therefore, turbidity quality control will follow different warning and control criteria. The warning criterion for turbidity is raised to 25% RSD. Triplicates with RSD ≥25% will be classified as *Conditional* data. Individual replicates will be *Censored* if they are identified as outliers by exceeding the seasonal mean by 3 SD and are also ±3x the closest replicate.

Temperature Exception. The same condition found for turbidity when minor differences at low values cause high RSDs also occurs for water temperature data when the temperature is close to zero. For water temperatures <0.5 °C, the RSD warning criterion of 5% will be relaxed and the replicates will be accepted if they do not vary by more than the sensor's accuracy (±0.15 °C).

Conductivity Exception. Conductivity values close to zero also exceed the 5% RSD with minor differences among replicates. When specific conductivity values are ≤0.050 mS/cm the RSD threshold is raised from 5% to 25%.

Stream Flow Data. Stream flow data collected from the three flow cells along a 0.5 m transect downstream of the tiles are not considered replicates. This is because true differences in water depth and velocity can be expected in turbulent riffles. The three measurements are taken to produce an average condition experienced by the tiles. Although the data are not replicates, the RSD should be calculated for flow and depth measurements and RSD ≥25% should trigger a review of the field data to see if a transcription error occurred or if one of the three measurements routinely had a strong negative or positive influence on the average values at a given river station. No data corrections are necessary following data review, although routinely high RSDs may be indicative of an unsuitable tile station.

Flow Meter Check. Each flow meter used should have quality control checks specified by the manufacturer to confirm suitable performance. Flow meter calibration is not an option for most meters. All meters should be cleaned with warm water after each use and allowed to air dry before storing in carrying cases. MA *MarineFisheries* primarily uses Price "bucket wheel" current meters made by Teledyne Gurley. A weekly spin test should be conducted with the time recorded on Form 3.1. For Price meters, the bucket wheel must spin freely for at least 1.75 min. If the meter fails a spin test, the meter should be disassembled, lubricated, and tested again. If it fails a second spin test, the pivot should be replaced, followed by another round of spin tests. Other types of current meters should be tested weekly according to manufacturer specifications.

Nutrients.

Field Sampling. Each program participant will collect one field duplicate for TN and TP weekly or at a rate to meet a target of 10% of the total seasonal sample number. The selection of rivers for duplicate sampling will be made randomly. Duplicates will be used only for quality control purposes and not averaged for reported values. The first sample collected will be used as the parameter measurement unless rejected by QA/QC protocols. Monthly trip blanks (N = 3) comprised of laboratory DDW water treated the same as actual samples should be processed each season by each program participant.

Total Nitrogen Laboratory Analysis. The Water Quality Analysis Laboratory at UNH uses an EPA approved QAPP to guide all aspects of their water quality analyses (UNH 2008). The TN analysis follows the methods of USGS (2003). Quality control samples from standards are run every 10-15 samples with a minimum of two per batch (typically 40-55 samples). Instrument calibrations are performed at the beginning of each batch using standards made from reagent grade chemicals. Calibration curves are generally linear and made of 4-7 points. A laboratory reagent blank, laboratory fortified blank, and laboratory duplicate are run every 10-15 samples during each batch. The USGS (2003) TN analysis reference is available at: http://nwql.usgs.gov/Public/pubs/WRIR03-4174/WRIR03-4174.pd

Total Phosphorus Laboratory Analysis. The Lakes Lay Monitoring Laboratory of the University of New Hampshire uses an EPA approved QAPP to guide all aspects of their water quality analyses (UNH 2007). Quality control samples from standards are run every 10-15 samples with a minimum of two per batch (typically 40-55 samples). Instrument calibrations are performed at the beginning of each batch using standards made from reagent grade chemicals. Calibration curves are generally linear, and made of 4-7 points. A laboratory reagent blank, laboratory fortified blank,

Table 3.3. QA/QC and Analytical Specifications for Nutrient Parameters.

Laboratory Quality Control	TOTAL NITROGEN		TOTAL PHOSPHORUS	
Units	mg/L		ug/L	
MDL	0.01 mg/L		0.8 ug/L	
RDL	0.05 mg/L		2.0 ug/L	
	(Frequency)	**(Control Limit)**	**(Frequency)**	**(Control Limit)**
Field Duplicate	1/week	<35% RPD	1/week	<35% RPD
Lab. Duplicate	1/10-15	≤15% RPD	1/10-15	≤15% RPD
Quality Control Sample	1/10-15	≤15% from control	1/10-15	≤15% from control
Lab. Reagent Blank	1/10-15	MDL	1/10-15	MDL
Lab. Fortified Blank	1/10-15	MDL	1/10-15	MDL
Lab. Fortified Sample Matrix	1/batch	<85% or >115% recovery	1/batch	<85% or >115% recovery

and laboratory duplicate are run every 10-15 samples during each batch (Table 3.3). The total phosphorus SOP is located in the appendix of the Newfound Lake Watershed Assessment at the following website: http://des.nh.gov/organization/divisions/water/wmb/was/qapp/documents/newfound_appendices.pd .

Nutrient Quality Control Acceptance Limits. A seasonal mean for all rivers will be calculated from duplicate parameter measurements with RSD <35%. Field nutrient duplicates with a RPD <35% and both measurements <2 SD from the season parameter mean (SPM) will be accepted. A higher warning limit of 50% will be used for low nutrient concentrations (≤ 10MDL). Low concentrations duplicates with an RPD <50% and with both measurements <2 SD from the SPM will be accepted. For duplicates that exceed the warning limit with one replicate >2 SD from the SPM, the duplicate <2 SD from the SPM will be used for the parameter measurement. Field duplicates with an RPD of ≥35% will be evaluated for handling errors and graphically to identify outliers. If no problems are identified and both duplicates are <3 SD from the SPM, the duplicates will be accepted as *Conditional* data. All values ≥3 SD from the SPM will be identified as outliers. All information on outliers will be evaluated and documented for final classification.

Periphyton Biomass.

Tile Rejection. Some randomly selected tiles may be disrupted and should not be used to process samples. This can happen from river flow shifting tiles, debris scraping the tile surface, high flows causing scouring, relatively high invertebrate grazing, and mishandling during retrieval. The sampler should anticipate these occurrences and look for these negative biases. All project samplers will receive field training for tile sampling that includes examples of disrupted tiles. With evidence of these biases, the tile should be rejected from sampling and substituted with a tile randomly selected prior to the trip as an alternative.

AFDW Adjustments. Organic materials other than periphyton can settle on the tile causing a positive bias to AFDW. Non-organic materials are not a concern since they are deducted from dry weights during AFDW processing. Adhesive smelt eggs and larval insects have been observed to settle on tiles and positively increase periphyton biomass estimates. Low numbers of smelt eggs and insect larvae should be removed with fine forceps from the sample before the first drying cycle. Large numbers of eggs or insects are more problematic and must be deducted from the sample weight if a suitable alternative tile is not available. Egg and insect weights can be measured by running subsamples of these organic materials through the

AFDW process. Random samples of at least 10 eggs or larvae should be placed in four subsample weigh boats and included in a batch run of AFDW samples. From the subsamples, a mean weight per egg or larva should be calculated and used to deduct weight from AFDW samples that were run without removing large numbers of eggs or larvae.

Weigh Boat Blanks. Four aluminum weigh boats should be run as blanks with each batch of AFDW samples. A negligible reduction in boat weight (0.0005 g) was recorded during one trial during *MarineFisheries* pilot efforts.

Periphyton Acceptance Limits. Large variation among periphyton replicates is expected and may represent fine-scale differences in natural controls on periphyton growth (Weitzel et al. 1979; APHA 1989; Morin and Catteneo 1992; and Lowe and Pan 1996). A warning limit of 35% RSD is set for AFDW replicates. Replicates with ≥35% RSD should be scrutinized for individual samples that may have been disrupted during the collection or drying process. Field notes and all drying weights should be evaluated. Replicates with ≥35% RSD with no evidence of disruption or outliers should be classified as *Conditional*. All samples that exceed seasonal mean of all periphyton replicates by ≥3 SD will be classified as outliers. The outliers should be evaluated graphically and by reviewing the field and laboratory data sheets. Marginal outliers with no evidence of handling disruption can be accepted as *Conditional* data and all others should be *Censored.*

Periphyton Identification. Quality control measures will be conducted to evaluate the precision of periphyton species identification among tile samples and within-sample jars. Data from each sample will be recorded by cell counts and relative percent abundance by genera or taxa group. The Bray-Curtis diversity index and Pinkham-Pearson coefficient of similarity (Weitzel et al. 1979) will be calculated for each sample to evaluate the similarity of samples. Each program participant will select weekly random tiles for duplicate periphyton identification or at a rate to meet a duplicate target of 10% of the total seasonal sample number. Periphyton identification will be done on single aliquots from the duplicate samples and a RPD of <35% for each index will be accepted. If either RPD is ≥35%, a third replicate should be identified. All triplicate samples with RSD of <35% will be accepted and all samples with an RSD ≥35% will be classified as *Conditional* data and reviewed by QA/QC Analyst for taxonomic errors. *Option:* precision among samplers can be assessed by drawing random triplicate samples from 10% of sample jars. Two samplers will identify periphyton from the same triplicate sample. Combined RSDs of <35% will be accepted for triplicate samples. Combined samples or individual sample RSDs ≥35% will be classified as *Conditional* data and trigger a review by the QA/QC Analyst for taxonomic errors.

Reference Conditions and Habitat Assessment.

Percentile Distribution. Smelt spawning stations are sampled during the spawning period in March-May. A median value for water chemistry and nutrient parameters should be calculated for each river for each sampling season. The reference condition for the ME/NH/MA smelt Species of Concern project will be calculated by grouping all median values from rivers in the three states and calculating the 25th percentile from this distribution. The data should also be summarized for each river annually by the following statistics: minimum, maximum, mean, standard error, and 25th, 50th, and 75th percentile.

Habitat Assessment. The spawning habitat station in each river will be classified as *Suitable* or *Impaired* based on the performance specification in the Table 3.1. The sources of these designations will be *Mass*DEP Surface Water Quality Criteria (temp., DO, and pH), US EPA's nutrient recommendations for Sub-Region 59 (TN, TP, turbidity and chlorophyll *a*), and BPJ for the physical habitat characteristics. For this SOP version, *Mass*DEP's *Suitable* designation will have equal standing as US EPA's *Minimally Impacted* criteria. The BPJ designations will utilize all available observations and data to assess a classification of *Suitable* or *Impaired* for the physical variables. Any classifications of *Impaired* will result in the documentation of the river reach where spawning habitat is present as *Impaired* with a list of the impaired variables (ex. the smelt spawning habitat in the Stony River is *Impaired* due to pH and DO criteria violations).

Data Management.

Chain of Custody. The Field Coordinator will be responsible for collection and processing of nutrient samples from the field to freezer storage at UNH, and will maintain a sample list (Form 3.2) that

includes date of collection and date of analysis and will serve as a chain of custody form. Samples will be placed in zip-lock bags and in coolers with ice and driven to the contract laboratory.

Data Documentation. Specific data forms will be used for each data collection task. Water chemistry and flow data will be recorded on Form 3.1 manually in the field or downloaded directly to an annual water chemistry Excel data file, depending on the data logging capabilities of field instruments. Nutrient data will be received from the analytical laboratory on Form 3.2 as an electronic file and downloaded to an annual nutrient Excel data file. Field notes on tile collections will be recorded on Form 3.3. Periphyton biomass (AFDW) data will be manually entered to Form 3.4 and transcribed to an annual periphyton biomass Excel data file. Periphyton identification data will be entered directly into a periphyton identification Excel data file. It is recommended that each sampling trip is assigned a common trip label that accounts for state, year and sampling trip (Ex. MA08-01). The sampling trip label will have a two -letter river code and a 1-3 letter code for sample type (ex. MA08-01-FR-TN). A separate column will record the type of sample (sample =1, duplicate = 2, triplicate = 3, blank = B). All quality assurance and control review will be conducted within the individual annual Excel files. When data have been classified and accepted by the QA/QC Analyst the annual files will be combined to a single Excel or Access database. The final database will only contain accepted data for use in subsequent analyses (no *Censored*, replicate, blank, or spike data).

Database Management. Data files will be saved on the common server (W:\) and back-up files will be saved on primary server (P:\) of the Database Manager. The data classification will be updated by the QA/QC Analyst and care should be made to ensure the back-ups are consistent with the primary files. Once all possible review is completed and data has received the *Final* classification, the annual data file will be saved as read-only files in both the primary and common server.

Data file Classification. The QA/QC Analyst should review the data and classify the QA/QC review status and data status using the classes listed below. The QA/QC status classes refer to the review stage for the entire data file. The data status classes refer to the status of data under the QA/QC review. This data file classification is consistent for all four SOPs in this QAPP.

QA/QC Status

1. ***Draft.*** Data processing is in progress, and QA/QC has not been conducted.

2. ***Preliminary.*** Data processing is complete, but QA/QC is not complete. Data can be used for internal project summaries.

3. ***Complete.*** All data processing and QA/QC review is completed.

Data Status

1. ***Preliminary.*** Data have been entered from field sheets or downloaded but QA/QC review is not complete.

2. ***Censored.*** Data are eliminated because of instrument failure or QA/QC performance.

3. ***Conditional.*** Data are fully audited and QA is complete, but have deficiencies that are documented and may limit use.

4. ***Final.*** Data are fully audited, checked and acceptable.

Technical Notes

The first four technical notes are not recommendations for optional SOP methods. The topics presented are commonly acknowledged limitations related to periphyton sampling that should be understood by program participants for this SOP and considered for future revisions.

Filamentous Algae. Two or three-week deployments may not well represent slow-growing filamentous algae. Secondly, cell counts during periphyton identification may not capture the contribution of filamentous algae. This limitation should be acknowledged within program applications. Most MA periphyton communities appear to be diatom dominated during the spring. However, if needed, program participants should consider additional procedures to gain more information on filamentous algae (longer deployments, sample natural substrata, measure

algae biovolume, % cover or subsample cell counts of filamentous algae strands) for future projects.

Tile Growth vs. Natural Substrate. Tile growth is beneficial in providing productivity estimates that can help characterize the status of eutrophication in rivers. However, the periphyton growth on tiles will represent first-growth, colonizing cells and may not depict all species that influence smelt egg survival. Similar to filamentous algae, this limitation should be acknowledged within program applications. The methods of ME DEP (Danielson 2006) for sampling natural rocks in wadeable streams has been adopted as a supplement to tile sampling for this SOP. Natural rock samples provide information on the standing algae community but are not controlled samples or measures of growth rates. Future efforts should evaluate the differences in methods and sampling results from these two periphyton sample sources when this SOP is revised.

Percent Cover of Periphyton. Another alternative or supplement to tile sampling is the estimation of percent cover of periphyton on substrata. *Mass*DEP considers a percent macroalgae (ex. green filamentous algae) cover of >50% to indicate degraded habitat and organic enrichment and provide an approach for estimating percent cover in streams (Beskenis 2002). Three samples are recorded at each of three transects crossing riffle habitat. *Mass*DEP is currently developing draft nutrient criteria for streams for aesthetics and aquatic life use using biological indicators, such as benthic algal biomass and % cover of macroalgae.

Species Identification. A large number of methods have been used to identify and enumerate periphyton taxa. Cell counts can easily be applied and provide information on relative percent abundance and dominance. Cell counts alone can over-estimate detrital diatoms and under-estimate the contribution of filamentous algae. Diatom treatments and biovolume estimates are options to improve data quality, but have not been selected because our desired level of taxonomic resolution does not justify the added cost and labor

M^3 Preservative. Add 5 g potassium iodide, 50 ml glacial acetic acid and 250 ml formalin and bring to 1 liter with distilled water. The recommended dose for algal preservation is 2 ml of M^3 per 100 ml of sample. We will use 3 ml of M^3 per sample jar to ensure that samples from tiles with high growth are well preserved. This preservative should be dispensed in a well-ventilated area and kept in laboratory storage designated for acids and preservatives. Dilutions of 3 ml per 100 ml of sample can be discarded down laboratory sink drains.

Table 3.4. Smelt sampling stations for tile deployment in Massachusetts, 2009.

River	Landmark	Town	Latitude	Longitude
Mill River	Route 1	Newbury	42º 44.63	70º 53.83
North River	Howley Street	Peabody	42º 31.28	70º 55.06
Crane River	Ash Street	Danvers	42º 33.28	70º 56.14
Fore River	MBTA RR Bridge	Braintree	42º 13.29	70º 58.55
Jones River	Elm Street	Kingston	42º 59.45	70º 44.07

Table 3.5. Sampling schedule for smelt sampling stations in Massachusetts, 2009.

Date	Activity
February 23rd	**Deploy tiles, deploy YSI 6920, record water chemistry, flow, and nutrients.**
March 16th	**1st tile retrieval, deploy 2nd batch of tiles, record abiotic field data.**
April 6th	**2nd tile retrieval, deploy 3rd batch of tiles, record abiotic field data.**
April 27th	**3rd tile retrieval, deploy 4th batch of tiles, record abiotic field data.**
May 18th	**4th tile retrieval, record abiotic field data. Field study is completed.**

Table 3.6. Smelt spawning habitat sampling parameter list for Massachusetts, 2009. Based on sampling four tile deployments in five rivers during 14 weeks.

Parameter	Samples/ River/Trip	Field Samples	Field Duplicates	Blanks	Total Samples	Laboratory Analysis
AFDW	5	100		0	100	UNH
Chl *a* (tile)	0					
TN/TP	1	70	14	6	90	UNH
YSI (chem.)	1	70	140	0	210	MA DMF
Flow	1	70	140	0	210	MA DMF

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Section 4.0 River Herring Spawning and Nursery Habitat Assessment

Scope and Application

River herring is the common name used for two anadromous fish, the blueback herring (*Alosa aestivalis*) and the alewife (*Alosa pseudoharengus*) that are similar in appearance and sympatric for most of their range. River herring make spring spawning runs from marine waters into freshwater rivers, lakes and ponds where eggs are deposited and juveniles grow for typically 3-4 months before emigrating to the ocean. River herring use a wide range of habitats for spawning and juvenile rearing across their native range from South Carolina to Newfoundland (Greene et al. 2009). In New England coastal rivers, alewife spawning runs tend to target headwater lakes and ponds and blueback herring utilize main stem rivers. The spawning runs were important sources of commerce in New England coastal towns until the latter half of the 20th century, and are valued today as forage to many species of wildlife and by citizens that harvest river herring for food and bait and appreciate the spawning runs as symbols of spring and healthy rivers. River herring populations in Massachusetts have declined in recent years, prompting *MarineFisheries* to ban all harvest in 2006 and extended the ban in 2009 through 2011.

An important component of river herring population restoration is the assessment of the suitability of spawning and nursery habitat in freshwater rivers, lakes and ponds. Section 4.0 outlines the target parameters and techniques needed to make habitat assessments and to identify water quality and habitat deficiencies. In many cases it is advantageous for volunteer organizations to assist with data collection and restoration efforts. The first step is to consult with state fisheries biologists for an update on the status of river herring in a river system based on existing knowledge and previous surveys (Reback et al. 2004a-d). If additional data are needed to confirm or update habitat status, the following guidelines can be applied.

The criteria presented in Section 4.0 were selected to allow rapid assessments of water bodies to assist resource management decisions. An important secondary goal of this SOP is to develop criteria that can be incorporated into water quality standards under Section 304(a) of the Clean Water Act (CWA). The CWA is administered at the Federal level by the US EPA and in Massachusetts by *Mass*DEP and is one of the most significant regulatory processes related to aquatic restoration. Minimum water quality criteria associated with river herring life history and habitat requirements could become a valuable tool for protecting and restoring water bodies. This SOP also adopts EPA's nutrient criteria recommendations for Ecoregion 14 to assess the influence of eutrophication on water quality (US EPA 2001).

Relationships between river herring life history and habitat performance standards are not well developed. Efforts to establish water quality standards for Pacific salmon habitat had difficulty determining biotic responses to human-induced stressors with adequate reliability and precision (Bauer and Ralph 2001). Pardue (1983) developed a habitat suitability index model for river herring that depended on variables for spawning substrate, spawning water temperature, zooplankton abundance, salinity and nursery water temperature. This version of Section 4.0 will not attempt to generate a numeric habitat score such as Pardue's index. Section 4.0 will use existing data, scientific literature and field measurements to relate river herring life history to relevant water quality criteria (Mass. SWQS, 314 CMR 4.00, *Mass*DEP 2007; and US EPA 2001) and develop best professional judgment (BPJ) criteria for other important habitat influences such as passage barriers, stream flow, and spawning substrate.

Monitoring Objectives. The primary objective of Section 4.0 monitoring is to determine if water quality is suitable to support river herring egg incubation and juvenile rearing, and to relate conditions of passage impediments and flow conditions to migratory requirements.

LAKES AND PONDS

Water Quality Monitoring.

Sample Stations. A review of the Massachusetts Division of Fish and Wildlife's (*MassWildlife*) bathymetric maps can assist project planning and site selection as can regional monitoring programs such as the Cape Cod Pond and Lake Atlas (Eichner et al. 2003) and the collaborative PALS sampling program (http://www.mass.gov/dfwele/dfw/habitat/maps/ponds/pond_maps.ht), (http://www.capecodgroundwater.org/pals.htm). The

preferred format is to select a shoal station (<3 m depth), a mid-depth (3-10 m) and deep (>10 m) station on a transect line towards the center of the pond. A minimum of two sampling stations should be established in each impoundment. Small, shallow ponds (<10 acres) may have just two shoal stations to represents spawning and nursery habitat. Large impoundments (>100 acres) may require additional stations. Project resources and the size, shape and bathymetry of the waterbody will influence station selection. Shallow stations (<3 m depth) should be sampled at 0.3 m from the surface and 0.5 m from the bottom. Stations with depths of 3 to 10 m should have an additional mid-water column sample. Stations with depths >10 m should have a fourth water column sample. The additional water column samples should follow intervals of 3.0 m (3, 6, 9, 12 m) depending on water depth and be sampled consistently once established. The added measurements in deeper lakes should allow the characterization of the thermocline.

Sampling Period and Frequency. Water chemistry measurements should be made at the targeted lake or pond during the months when adult spawning and juvenile growth occurs. The period of May-September should be sampled to capture worst case water quality during the spawning and nursery season. Water quality is typically not a concern for May but it is an important month for spawning activity and passage limitations could exist. A monthly sample should be targeted for the second or third week of the month during May-September.

Water Quality Parameters. Basic water chemistry parameters will be compared to *Mass*DEP's SWQS and river herring biological requirements (see Reference Conditions) to determine if the waterbody is suitable for supporting spawning and juvenile growth. The following parameters should be recorded: water temperature, specific conductivity, pH, dissolved oxygen (DO), turbidity, depth, and secchi disc. Water chemistry sampling should follow SOP Section 2.0 for YSI sondes. If other instruments are used, differences in protocols should be documented in SOP appendices. See Lakes and Ponds (Optional) for discussion on sampling nutrients and other parameters.

Passage Impediments. River herring depend on adequate upstream passage for spring spawning runs and downstream passage for juveniles migrating to marine waters later in the season. In most MA rivers the migration path for adult river herring during their spring spawning run is documented (Reback et al. 2004a-d) and spring flows are not a limiting factor to migration success. The focus for passage assessment for a majority of projects will be the emigration of juveniles in the summer and fall. The onset of juvenile emigration is usually the early summer, although juveniles will exit with much variability until late fall (Kosa and Mather 2001; Yako et al. 2002; Iafrate and Oliveria 2008). The point of spawning habitat entry/exit (outlet) should be inspected with each site visit to assess passage potential. The migration path downstream of the outlet should be reviewed (Reback et al. 2004a-d) and surveyed by foot or boat if the reach is unfamiliar to program participants. Obstructions that impede passage downstream of the outlet should be identified and added as sampling stations as necessary.

A sampling transect should be designated at the outlet (top fishway step or structure that acts as a hydraulic control). Water surface width (± 5 cm) and depth (± 1 cm) should be measured at the transect. Depth should be recorded at a minimum of three locations (25, 50 and 75% of stream width) on the transect with additional measurements every meter of channel width for wider channels (> 5 m). The exit flow and water level of the impoundment should be assessed with each visit. Discharge data from a nearby USGS streamflow gage should be recorded if available. A location should be selected next to the upstream side of the outlet to measure relative staff height (± 1 cm) from the water surface. If water flow is exiting the impoundment, measure flow depth (± 1 cm) over the control structure and minimum mid-channel water depth (± 1 cm) in the reach below the outlet. The minimum water depth recommended by *MarineFisheries* for adult river herring is 6 inches (15.2 cm). Water velocity is an important measurement for river herring passage at restrictions; however, due to limited instrument availability it is an optional feature of this SOP.

In addition to physical measurements, BPJ observations should be recorded on the potential for successful passage in Form 4.1. The Fish Passage and Stream Flow observations listed in Form 4.1 are designed to indicate if it is possible for adult river herring to safely migrate upstream to spawning habitat and juvenile river herring safely migrate downstream from nursery habitat. The BPJ

classifications are further described in this section under Assessment Criteria.

Spawning Substrate. A wide range of spawning substrate is used by river herring for depositing eggs (Pardue 1983; Bozeman and Van Den Avyle 1989; O'Connell and Angermeier 1997). Fertilized eggs are demersal and adhesive for 24 hours and will stick to any surface encountered. After 24 hours the eggs become non-adhesive and hatching typically occurs within 3-4 days. Depending on the river system, there can be spatial overlap or isolation in spawning habitat use for the two species. Generally, blueback herring spawn in swifter flow than alewife where hard bottom or larger sediments are found (Loesch and Lund 1977; Loesch 1987). Although preferences are not well documented, in New England coastal streams, alewife appear to target shallow fringes of headwater ponds where coarse sediment and gravel substrate may be more suitable substrate for egg incubation than fine sediments or dense periphyton. The percentage of substrate type should be visually estimated to the nearest 10% at each shoal water quality station. The substrate observation shall be made at the station and can extend beyond the station as needed to determine a representative percentage of bottom cover. The smelt egg scoop used in SOP 2.0 is useful for raising substrate samples from the bottom. Percentages should be assigned on Form 4.1 for the following substrate types: silt (<0.06 mm diameter), sand (0.06-2.0 mm), gravel (2-64 mm), cobble (64-256 mm), boulder (>256 mm), detritus, periphyton, aquatic moss, and vascular plants. Because of the variety of spawning substrates used by river herring and the lack of consensus in the literature over optimal habitat, no substrate criteria will be selected for this QAPP version. Observations on the presence of invasive plants and the influence of beach nourishment and streambank erosion should be recorded.

Lakes and Ponds (Optional).

Spawning Substrate. If necessary and project resources are available, quantitative data can be obtained on spawning substrate. Fifty meter transects can be set parallel to shore at shoal stations where six random, grab samples can be collected along the transect. The transect location should represent the typical substrate type along the shore next to the shoal station and will target 1-2 m of depth in most cases. A small bottom dredge should be used that collects approximately 100-200 cm^2 of substrate material. The collected sediments can be measured following Wentworth's classification of sediments (Nielson and Johnson 1983) and all substrata types can be assigned a percentage based on volumetric measurements. This includes macrophytes and periphyton identified to the lowest possible taxa and classified as native or invasive.

Velocity and Discharge Measurements. Stream flow data should be recorded if gages are located close to sampling stations in order to relate discharge to water depth. In the absence of gage stations, consideration should be given to measuring discharge at the outlet transect, or depending on available resources, recording water velocity and relative stage height. Measuring velocity at the outlet station will be useful in cases where a suspected velocity barrier exists or swift flow is present at a fishway entrance. Water velocity at outlet stations should be measured at the same transects and locations as depth measurements. The current meter should be positioned at six-tenths of the water depth. Do not use automatic readings for instantaneous measurements of flow; instead record average velocity over a 40 second interval. Discharge measurements should follow the USGS midsection method described in Buchanan and Somers (1969). See Section 3.0 for instructions and QA/QC for discharge measurements. This option is most applicable when all flows exit through a natural outlet, a single sluice or fishway and will be less feasible when flows are divided between outlets or pass over irregular spillways.

Sampling Frequency. It is acknowledged that the SOP 4.0 sampling design produces relatively low spatial and temporal coverage. If resources are available, consideration should be given to increasing the sampling frequency to two samples per month or deploying multi-probe water quality sondes to continuously log data. These instruments are costly and require intensive QA/QC review (see Section 2.0). However, extended deployments during the warmest period of summer will better characterize water quality than five grab samples. Deploying these instruments at shoal stations will also capture daily DO cycles and the influence of stormwater events. Water quality is not often limiting to river herring life history in April and October; however, these months could be sampled if more information is needed on the onset of spawning or late migration. Additional water

column depth intervals (every m) can be sampled if more information on stratification is needed.

Eutrophication. Water bodies that display evidence of eutrophication (low DO, low water clarity, and high plant growth) should be sampled for nutrient concentrations. Nutrient sampling is a high priority for this SOP, although it must be recognized that not all assessments will have funds to conduct high quality nutrient analyses. Total nitrogen and total phosphorus should be sampled at the same stations and frequency as other water chemistry parameters. If available, existing nutrient data from other projects in the watershed can be adopted to assist the habitat assessment. The preferred approach would be to sample inorganic and organic constituents of nitrogen and phosphorus at locations of stream inflow and outflow and a shoal water quality station for each waterbody. These data can contribute to assessments on trophic status and nutrient loading. Refer to SOP Section 3.0 for methods and QA/QC on nutrient sampling.

Food Supply. Juvenile river herring feed on a variety of aquatic invertebrates, including copepods, dipterian midges, and cladocerns (Pardue 1983). Although food supply is important for nursery habitat, in most cases, zooplankton sampling is beyond the scope of the SOP.

Temperature Loggers. Continuous temperature loggers are a useful option in water bodies that have warm water approaching the water temperature criterion and for assessing the 7-day mean of daily maximum temperature. Temperature loggers can also provide data on fish migration influences. See SOP Section 1.0 for logger deployment instructions. Site selection in lakes and ponds will take careful consideration to account for inlets and outlets.

Rivers

A large majority of cases where spawning habitat assessments are needed will involve lentic habitat in lakes and ponds. In some Massachusetts river systems, particularly with substantial passage alterations, there appears to be little spatial segregation in spawning habitat use by the two species. However, there is a general understanding that blueback herring can use spawning habitat with stronger currents than alewives and that alewives tend to spawn in lakes and ponds (Loesch and Lund 1977; Pardue 1983; Bozeman and Van Den Avyle 1989; Collette and Klein-MacPhee 2002). Some assessments may be needed where river herring spawn in the lotic flow of river channels. The monitoring objectives to assess water quality, passage impediments, and substrate in rivers are the same as with lakes and ponds. However, sample station selection and depth measurements will differ and require a case-by-case evaluation that is supplemented by reviewing existing knowledge and data on the river. River sampling will use SOP Sections 2.0 and 3.0 for guidance and the additional methods should be described in the resulting assessment reports.

Assessment Criteria

The objective of assessing the suitability of river herring spawning and nursery habitat will be met by comparing monitoring data to quantitative criteria for water temperature, pH, and DO, secchi disc, and turbidity; and qualitative criteria on eutrophication, passage barriers, and stream flow. The assessment criteria are derived from a synthesis of the available scientific literature, *Mass*DEP's Surface Water Quality Standards (SWQS), US EPA nutrient criteria and BPJ. For most criteria, existing knowledge is insufficient to clearly establish thresholds for both blueback herring and alewife survival at all critical life stages. Such thresholds have been provided for anadromous striped bass (*Morone saxatillis*) (Hall 1991) and may be adopted in future versions of Section 4.0 as information becomes available.

Reference Conditions: for Quantitative Classifications.

Nutrients. The US EPA's Nutrient Criteria Technical Guidance Manual for Lakes and Reservoirs (US EPA 2000c) recommends several statistical approaches for developing nutrient criteria for total phosphorus (TP), total nitrogen (TN), chlorophyll *a* (chl *a*), and secchi disc. In the absence of data on minimally impacted (reference) conditions for protecting designated uses, US EPA recommends using the lower 25th percentile of the distribution of measured variables from a population of lakes and ponds within a region. The 25th percentile serves as a threshold between minimally impacted and degraded locations. The US EPA has generated reference conditions using the median of the four seasonal 25th percentiles for all lakes and ponds sampled in the Northeastern Coastal Zone (Ecoregion 14, sub-region 59; US EPA 2001). When available, nutrient data will be

compared to these thresholds (Table 4.1) to assist habitat assessments. In addition, independent reference conditions will be calculated using field data from all ponds (25th percentile) once an adequate number of Section 4.0 assessments have been conducted. These data will also contribute to the development of designated use criteria related to river herring spawning and nursery habitat.

Physico-Chemical. The US EPA recommendations for nutrient criteria do not include criteria for water chemistry response variables such as DO and pH. For this QAPP version, thresholds for habitat designations will be adopted using the scientific literature on river herring and guidelines from *Mass*DEP's SWQS on temperature, DO, and pH (Class B Warm Water Fishery). These thresholds along with other variables related to migratory, spawning, and nursery habitat will be refined in future versions as the state of knowledge on this topic improves. Reference criteria are presented in Table 4.1 and discussed in the following paragraphs.

Water Temperature. Reported critical temperatures for river herring are inconsistent and do not fully describe all early life history concerns. Optimal spawning temperatures were assumed to be 15-20 ºC for alewife and 20-24 ºC for blueback herring (Pardue 1983). Kellog (1982) reported that hatching success for alewife eggs declines sharply at 26.7-26.8 ºC and that larval and juvenile survival is supported at higher temperatures. Alewife temperature preferences have been reported as 26.3 ºC for larvae (Kellog 1982) and 19-25 °C for juveniles (Otto et al. 1976). A more recent study on the survival of embryonic alewife (24 hours post-fertilization) found maximum survival of alewife eggs occurred from 13-15 °C and that mortality increased significantly above 18 °C (O'Keefe and Skomal 2005).

The application of water temperature criteria for river herring is difficult because four life history stages of two species occur during a wide range of temperatures. For example, Kellog's (1982) optimal temperature for alewife larvae growth is >10 ºC warmer than peak spawning periods. This SOP will adopt three temperature criteria to account for different life stages and the uncertain status of the available information on this topic. The Massachusetts SWQS water temperature criterion (Class B) of ≤28.3 ºC for support aquatic life in warm water fisheries will be used for the nursery period of July-October. The cold water fishery SWQS of ≤20 ºC for the seven-day mean of daily maxima will be used for the spawning months of May and June when temperature logger data are available. Lastly, 26 ºC was identified as an upper threshold for suitable temperature ranges for alewife egg hatching (Kellog 1982) and for blueback herring prolarva (Klauda et al. 1991). Based on these scientific citations and a review by Greene et al. (2009), ≤26 ºC will be adopted as *suitable* for river herring early life history during May-June.

Water pH. The acidification of surface waters is a recognized ecological concern for aquatic resources and fish populations (Haines 1981). Environmental acidification has been linked to the elimination of anadromous populations and chronic poor recruitment of anadromous fish in North America. The disruption of ionoregulation in gill tissues is a primary cause of death related to low pH levels. Studies on blueback herring from Chesapeake Bay tributaries provide survival data that can be used to establish thresholds (Klauda and Palmer 1985; Klauda et al. 1987). Fertilized blueback eggs were more tolerant of acidity than yolk-sac larvae and had the following mortality rates during static pH treatments with no aluminum: 69% at 5.0 pH, 7% at 5.7 pH, 7% at 6.5 pH, and 6% at 7.8 pH. The same treatment for yolk-sac larvae resulted in the following mortality rates: 99% at 5.0 pH, 89% at 5.7 pH, 38% at 6.5 pH, and 16% at 7.8 pH. Mortality increased with higher concentrations of aluminum and increasing duration of exposure. The overall trend for yolk-sac larvae was rapidly improving survival at ≥6.5 pH and declining survival below 6.5 pH. The SWQS for pH in Class B waters is within the range of 6.5 – 8.3 pH. High pH values are associated with eutrophication and can be related to ammonia toxicity to aquatic life. The SWQS pH range is adopted as *suitable* for river herring spawning and nursery habitat. Values outside the range will be assessed as *impaired*.

The adverse effect on fish health of increasing hydrogen ions can be augmented by the mobilization of metal ions (Haines 1981). Increasing aluminum concentrations will increase fish egg and larvae mortality in low pH water. Klauda and Palmer (1985) also demonstrated higher tolerance of blueback eggs and larvae to episodic exposure to low pH and rapidly increasing mortality when exposure duration exceeded 24 hours. In most cases, the analysis of metals in surface waters and

continuous pH measurements will be beyond the SOP scope. In addition to taking discrete pH measurements, existing information for each waterbody should be reviewed for data trends in pH and metal ion concentrations.

Dissolved Oxygen. Dissolved oxygen concentrations in water are highly influenced by temperature and biological processes, resulting in seasonal and diurnal cycles. Eutrophied water bodies can display DO fluctuations that become a threat to aquatic organisms. Plants produce DO during daylight photosynthesis. At night, they consume DO and produce carbon dioxide. Therefore, the lowest DO occurs just before sunrise and supersaturation can occur later in the day. Critical swings in DO concentration can occur during the warmest summer days when high algal growth reduces DO at night to low levels that may remain suppressed during hazy or cloudy days. Seasonal and daily depression of DO is a major concern for degrading river herring habitat; as severe conditions can result in widespread fish mortality.

Specific tolerances of different life stages of river herring to DO concentrations are not well described. Water temperature is critically linked to the influence of DO on river herring survival. Rising temperature reduces the capability of water to maintain DO concentrations. Bozeman and Van Den Avyle (1989) reported experiments of river herring exposed to hypoxic conditions: mass mortalities of juvenile blueback herring were documented with DO at 3.6 mg/L at 27.6 °C; however, limited survival was observed with short-term exposure below 3.0 mg/L. The Massachusetts SWQS for DO is ≥5.0 mg/L for Class B waters. A habitat requirement of 5.0 mg/L was adopted for striped bass larvae and juveniles following findings that egg survival could occur with DO <5.0 mg/L; however, the incidence of deformed larvae and egg mortality increased with hatching <4.0 mg/L (Hall 1991). Given the available references, DO <5.0 mg/L will be designated as *impaired* and DO levels above will be designated as *suitable*.

Dissolved oxygen concentrations in a given waterbody can have substantial variability due to changes in temperature, precipitation and wind direction. Changes in environmental conditions can diminish the capability of monthly monitoring to assess the suitability of DO concentrations for supporting aquatic life. Another condition to consider is the effect of thermal stratification that naturally occurs in deeper lakes and ponds during the summer. Deeper lakes begin to stratify in the early summer. The upper layer (epilimnion) becomes separated from the lower layer (hypolimnion) by a thermocline often near 4-6 m. The epilimnion continues to warm as summer progresses and remains oxygenated due to surface disruption and photosynthesis. The hypolimnion becomes hypoxic or anoxic as bacteria in bottom sediments consume oxygen. This zone becomes poor habitat for fish until the stratification breaks down with increased wind in autumn. The presence of hypolimnetic anoxia is problematic for DO classifications because it is a natural and common occurrence in productive lakes and ponds.

*DO Criterion Exception. Mass*DEP provides DO guidance on designations for Aquatic Life when excursions from the criterion are infrequent or for the presence of a hypoliminion in stratified lakes. For rivers or shallow lakes DO exceedances up to 10% of the representative samples will allow a *Support* classification. The *Mass*DEP guidance for deep lakes with a hypolimnion is dependent on the surface areas of stratified lake layers. For this QAPP version, the exceedance allowance of ≤10% will be used for all DO measurements at all depths excluding the bottom measurement in stratified lakes. Hypolimnetic anoxia naturally occurs in deeper lakes and should not trigger an *impaired* classification without additional criteria violations. In assessment reports for stratified lakes, the depth of the epilimnion boundary shall be identified and the bottom DO measurements will be reported with discussion on the influences of seasonal climate variations and stratification.

Secchi Disc. Secchi disc is an easily retrieved measurement of water clarity and indicator of water quality that has been used around the world for decades. The measurement is most influenced by suspended plankton and inorganic particles. Of the parameters that presently have US EPA recommended criteria, only secchi disc is set to the 75th percentile of the data distribution. This is because secchi disc measurements increase with greater water clarity. The US EPA secchi disc criterion for subecoregion 59 is 4.9 m, representing the 75th percentile of all sampled lakes. This high water clarity is not likely for many small Massachusetts lakes and ponds during the river herring spawning and nursery season. The secchi disc criterion for subecoregion 84 (including Cape

Cod) is 2.0 m; a value that represents a more likely threshold for degraded water quality. *Mass*DEP has a SWQS threshold of 1.2 m secchi disk transparency under the designated use of Primary Contact Recreation. Until river herring assessment data can be accumulated to develop an independent reference for secchi disc, the subecoregion 84 criterion will be adopted for this SOP, and the subecoregion 59 and *Mass*DEP criteria will be used as a comparative range of water clarity.

Best Professional Judgment: for Qualitative Classifications.

Eutrophication. Eutrophication is the response to excessive nutrients that a waterbody undergoes as it moves towards a highly productive trophic state. Relationships between causal factors of eutrophication and biotic and abiotic responses are not well defined. Consequently, quantitative criteria on eutrophic thresholds are not well developed and receiving much research interest presently. A detailed analysis of the trophic state of freshwater habitats is beyond the scope of Section 4.0. Instead, river herring assessments will use the US EPA Ecoregion recommendations for TN and TP when those measurements are available and otherwise record qualitative symptoms of eutrophication using BPJ. Presently, the Massachusetts SWQS do not contain nutrient criteria, although it encourages the development of site-specific criteria.

Common symptoms of chronic nutrient enrichment include: reduced DO, reduced water clarity, and increased phytoplankton, periphyton and macroalgae growth. Seasonal hypolimnetic anoxia can enhance eutrophication as anoxic sediment can release ammonia and orthophosphate. Severe eutrophic conditions can cause fish kills and alterations in natural communities of flora and fauna. A BPJ assessment will be made with each site visit using the following indicators: high nutrients, low DO, high pH, high turbidity, low secchi disc depth, and high periphyton or macrophyte growth. Plant growth on substrata and water column will be assigned a percent coverage to the nearest 10%. Plant growth coverage of ≥50% in combination with one or more violations of quantitative criteria (high pH, low DO, low clarity) will result in an *impaired* classification. Plant growth coverage of <50 to ≥25% in combinations with at least two criteria violations will also result in an *impaired* classification for that visit. Habitat assessments that lack these violations will be classified as *suitable*. For assessments with TN and TP data, the seasonal median will be compared to US EPA eutrophication criteria. Independent of BPJ observations, an *impaired* classification will be applied if the seasonal median exceeds the Table 4.1 criteria for nutrients.

Trophic Index (Option). Water quality indices can be a useful tool for assessing the trophic status of a waterbody. Carlson's Trophic State Index (Carlson 1977) uses measures of TP, chl *a* and secchi disc to classify the trophic state of lakes and ponds. Eichner et al. (2003) recently applied Carlson's index to assess Cape Cod ponds. In lakes and ponds where data from previous or ongoing assessments are available, it is recommended that Carlson's index be generated and used to classify lakes and ponds by trophic status as adopted in US EPA (2000c)

Passage Impediments. With each visit, an assessment should be made of the condition of the spawning/nursery habitat outlet and any downstream barriers. The physical dimensions of flow over the outlet should be recorded. Field staff should classify the outlet type (dam, culvert, natural, fishway, flume, sluiceway, other) and record the presence (Yes/No) of impediments to upstream or downstream passage on Form 4.1. If "Yes is recorded, then the type of impediment should be recorded from the list below:

1. Excess vertical rise at outlet.
2. Excess water velocity at outlet.
3. High turbulence or irregular flow at outlet.
4. No flow at outlet.
5. Shallow water depth for passage (<6").
6. Debris blocking passage.
7. Beaver dam blocking passage.
8 Vegetation blocking passage.
9. Attraction flow for passage is inadequate.

These observations should be recorded on Form 4.1. The table for Fish Passage in Form 4.1 accounts for upstream (adult river herring) and downstream (passive emigration of adults and juveniles) passage. Once these observations have been recorded, BPJ should be used to assign one of the following designations for immigration and emigration for each visit: *impaired*, *suitable*, *optimal* and *unsuitable*.

The basis for *optimal* (no barriers or impediments) and *unsuitable* (passage is not

possible) classifications will be readily apparent. The separation of *impaired* and *suitable* will require professional experience with fish passage and for this QAPP version rely on determinations made by *MarineFisheries* staff. For example, the BPJ classification of *impaired* would be applied in cases where upstream migration is limited by high fishway entrance velocity or a shallow, craggy channel substrate that does not prevent passage, but causes inefficient passage and physical damage to adult herring (scale loss). The same would apply for cases when low flow and absence of plunge pool causes mortality to some but not all emigrating juveniles. For the Fish Passage classification, *MarineFisheries* staff should be providing the monthly assessments or be called in by program participants to view the impediments and provide a seasonal classification.

Stream Flow. Decreased stream flow can reduce the quality and quantity of both spawning and nursery habitat. Juvenile growth can be impaired through negative influences on food sources and mortality can increase through increased predation and entrapment in dewatered reaches during emigration. In many cases, the assessment of stream flow will be linked with passage impediments because low flow prevents passage over an obstruction. A separate criterion for stream flow is needed for cases when habitat impairment or suitability resulting from stream flow is independent of an obstruction. Additionally,

Table 4.1 Physical, Chemical and Biotic Criteria used for Reference Conditions and Best Professional Judgment Classifications at River Herring Spawning and Nursery Habitat. [The water chemistry parameters relate to Massachusetts Class B SWQS for protecting Aquatic Life (*Mass*DEP 2007), and US EPA reference conditions for the Northeast Coastal Zone sub-ecoregion 59, with the exception of subeco-region 84 (includes Cape Cod) for secchi disc (US EPA 2000c). Additional references (75th percentile), variables and criteria (*optimal, unsuitable*) may be developed following the application of projects under Section 4.0.]

Variables	**Suitable** (SWQC or BPJ)	**Minimally Impacted** (25th percentile)	**Notes/Source**
REFERENCE			
Temperature (ºC) (July-Oct.- nursery)	≤ 28.3		Maximum limit (*Mass*DEP 2007)
Temperature (ºC) (May/June spawning)	≤ 26.0		Scientific literature and BPJ
Temperature (ºC) (May/June spawning)	≤ 20.0 (7-day mean)		7-day mean of daily max. from logger data (*Mass*DEP 2007)
pH	≥ 6.5 to ≤ 8.3		(*Mass*DEP 2007)
DO (mg/L)	≥ 5.0		(*Mass*DEP 2007)
Secchi disc (m)		≤ 2.0	75th percentile; EPA Ecoregion 14, sub-84 (US EPA 2000c)
Turbidity (NTU)		≤ 1.7 (rivers only)	EPA Ecoregion 14, sub-59 (US EPA 2000b)
TN (mg/L)		≤ 0.32	EPA Ecoregion 14, sub-59 (US EPA 2000c)
TP (ug/L)		≤ 8.0	EPA Ecoregion 14, sub-59 (US EPA 2000c)
Chlorophyll a (ug/L) (Fluorometric)		≤ 4.2	EPA Ecoregion 14, sub-59 (US EPA 2000c)
QUALITATIVE			
Fish Passage	BPJ		Section 4.0
Stream Flow	BPJ		Section 4.0
Eutrophication	BPJ		Section 4.0

documented observations will be useful for cases where stream flow would be ample to support habitat requirements in the absence of an obstruction. Stream flow indicators should be recorded in Form 4.1 and BPJ should be used to assign one of the following designations for the influence of stream flow on spawning, nursery, and migratory habitat: *impaired*, *suitable*, and *unsuitable* (no flow to support passage). Higher flows that contribute to velocity barriers will not be considered *impaired;* however, the structure that causes the condition is likely to be flagged as *impaired* under Fish Passage.

Assessment Reporting. River herring spawning and nursery habitat assessments will be drafted by *MarineFisheries* staff following two seasons of monitoring. If sufficient data is collected, the waterbody will receive designations based on a comparison of the sampling results to reference condition and BPJ classifications. The assessments should be brief. For example, water bodies with 2-3 monitoring stations and one passage barrier should require only 4-5 pages for reporting. All data will be available for use by project partners. Assessments reports will be posted on the *MarineFisheries* website, http://www.mass.gov/dfwele/dmf, for any interested party to retrieve.

Classification Guidance. The following guidance shall be applied for habitat classifications. Final classifications will be assigned for each of the four reference parameters (water temp., pH, DO, and secchi disc), and three BPJ classifications (Eutrophication, Fish Passage and Stream Flow). If available, the same will apply to optional reference conditions (turbidity, chl *a*, TN, and TP). For example, a waterbody can be classified as *suitable* for DO and *impaired* for Fish Passage. *Mass*DEP allows the classification of *support* for Aquatic Life Uses when infrequent excursions occur for some parameters. In certain cases, *Mass*DEP allows 10% of the representative samples to exceed the criteria for water temperature and DO. A similar approach will be adopted for this SOP. If ≤ 10% (or ≤1 exceedance for small sample sizes, N = 5-9) of the respective samples at the primary transect stations exceed the *Mass*DEP criteria for water temperature, pH and DO a *suitable* classification will be applied. Exceedances >10% (or >1 exceedance for small sample sizes, N = 5-9) for May-September sampling will trigger an *impaired* classification. Nutrient classifications will be made strictly by comparing the parameter median value to US EPA nutrient criteria. No excursions are allowed for *Optimal* and *unsuitable* classifications, although for this QAPP version, *optimal* and *unsuitable* conditions for river herring are not well defined by existing knowledge and will only be applied for Fish Passage and Stream Flow.

Equipment List.

1. Multi-probe water quality instrument (see Section 2.0 of Standard Operating Procedure for YSI 6-Series Multi-Probe Instruments).
2. Secchi disc.
3. Measuring tape.
4. Meter stick.
5. Gravel scoop attached to broom handle or telescoping pole for sediment grab.
6. Handheld GPS unit.
7. Canoe or skiff with anchor and life vests for each passenger.
8. Water current meter: either Pygmy style meter for low flow and depth or Price style meter for flows >0.25 cfs and depths >0.5 ft.
9. Camera (all passage structures and outlets should be photographed).

Quality Control and Assurance

Quality control and assurance protocols will be applied for basic water chemistry and stream flow data collections, and if applicable, to water nutrient samples. The QA/QC review will depend on performance criteria that target indicators of accuracy and precision. The analysis of pre and post -deployment calibration data will evaluate accuracy for basic water chemistry measurements. Precision will be evaluated with the analysis of the similarity of replicates (field samples, laboratory, field and blanks) for any water chemistry collections. Each data collection will also be subject to an outlier review.

Data Quality Objectives. Data quality objectives will be specified for each water quality parameter and evaluated primarily through analysis of data accuracy and precision. Water quality data within the accuracy range specified by YSI for each parameter should be attainable with accurate and consistent calibrations. Refer to Table 2.2 of Section 2.0 for specifications on resolution, range and accuracy for YSI sonde parameters and Table 3.2 in Section 3.0 for data quality objectives for sonde parameters and nutrients. The data quality objectives should be monitored by conducting and

reviewing pre-deployment and post-deployment calibrations. The precision of sensor measurements shall be monitored in the field and during laboratory calibrations by recording the relative percent difference [RPD = (difference of two consecutive readings/average of two consecutive readings) x100]. Data quality objectives for Eutrophication (except when nutrient data are available), Stream Flow, and Fish Passage criteria will be undefined for this SOP version because these qualitative criteria are presently based on BPJ.

Water Chemistry.

Basic Water Chemistry. All instrument handling, calibration, and calibration data review procedures are outlined in Section 2.0. Only procedures specific to collecting water chemistry samples for Section 4.0 are listed here. One duplicate sample will be collected at the surface from one transect station at each waterbody during each sampling trip. The RPD will be calculated from the duplicate and will serve as the field precision measurement for that sampling trip. The sonde will be positioned at the surface (depth sensor reading approximately 0.3 m) for the duplicate sample and allowed to acclimate for 5-10 minutes. A measurement will be saved, followed by the second measurement after two minutes. The first measurement will be recorded as the sample, and second measurement will be used only for QA/QC evaluations.

All duplicates that have a RPD ≤5% will be accepted. A seasonal mean will be calculated for the daily parameter measurements with RPD ≤5%. A warning limit of ±3 SD from the seasonal mean will be used to flag potential outliers. All duplicates with RPD >5% will be classified as *Conditional* data and reviewed graphically for outliers. Outliers and replicates with that are >3 SD from the seasonal mean should be *Censored.* All calibration data should be evaluated to determine if sensor performance was responsible for the censorship of precision samples.

Turbidity Exception. Turbidity measurements are subject to interference from suspended objects and will show natural variation in stream flow. Also, base flows can have low NTU values where minor differences of low values can cause high RPDs. This is a function of proportional statistics and not necessarily related to precision. Therefore, turbidity quality control will follow different warning and control criteria. The warning criterion for turbidity is raised to 25% RPD. Duplicates with RPD >25% will be classified as *Conditional* data and reviewed as outliers. Outliers that exceed the seasonal mean by >3 SD, will be *Censored*. Individual replicates will also be *Censored* if they vary from their duplicate by 3x while exceeding the seasonal mean by >2 SD.

Depth Measurements. Depth is the only YSI parameter that can be calibrated in the field. The depth sensor can be calibrated by positioning the sonde at the water's surface and entering a calibration value of 0.0 m. Surface measurements should target 0.3 m of depth by positioning the sonde cable connector at the water's surface. Bottom measurements should be approximately 0.5 m from the bottom. Using cable tension, the user should find the bottom and record the bottom depth at each station. The sonde should next be raised up 0.5 m to avoid suspension of bottom sediments. Monitoring turbidity during the 10-minute acclimation period will confirm independence from the bottom.

Stream Flow Data. Price current meters used by *MarineFisheries* do not allow user calibration. An accuracy check shall be conducted each week to be sure the bucket wheel is operating according to manufacturer's specifications. The bucket wheel must spin freely without vibration for at least 1.75 minutes. If the current meter fails two consecutive spin checks, it should be serviced as instructed in the operation manual prior to field use. Other types of current meters used by project partners should be documented in a QAPP appendix and tested weekly according to manufacturer specifications to confirm proper performance. Similarly, precision checks are difficult for a single current meter. This is because true differences in water velocity can be expected over small spatial and temporal scales in turbulent riffles. At each flow transect station a single duplicate measurement should be made at one flow cell. All duplicates with RPD <10% will be accepted. Values that exceed 10% RPD will be classified as *Conditional* with no further action other than diligent maintenance and spin checks.

Nutrients. Nutrient sampling is an optional component of Section 4.0. It is expected that some assessments will not have the resources to sample nutrients. However, eutrophication is a substantial threat to aquatic habitats that should be evaluated when possible at watersheds where baseline information is lacking. Nutrient sampling should be

conducted at the same stations used for basic water chemistry measurements. Refer to Environmental Data in Section 3.0 for guidelines on nutrient sampling and QA/QC procedures.

Project and Data Management.

SOP Training. At the start of each waterbody assessment, the *MarineFisheries* QA/QC analyst will train project partners on all aspect of field data collection and accompany project partners on at least the first assessment trip to continue hands-on training.

Chain of Custody. In the absence of nutrient analysis at an external laboratory, all data will be recorded in the field on Form 4.1. The project manager for each assessment is responsible for maintaining a file for all field data sheets. Nutrient sampling will require a separate chain of custody form (Form 3.2).

Data Documentation. A separate Form 4.1 will be used for each sampling trip. The project manager will maintain a file for each assessment project and supervise the entry of the data into an annual Excel datafile for each location. Sampling stations should be labeled with a unique two or three letter/one number code (ex. SL-1) and the position should be recorded with GPS.

Database Management. Data files will be saved on the common server (W:\) and back-up files will be saved on primary server (P:\) of the Database Manager. The data classification will be updated by the QA/QC Analyst and care should be made to ensure the back-ups are consistent with the primary files. Once all possible review is completed and data has received a *Final* classification, the annual river datafile will be saved as read-only files in both the primary and common server.

Datafile Classification. The QA/QC Analyst should review the data and classify the QA review status and data status using the classes listed below. The QA status classes refer to the review stage for the entire datafile. The data status classes refer to the status of data under the QA review.

QA/QC Status

1. ***Draft.*** Data processing is in progress, and QA/QC has not been conducted.
2. ***Preliminary.*** Data processing is complete, but QA/QC is not complete. Data can be used for internal project summaries.
3. ***Complete.*** All data processing and QA/QC review is completed.

Data Status

1. ***Preliminary.*** Data have been entered from field sheets or downloaded but QA/QC review is not complete.
2. ***Censored.*** Data are eliminated because of instrument failure or QA/QC performance.
3. ***Conditional.*** Data are fully audited and QA is complete, but have deficiencies that are documented and may limit use.
4. ***Final.*** Data are fully audited, checked and acceptable.

Maintenance

Storage and Transportation. During the sampling season, instruments should be transported and stored in a carrying case. The case should be cushioned to prevent movement of the sonde during transport. The probes should be protected in the calibration cup with a third volume of tap water. After each use, the sonde (with calibration cup attached) and display unit should be allowed to air dry on the bench top. After each marine deployment, all components should be cleaned with tap water. On a weekly basis, the carrying case should be dried out and the cable should be dried out and re-coiled. Cables should be carefully hand-coiled to loops no smaller than 1 ft diameter to reduce memory and the potential for kinking.

With-in Season. It should not typically be necessary to remove probes from sonde during with -in season maintenance for freshwater deployments. A test-tube brush or toothbrush is suitable for dislodging sediment and organic deposits. The probes can be soaked briefly in warm, soapy water prior to cleaning. With each cleaning between long -term deployments inspect conductivity ports, DO anodes, and the glass bubble of pH probe and refer to YSI operational manual for specific cleaning instructions. Wiper pads should be removed and cleaned (or replaced) following each long-term

deployment. The membrane for DO sensor #6562 should be inspected at each weekly calibration to ensure it has not been worn or breached and should be replaced routinely every 3-4 weeks.

Annual Maintenance. At the end of the sampling season, remove all probes and clean o-rings. Probes should be cleaned and stored dry, except the DO probes should be stored in tap water, and the pH probe stored in 2 M KCL. The pH probes can be stored for a month or less in tap water, but never in distilled water and should not be allowed to dry out. When probes are re-installed for the start of the sampling season, replace o-rings if needed and lubricate all o-rings with a light application of silicon grease.

Technical Notes

Secchi Disc. Secchi disc depth is an easily measured parameter that has been used for decades around the world as a measure of water clarity and a relative indicator of waterbody health. The depth of secchi disc measurements can provide information on light attenuation, suspended particles, and plankton production. When possible, secchi disc depth should be recorded on the leeward and shady side of the boat or platform used by field staff. It is recognized that there will be occasions when it is not possible to record the measurement out of direct sunlight. These measurements can have increased visibility over a cloud cover or shaded condition. For these situations there is not much that can be done other than make a note on the conditions. The measurement recorded will be the average of the ascending and descending depths at which the disc cannot be seen. Because of varying eyesight among users, the same user should take all secchi disc measurements on a given sample trip, and if possible, for the entire season.

Dissolved Oxygen. The users of this QAPP should be aware that DO concentrations in water can vary dramatically throughout the day due to diurnal dynamics involving photosynthesis, respiration and temperature changes. Monthly grab samples taken at different times of the day can lead to biased average DO values for a waterbody. Continuous measurements are the only means to fully characterize DO trends throughout the warm months of the assessment period. It is recognized that continuous measurements will not be possible for most projects. Consideration should be given to deploying continuous water chemistry loggers in water bodies where grab samples identify DO concerns but result in marginal designations. Another DO topic for consideration is the use of profile sampling at each meter interval of depth to gain better resolution of water column stratification. This sampling approach is time consuming and won't be compatible with the present SOP 4.0 sampling design at lakes and ponds. Profile sampling should be considered for specific applications that have few sampling stations and for future versions of this QAPP.

Water pH. Water pH is a measure of hydrogen ion concentration in water as an indicator of acidity. The negative log of hydrogen ion concentrations are reported as standard units (SU). Water pH at 7.0 is neutral, while values below 7.0 are acidic and values above 7.0 are basic. The pH of rainwater when at equilibrium with carbon dioxide is typically 5.65. Natural buffering in waterbodies tends to raise pH above the acidity contributed from rainfall. Aquatic plants take up carbon dioxide and hydrogen ions during photosynthesis. This process increases pH values in ponds, particularly in ponds with elevated productivity.

Global Positioning Systems Data. Projects should only use GPS units that report on the accuracy of measurements and should document the spatial accuracy when data are saved. DMF staff presently use a Garmin GPSmap76 recording decimal degrees under datum NAD83.

Environmental Data. Daily and monthly precipitation and monthly average air temperature should be recorded during the assessment period from a nearby weather station accepted by the NOAA's National Climatic Data Center, http://www.ncdc.noaa.gov/oa/ncdc.htm. Monthly NCDC data during assessments should be compared to long-term station averages and departure of normal for precipitation and temperature in the assessment report.

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River Herring Habitat Assessment: Field Data Sheet (Form 4.1)

Location: **Organization:**

Date: **Field Crew:**

STATION

Name	Latitude	Longitude	Type	Max. Depth (m)	Notes

EQUIPMENT

Name	Type	Calibration (Y/N)	Calibration (Date)	Notes

WATER CHEMISTRY

Station	Time	Depth (M)	Water Temp. (^{o}C)	Water D.O. (mg/l)	Water D.O. (% sat.)	Water pH	Water Sp. Cond. (mS/cm)	Water Turbidity (NTU)	Secchi Disc (m)

OUTLET

Name	Latitude	Longitude	Type	Width (m)	Depth - 1 (cm)	Depth - 2 (cm)	Depth - 3 (cm)	Depth - 4 (cm)	Discharge (cfs)

NOTES

List of Massachusetts Division of Marine Fisheries Technical Reports (continued from inside front cover)

TR-34 Nelson, G. A. 2008. **2007 Massachusetts striped bass monitoring report**.
TR-35 Barber, J. S., K. A. Whitmore, M. Rousseau, D. M. Chosid, and R. P. Glenn. 2009. **Boston Harbor artificial reef site selection and monitoring program.**
TR-36 Nelson, G. A. 2009. **Massachusetts striped bass monitoring report for 2008**.
TR-37 Leschen, A. S., R. K. Kessler, and B. T. Estrella. 2009. **Eelgrass restoration used as construction impact mitigation in Boston Harbor, Massachusetts.**
TR-38 King, J. R., M. J. Camisa, V. M. Manfredi. 2010. **Massachusetts Division of Marine Fisheries trawl survey effort, list of species recorded, and bottom temperature trends, 1978-2007.**
TR-39 Dean, M. J. 2010. **Massachusetts lobster fishery statistics for 2006**.
TR-40 Pol, M., P. He, and P. Winger. 2010. **Proceedings of the international technical workshop on gadoid capture by pots (GACAPOT).**
TR-41 Nelson, G. A. 2010. **Massachusetts striped bass monitoring report for 2009.**