Narraguagus River Water Quality Monitoring Plan

A Guide for Coordinated Water Quality Monitoring Efforts in an Atlantic Salmon Watershed in Maine

By
Barbara S. Arter
BSA Environmental Consulting
And
Barbara Snapp, Ph. D.

January 2006

Sponsored
By The
Narraguagus River Watershed Council
Funded
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Preface

In an effort to enhance water quality monitoring (WQM) coordination among agencies and conservation organizations, the Project SHARE Research and Management Committee initiated a program whereby river-specific WQM Plans are developed for Maine rivers that currently contain Atlantic salmon populations listed in the Endangered Species Act. The Sheepscot River WQM Plan was the first plan to be developed under this initiative. It was developed between May 2003 and June 2004. The Action Items were finalized and the document signed in March 2005 (Arter, 2005).

The Narraguagus River WQM Plan is the second such plan and was produced by a workgroup comprised of representatives from both state and federal government agencies and several conservation organizations (see Acknowledgments). The purpose of this plan is to characterize current WQM activities, describe current water quality trends, identify the role of each monitoring agency, and make recommendations for future monitoring. The project was funded by the National Fish and Wildlife Foundation.

Finally special thanks to Project SHARE for hosting all of the WQM projects and several related nonpoint source pollution prevention and restoration projects on their website at http://salmonhabitat.org/projects.htm.

Narraguagus River
Water Quality Monitoring Plan

Stakeholder Agreement

The following stakeholding agencies and organizations agree to fulfill the Action Items in this plan (Table 6.1) to the best of their ability. In an effort to achieve these items, each WQM agency and organization will use this plan as a springboard for the development of agency-specific work plans that:

- incorporate the recommendations from this plan,
- coordinate WQM activities with other agencies, and
- develop new studies that are consistent with the findings of this plan.

The stakeholders also agree to meet annually to review plan progress and to update the action items. A late fall or early winter annual meeting is recommended as it will enable the workgroup to review the previous season's monitoring results and provide enough time to make changes for the following monitoring season.

George Leinbaugh, Council President
Narraguagus River Watershed Council

Scott Williams, Executive Director
Volunteer Lake Monitoring Program

Patrick C. Keliher, Executive Director
Atlantic Salmon Commission

John Kocik, Supv. Research Fishery Maine
Biologist, NOAA Fisheries Service

David Courtemanch, Division Director
Environmental Assessment, Maine
Department of Environmental Protection

Robert Batteese, Director
Maine Board of Pesticide Control

Gordon Russell, Supervisor
Maine Field Office
US Fish and Wildlife Service

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The following individuals have contributed to the development of this plan:

Marty Anderson	Great Auk Land Trust
Ernie Atkinson	Maine Atlantic Salmon Commission
Linda Bacon	Maine Department of Environmental Protection
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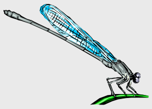
Dan Bradstreet	Town of Milbridge
Greg Burr	Maine Department of Inland Fish and Wildlife
Charles Corliss	Maine Land Use Regulation Commission
Richard Dill	Maine Atlantic Salmon Commission
Robert Dudley	US Geological Survey
Adria Elskus	US Geological Survey /University of Maine
John Fendle	Maine Department of Marine Resources
Tracey Gamache	Narraguagus River Watershed Council
John Goodwin	Maine Department of Marine Resources
Darren Hammond	Cherryfield Foods, Inc.
James Hawkes	NOAA Fisheries Service
Heather Jackson	Maine Board of Pesticide Control
Henry Jennings	Maine Board of Pesticide Control
Ken Johnson	University of Maine Senator George Mitchell Center
Dan Kircheis	NOAA Fisheries Service
John Kocik	NOAA Fisheries Service
George Leinbaugh	Narraguagus River Watershed Council
Steven Koenig	Project SHARE
Greg Mackie	Maine Atlantic Salmon Commission
Steve Mierzykowski	US Fish and Wildlife Service
Dana Murch	Maine Department of Environmental Protection
Nate Pennell	Washington County Soil and Water Conservation District
Syd Reynolds	Cherryfield Foods
Allie Rohrer	Maine Atlantic salmon Commission
Dwayne Shaw	Downeast Salmon Federation
Torrey Sheafe	Kleinschmidt Associates
Marcia Spencer-Famous	Maine Land Use Regulation Commission
Jared Stanley	Maine Department of Transportation
Greg Stewart	US Geological Survey
Joan Trial	Maine Atlantic Salmon Commission
Leon Tsomides	Maine Department of Environmental Protection
Jacob van de Sande	Downeast Salmon Federation
Mark Whiting	Maine Department of Environmental Protection
Scott Williams	Volunteer Lakes Monitoring Program

Special Thanks to Craig Snapp, volunteer for the Downeast River Land Trust, for his expertise in GIS Mapping.

List of Acronyms

Biom	Biomonitoring (MDEP)
BOD	Biological Oxygen Demand
DE	Down East
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DPS	Distinct Population Segment
EPA	Environmental Protection Agency
E. coli	*Escherichia coli*
KRIS	Klamath Resource Information System
MASC	Maine Atlantic Salmon Commission
MASTF	Maine Atlantic Salmon Task Force
MBPC	Maine Board of Pesticide Control
MDEP	Maine Department of Environmental Protection
MDEPAS	Maine Department of Environmental Protection Atlantic Salmon Rivers Program
MDMR	Maine Department of Marine Resources
MIF&W	(Maine Department) Inland Fish and Wildlife
MS	Mainstem (of the Narraguagus River)
NBCWC	Narraguagus Bay Clean Water Coalition
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source (Pollution)
NRW	Narraguagus River Watershed
NRWC	Narraguagus River Watershed Council
NRWQMP	Narraguagus River Water Quality Management Plan
OBD	Overboard Discharge (System)
PEARL	Public Educational Access to Environmental Information in Maine
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
UMSGMC	University of Maine Senator George Mitchell Center
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WB	West Branch (of the Narraguagus River)
WC	Water Chemistry
WCSWCD	Washington County Soil and Water Conservation District
WQ	Water Quality
WQM	Water Quality Monitoring
VLMP	Volunteer Lake Monitoring Program

Table of Contents



Executive Summary

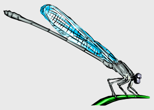
This plan was funded by the National Fish and Wildlife Foundation for the purpose of gaining a better understanding of water quality (WQ) trends in Maine's Atlantic salmon rivers and to subsequently make better decisions regarding state and federal recovery plans and activities. To that end, the goal of this plan is to improve coordination of water quality monitoring activities among governmental agencies and conservation organizations within the rivers comprising the Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon. Information for the development of this plan was gathered during nine workgroup sessions in which WQ indicators were reviewed and recommendations addressing future monitoring were developed. The plan can be used to develop agency-specific and staff workplans, develop proposals for funding, direct future research, and guide conservation and restoration projects.

The Narraguagus River Watershed (NRW) drains an area of 232 square miles and is located in eastern Hancock and Western Washington counties, Maine. Highest flows typically occur in early spring and late fall, with much lower flows in summer and early fall. Land use within the NRW is distributed into four major categories as follows: timber management landholdings (63%), primarily-residential small private landholdings (27%), blueberry cultivation landholdings (5%), and public lands and roadways (5%). In accordance with the MDEP Water Classification Program, the mainstem and its tributaries above the confluence with the West Branch are classified as Class AA or A while waters below the confluence are designated as Class B. The river has over 6,000 units of salmon rearing habitat (100 m^2 units), 29% of which are located in the reach between Stud Mill Road and the inlet of Beddington Lake. Smolt studies indicate that smolt production has declined over the past eight years, that approximately 11% of parr survive to become smolts, and that 84% of smolts go to sea at age 2 years.

The NRW is currently, or has recently been, monitored as part of 18 programs managed by at least ten different agencies/organizations. The details of each of the programs have been compiled into a spreadsheet. This file is called the Narraguagus WQM Data Index, and it can be viewed at http://www.salmonhabitat.org/projects.htm. Although the term "Water Quality Monitoring" is used loosely throughout this document, review of the various programs reveals that there are generally three types of WQ data collection occurring in the NRW: long-term monitoring, investigative studies, and one-time assessments. Five maps, which indicate the location of monitoring sites (Maps 1-4) and areas of diminished water quality (Map 5) in the watershed, can be found in Appendix A. In general, monitoring is evenly distributed throughout the watershed, but the West Branch, several tributaries, and most lakes should be considered for additional monitoring.

The plan reviews data on ten WQ indicators, identifies trends, and provides locations (reaches, streams, lakes) of documented diminished water quality and areas that require further investigation. Parameters reviewed include DO, bacteria, temperature, pH, nutrients, macroinvertebrates, pesticides, metals and other toxins, embeddedness, and streamflow. Areas in the watershed with data suggesting significant natural or anthropogenically produced diminished WQ include Schoodic, Beddington, and Spruce Mountain lakes, Schoodic, Sinclair, Bog, and Lawrence brooks, the mainstem at Cherryfield and Little Falls, and the West Branch at Sprague Falls.

Based on the review of the WQM history, data, and trends, the plan provides strategies to refocus and/or support future monitoring and restoration efforts. The plan provides 75 action items addressing administration, quality assurance and quality control, planning, experimental design and analysis, and restoration and management. The action items are prioritized, and lead and partnering agencies have been assigned to each. The action items are detailed in Table 5.1.



Chapter 1

Introduction

1.1 Project Origin and Background

Understanding water quality (WQ) status and trends in Maine's Atlantic salmon rivers is essential to the success of state and federal recovery plans and activities. The Draft Recovery Plan for the Gulf of Maine Distinct Population Segment (DPS) of Atlantic Salmon (National Oceanic and Atmospheric Administration and United States Fish and Wildlife Service, 2004) states that "there are a number of water quality issues that have the potential to adversely affect the recovery of the DPS." Specifically, chronically low pH, aluminum, pesticides, sediment, excess nutrients, and elevated water temperatures are listed as potential threats.

Currently, WQ data is collected on Maine's DPS rivers by a variety of agencies and organizations with different goals. Within any one watershed, data and information may be collected by as many as ten different agencies or organizations, including:

- Maine Department of Environmental Protection Biomonitoring Program (MDEP Biom)
- Maine Department of Environmental Protection Atlantic Salmon Rivers Program (MDEPAS)
- Maine Atlantic Salmon Commission (MASC)
- Maine Department of Marine Resources (MDMR)
- National Oceanic & Atmospheric Administration (NOAA)
- Maine Inland Fish and Wildlife (MIFW)
- US Fish &Wildlife Service (USFWS)
- University of Maine (UM)
- US Geological Survey (USGS)
- Maine Board of Pesticide Control (MBPC)
- Narraguagus River Watershed Council (NRWC)
- Volunteer Lake Monitoring Program (VLMP)

This plan is an effort to coordinate the collection, storage, review, and distribution of water quality monitoring (WQM) information and data gathered by these agencies and organizations. The plan is a tool that can help agencies and organizations determine WQ trends and conditions in a consistent, credible, and coordinated manner that may be used to further effective restoration efforts. Initiatives that may directly benefit from the information and strategies in this plan include:

- Narraguagus River Watershed Council Outreach Efforts
- Watershed Council and Project SHARE NPS Pollution Remediation Projects
- Project SHARE Restoration Committee

- Project SHARE Research Committee
- NOAA/SHARE Liming Committee
- USFWS/NOAA Maine Atlantic Salmon Recovery Plan
- Atlantic Salmon Technical Advisory Committee

1.2 Project Goal and Objectives

The Goal: Improve coordination of water quality monitoring activities among governmental agencies and conservation organizations within the rivers comprising the Maine Distinct Population Segment (DPS) of Atlantic salmon.

The Objectives:

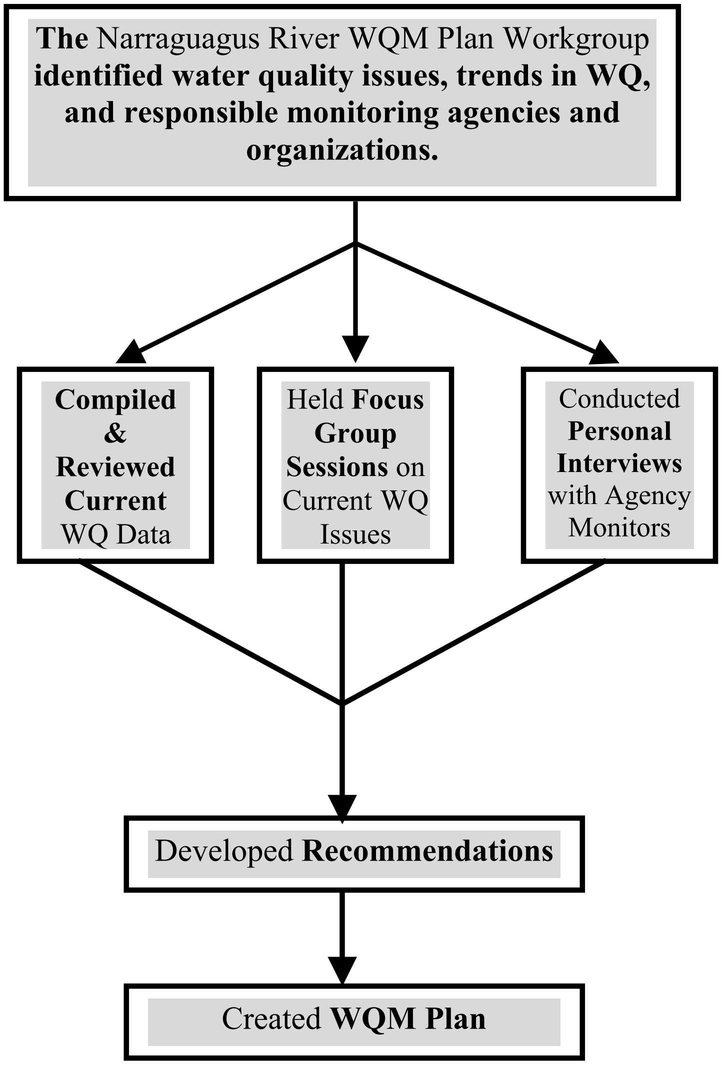
1. Summarize current monitoring efforts: collecting agency, parameters, and locations.
2. Characterize current water quality trends: DO, temperature, bacteria, pH, nutrients, toxins, and pesticides.
3. Identify gaps in current monitoring efforts and water quality information.
4. Determine the role of each monitoring agency: the type, location, and outcome of monitoring and data.
5. Identify those locations and activities that require targeted monitoring, such as priority habitat or restoration sites.
6. Make recommendations for future monitoring and data storage and dissemination.
7. Create a mechanism for agencies and organizations to agree to specific recommendations by developing a workplan that is signed by each agency.

Although this project is funded by the Maine Atlantic Salmon Conservation Fund of the National Fish and Wildlife Foundation, and the goal addresses Maine's DPS of Atlantic salmon, it should be noted that the WQ trends and standards discussed herein are relevant for all native species in Maine rivers. Overall WQ and the health of all native freshwater species should be considered when making monitoring or management decisions,

1.3 Plan Development Methodology

Information for the development of this plan was gathered between November 2004 and October 2005 using the methodology described in Figure 1.1. During that time, nine facilitated focus-group sessions were held for the purpose of discussing WQ issues, characterizing WQ trends, identifying agency roles, and establishing recommendations for future monitoring. Data from the various monitoring agencies and organizations were compiled and reviewed, and several personal interviews were conducted to clarify data results. Lastly, the workgroup reviewed each recommendation and assigned a lead agency and a priority level (Table 5.1), thus transforming the recommendations into Action Items that can become part of individual agency workplans.

Figure 1. 1. Narraguagus River WQM Plan Development Methodology



1.4 Recommendations for Use of the Plan

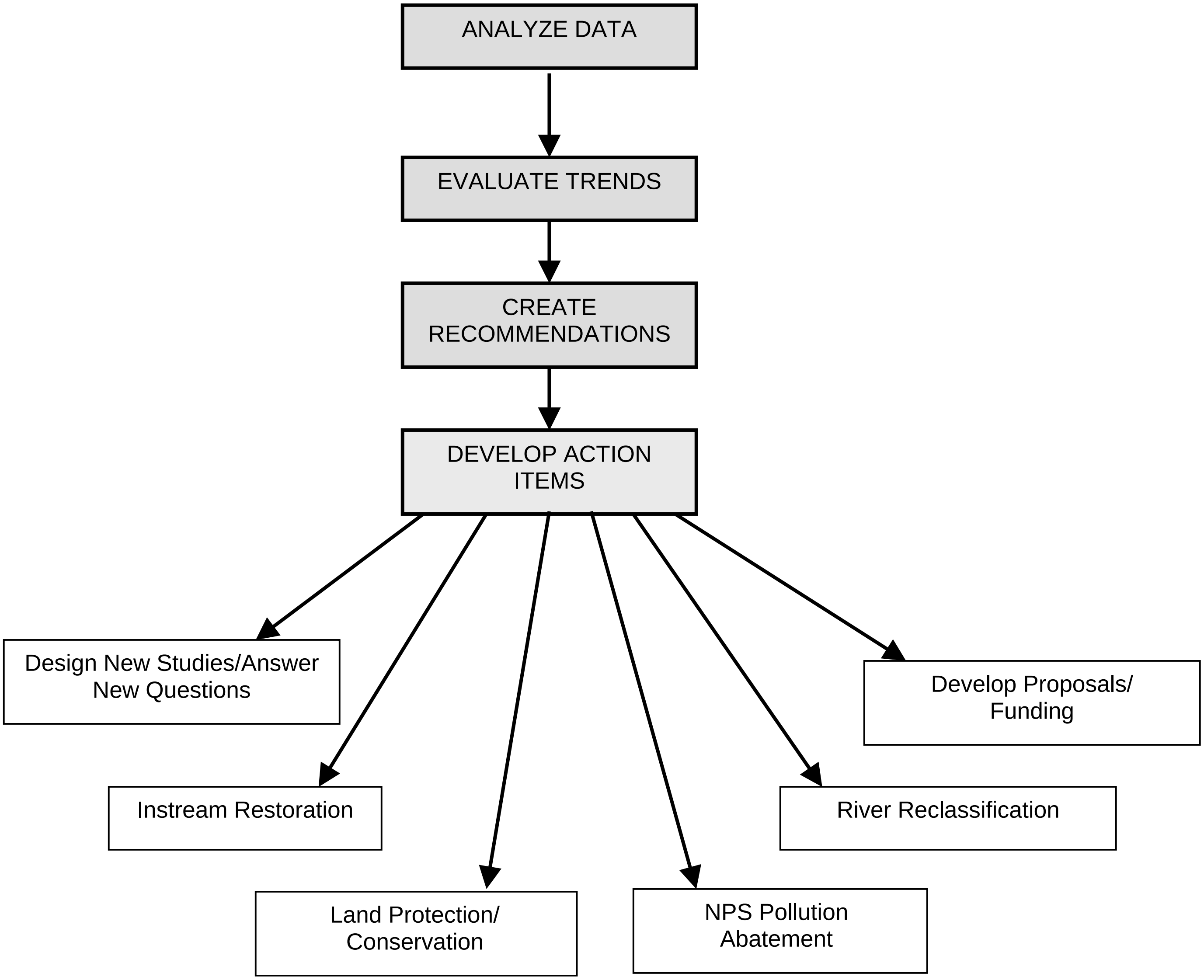
The results from a WQM program have the potential to steer, refocus, support, and justify conservation and management initiatives and efforts. The data can facilitate work between agency personnel and landowners. It can make changes in river segment classification and TMDL listings. It can direct land and water conservation, restoration, and protection efforts. Lastly, the data and information can be used to find funding for all of these efforts.

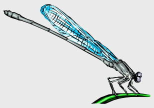
The key to effective WQM is not in the collecting, compiling, or storing of data but rather in its use. The ultimate goal in monitoring water quality is to work with other agencies to achieve management goals and ensure better water quality (Figure 1.2). The success of the strategies and recommendations in this plan will depend on all agencies' ability to improve WQM planning and to quickly analyze and utilize results and conclusions for better management decisions.

By following the recommendations in Chapter 5 of this document, WQM agencies and organizations can better coordinate their efforts. This can be done in a few simple steps:

1. This plan is designed to be used as a springboard for the development of agency-specific workplans that:
    - incorporate the agency-specific recommendations from this plan,
    - assign staff, funding, equipment, and time to specific action items
    - coordinate WQM activities with other agencies'
    - develop new studies that are consistent with the findings in this plan
2. This plan presents a large volume of water quality information and recommendations representing the diligent efforts of the Workgroup. However, the success of this Plan depends on the willingness of each agency to follow through with the recommendations and to communicate, coordinate and collaborate with each other. It may be necessary for one coordinating body, such as a subcommittee of the Maine Atlantic Salmon Technical Advisory Committee (TAC) or the Recovery Team, to take the lead and ensure that agencies are on task.
3. Information from this plan can be used to support funding proposals for future projects, such as monitoring equipment, research projects, monitoring staff, etc. Furthermore, the action items provide agency consensus support for restoration activities such as the placement of large woody debris and channel restoration.
4. Several recommendations are umbrella action items that will apply to all agencies. In this case, one agency or task force will be needed to take the lead in order to achieve the recommendation. One important example is the creation of data storage and dissemination mechanism. Several web-based options are available including KRIS and PEARL. In either case, direction will be required to meet recommendation goals.
5. All monitoring agencies and organizations should consult this plan for guidance:
    - before beginning or continuing any future monitoring effort; monitoring agencies are advised to consult this document for monitoring guidance, and
    - agencies should refer to this plan annually as a measure of outcome success.

Figure 1.2. Recommendations for Use of the NR WQM Plan.





Chapter 2
Description of Watershed

The Narraguagus River Watershed has been described in detail in previous publications. Sections 2.1 through 2.3 have been drawn primarily from Baum and Jordan (1982) and Arter (2003).

2.1 Physical Description

Location. The Narraguagus River Watershed (NRW) is located in eastern Hancock and western Washington Counties, Maine. The river originates at Eagle Lake in T34MD and flows 43 miles to head of tide in Cherryfield and an additional 5 miles to its mouth in Milbridge, Maine. The watershed covers portions of eight organized towns (Beddington, Deblois, Cherryfield, Columbia, Franklin, Milbridge, Steuben, and Eastbrook) and eight unorganized townships (T10SD, T16MD, T18MD, T22MD, T28MD, T29MD, T34MD, T35MD). Public access points along the mainstem (MS) are located at the ice-control dam in Cherryfield, the Milbridge Town Landing, and in areas where the river crosses the Stud Mill Road, Route 193, and Route 1.

Size/Stream Flow. The NRW drains an area of 232 square miles (148,480 acres) and includes 250 miles of tributaries and a lake and pond surface area of 2,167 acres in 30 bodies of water. The average precipitation is 49 inches and is somewhat evenly distributed throughout the year. The estuary portion from Cherryfield to Milbridge is relatively narrow and shallow at low tide. Tidal fluctuation in the estuary is about 11 feet and causes a reversal of river flow in this area at flood tide.

Discharge in the Narraguagus River is not regulated, but fluctuates naturally with precipitation and snowmelt. The two dams in the watershed are equipped with fishways and generally do not hinder water flow: the Stillwater Dam in Cherryfield controls ice, and the Bog Brook Dam creates an impoundment managed for aquatic wildlife. Highest flows typically occur in early spring and late fall, with much lower flows in summer and early fall. Median monthly stream flows from 1948-1992 ranged between 93.0 ft^3/s (August) to 1,000 ft^3/s (April).

Topography. The Narraguagus River flows primarily from north to south, beginning at Eagle Lake, which is 406 feet above sea level. The terrain is rugged and includes rocky hills and ridges ranging from 200 feet to 1,475 feet in elevation. Lead Mountain (1475 feet) is the most prominent peak in the western area of the watershed. Pleasant Mountain (1,374 feet) is most prominent in the east. Elevation drops to between 100 and 200 feet in the towns of Deblois and Cherryfield, where the landscape is characterized by extensive, flat “barrens” with scattered drumlins (low, rounded hills of glacial till) and kettles (depressions in glacial debris). The river and its tributaries have cut channels 10 to 20 feet deep, and sections of the river in the barrens are bordered by lowland swamps and bogs. The estuary portion is relatively narrow and shallow, with surrounding elevations generally less than 50 feet.

Soils and Vegetation. Soils of the upper portion of the watershed are generally of the Monadnock-Hermon-Dixfield Complex and are loamy, well-drained, and stony to extremely bouldery. Sections of Brayton-Colonel Association are also common and are more hydric. Bedrock is a dark gray metamorphosed shale phyllite schist. Upland soils support forests of northern hardwoods (oak, maple, birch, and beech), spruces (red, white, and black), red and white pines, balsam fir, and eastern hemlock.

The barrens consist of well-drained, sandy-gravelly soils with bedrock of biotite, biotite-muscovite granite, and a hornblende form of granite. Vegetation in the barrens includes low-bush blueberry, sweetfern, rhodora, and viburnums. Low lying areas in this section of the watershed may consist of poorly drained soils forming lowland swamps or peat bogs which support alders, sweetfern, and sphagnum moss. Flowage soils have been classified as Wonsqueak and Bucksport mucks.

2.2 Lakes and Tributaries

The NRW has over 250 miles of river and tributaries and more than 30 lakes and ponds covering 2,167 acres. The West Branch of the Narraguagus River (WB) is the main tributary. It originates in T22 at an elevation of 460 feet, drains 70 square miles, and flows 24 miles in a southeasterly direction before joining the mainstem of the river in Cherryfield. The West Branch can be accessed at several points including Sprague Falls Road in Cherryfield. Features of the major lakes are summarized below.

Table 2.1. Major lakes in the Narraguagus River Watershed

Name	Location	Public access	Use	Surface Acres
Eagle Lake	T34	Boat launch at north end	Recreation	260 acres
Beddington Lake	Beddington	Boat launch on south shore	Recreation	402 acres
Spruce Mountain Lake	Beddington	Private boat launch at north end	Recreation	448 acres
Bog Brook Flowage	Beddington/ Deblois	Boat launch at north end near dam	Recreation and wildlife management	565 acres
Schoodic Lake	Cherryfield/ Columbia/T18	Boat launch at north end in T18	Recreation and agricultural water withdrawal	389 acres
Narraguagus Lake	T16, T10, T9	Rough landing near Mill Stream	Recreation	426 acres

2.3 Land Use in the Watershed

Recreation Use of Waterbodies. Historically, the Narraguagus River and its tributaries were used extensively for lumbering. The river transported logs downstream to sawmills, and several dams were built to create sawmill ponds. The dams were removed following the demise of the lumbering efforts in the area, and recreational uses (fishing, trapping, hunting, canoeing, kayaking) now dominate public activity in the watershed. Recently, ATV use has increased to an extent that stream bank erosion, shoulder erosion, and loss of vegetation are concerns. Similar erosion concerns also relate to remaining logging roads and access roads used by blueberry growers and recreational users.

Commercial/Agricultural Use. Land use within the Narraguagus River Watershed is distributed into four major categories as follows: small private landholdings, primarily residential (27%), timber management landholdings (63%), blueberry cultivation landholdings (5%), and public lands and roadways (5%). Timber management is the primary land use in the upper regions of the watershed (T34, T35, T28, T22, T16, T10, Devereaux Township, Beddington). Blueberry barrens and peat harvesting occur in Deblois, Beddington, T16, and T22. Residential land use is concentrated around the towns of Cherryfield and Milbridge.

Wildlife Protection and Management Use. There are two wildlife management areas within the watershed. The Narraguagus Wildlife Management Area encompasses 1,450 acres of forested upland between the West Branch and the mainstem of the Narraguagus River in the town of Cherryfield. It is managed for wetland habitat, upland habitat, and public recreation, and focuses on management of small game, furbearers, migratory game, big game, and fisheries. The Bog Brook Wildlife Management Area is in the towns of Deblois and Beddington. It consists of a 924-acre impoundment with a 250-foot riparian buffer surrounding the flowage on Bog Brook approximately 0.4 mile east of its confluence with the Narraguagus River. Bog Brook is managed for its wetland habitat and warm-water fishery.

2.4 Water Classification and Attainment Status

The Narraguagus River and its tributaries are classified as Class AA, A, and B in accordance with the MDEP Water Classification Program. Table 2.2 summarizes the dissolved oxygen, bacteria, habitat and biological criteria for Class AA, A, and B waters. Table 2.3 lists the class for various reaches and tributaries in the watershed. Details regarding class water chemistry and attainment of class are discussed in Chapter 3.

Table 2.2. Water Chemistry and Biological Criteria for Class Waters

Class	DO	Bacteria	Habitat	Aquatic Life (Biological) Narrative Criteria
Class AA	as naturally occurs	as naturally occurs	free flowing and natural	No direct discharge of pollutants; as naturally occurs
Class A	7 ppm; 75% saturation	as naturally occurs	natural	as naturally occurs
Class B	7 ppm; 75% saturation	64/100 ml (g.m.*) or 427/100 ml	unimpaired	Discharges shall NOT cause adverse impact to aquatic life
Class C	5 ppm; 60% saturation	142/100 ml (g.m.*) or 949/100 ml (inst.*)	habitat for fish and other aquatic life	Discharges MAY cause some changes to aquatic life

g.m. = Geometric mean
inst = Instantaneous mean

Table 2.3. Classification of Water Bodies in the Narraguagus River Watershed

Class	Reach and Tributaries
Class AA	MS from Headwaters to WB Confluence, West Branch, Baker, Pork, Rocky, Gould, Sinclair, Schoodic, Humpback, and Shorey brooks, Little Narraguagus River, West Branch Stream (T22), Great Falls Branch below Rt. 193
Class A	All other tributaries entering the mainstem above the confluence with the West Branch (e.g., Crotch Camp, McCoy, and Bobcat brooks)
Class B	Mainstem from the confluence with the West Branch to tidewater in Cherryfield and all tributaries entering below the river confluence with the West Branch

2.5 Atlantic Salmon Habitat

All information contained in this section was obtained from the MASC Presentation to the NRWQMP Workgroup, January 2005.

For a river to serve as good salmon habitat, it must have deep holding pools for adult salmon, adequate spawning habitat, and nursery areas suitable for rearing juvenile salmon. Spawning habitat requires a substrate of loose rubble (2-10 cm in diameter) that is permeable to water flow that exchanges dissolved gasses and removes metabolic wastes from the redd. Water depth should be between 25 cm and 75 cm with water flows from 27 to 80 cm/s.

Juvenile salmon habitat is quantitatively assessed in terms of juvenile salmon rearing habitat units. One rearing habitat unit is the equivalent of 100 m^2 of habitat possessing the following features (Heggenes, 1990):

- 1-1.5% gradient,
- substrate of cobbles and small boulders (7-50 cm in diameter),
- temperatures that do not exceed 27 ^{o}C for extended periods of time and are generally less than 22 ^{o}C,
- depths that range from 20-70 cm,
- water velocities ranging from 10-60 cm/s, and
- overhead cover.

Each salmon rearing unit can support 20-50 parr through the end of the first summer post-hatch and approximately 20 parr at 15 months. Juvenile salmon tend to occupy habitats in the shallower and slower parts of the habitat range, moving to deeper and faster waters with larger cobble as they increase in size (Heggenes, 1990). Juveniles also move from shallower riffles in the summer to deeper pools or lakes in the winter to avoid exposure to anchor ice.

Historically, the Narraguagus River has averaged 4.3 parr per rearing unit, which could reasonably be expected to produce 10,000 smolts annually for the entire Narraguagus River Watershed (Baum and Jordan, 1982). However, recent data indicate that the watershed currently only produces between 1200 and 2600 smolts per year (Jim Hawks, NOAA, Personal Communication, 2005). Adult salmon returns averaged 173 between 1962 and 1974 but have dropped to less than 35 between 2000-2005.

The MASC has divided the mainstem into strata based on quantity and productivity of habitat. The most productive habitat in the Narraguagus River Watershed occurs in the upper stratum or the mainstem between Stud Mill Road in T35 to the inlet of Beddington Lake. Although containing only 29% of the total salmon habitat, this section produces 40-50% of the juvenile salmon population (based on electrofishing data) and contains more than 1,700 salmon rearing units. The quality of habitat in this reach is considered to be very good.

The reach of the mainstem from Beddington Lake Outlet to Route 193 is referred to as the middle stratum and is also considered to be very good. It contains 20% of the habitat and over 1,200 rearing units. The lower stratum from Route 193 to Cherryfield Dam is considered fair to good habitat, as is the reach below the dam and most of the tributaries.

The tributaries are considered less productive, in part due to lower summer flows and limited spawning areas and rearing areas. In addition, the West Branch, with 6% of the total habitat, has poor water chemistry due to peat bog drainage upstream. Baker and Shorey brooks have the most promising habitat in terms of juvenile salmon rearing capacity and are rated as very good.

Table 2.4. Distribution of salmon rearing habitat in Narraguagus River Watershed.

River segment	Rearing habitat ($100\ m^2$ units)	Percent of total habitat	Juvenile salmon production potential
Mainstem: Stud Mill Road to Beddington Lake	1,730	28.8%	Very good
Mainstem: Beddington Lake Outlet to Route 193	1,223	20.3%	Very good
Mainstem: Route 193 to Cherryfield Dam	1,261	21.0%	Fair/good
Mainstem: Cherryfield Dam to head of tide	556	9.2%	Fair
Tributaries: West Branch	393	6.5%	fair
Tributaries: all except West Branch	851	14.1%	Fair/good
Baker Brook; Shorey Bk			Very good

2.6 Atlantic Salmon Habitat Prioritization

In 2002, the MASC developed a subwatershed prioritization mapping system that divides each watershed into subwatersheds based on the quality and quantity of available habitat and access to that habitat. The purpose of the prioritization scheme is to provide guidance for the prioritization of salmon restoration projects. The three subwatersheds in the mainstem above the Cherryfield Dam are often referred to as the upper, middle, and lower strata. Table 2.5 lists the priority drainages and strata.

Table 2.5. Priority Salmon Habitat

SUBWATERSHED LOCATION	PRIORITY	STRATUM
Stud Mill Road to Beddington Lk.	1	Upper
Beddington Lk. Outlet to Deblois Falls (Rt. 193)	2	Middle
Deblois Falls (Rt. 193) to Cherryfield Dam	3	Lower
West Branch from Rock Dam to Sprague Falls	4	N/A
Other Freshwater (MS Headwaters above Stud Mill, WB Headwaters and below Sprague Falls)	5	N/A
Estuary	6	N/A

2.7 Salmon Smolt Production and Migration

The following was presented to the workgroup by James Hawkes, NOAA in January 2005.

Atlantic salmon smolts make the transition from freshwater to saltwater during spring of each year. NOAA monitors smolt production, smolt migration, and post-smolt assessment on all of the listed Atlantic salmon rivers in Maine. Smolt-production monitoring using rotary screw traps (RST) began on the Narraguagus River in 1996. Since 1997, population estimates have been derived using a paired trap and mark-recapture design (upstream and downstream rotary screw trapping sites). Salmon are "marked" with a caudal fin clip or punch and estimates are developed using recapture numbers.

In addition to sampling smolts and deriving population estimates using RSTs, NOAA also conducts ultrasonic telemetry studies. In these studies, smolts are surgically implanted with an ultrasonic serial-coded tag (pinger) that is detected by fixed locationVR2 automated fish receivers throughout the riverine, estuarine, and nearshore marine environments in Narraguagus Bay. Through these studies NOAA researchers are able to determine timing, behavior and survivorship, as well as where and when mortalities may occur.

Although the environmental factors that trigger smolt migration are not fully understood, biologists have observed that smolt migration is occurring later in the season in recent years (based on an eight-year time series). Some of the reasons for later migration may be related to:

- Timing of snowmelt/ice-out
- Temperature differences
- Flow
- Timing of Precipitation

Results from the Narraguagus River smolt studies indicate the following:

1. Smolt production appears to have declined from 1997 to 2004. However, production from 2002-2004 was consistent.

2. The 2004 scale sample data indicate the age range of smolts going to sea is as follows:
   - 84% of smolts leave at age 2
   - 15% leave at age 3
   - 0% leave at age 0
   - 1% is unknown (unreadable scales, regenerated, etc)

3. Overwintering survival studies indicate that overwintering between parr and smolt stage is poor. On average, approximately 11% of parr survive to become smolts.

4. Telemetry studies were conducted from 1997 to 1999 and from 2002 to 2004 to monitor smolt survival to the Gulf of Maine, determining migration behavior, path, and timing, and location of greatest mortality. The following results indicate the level of smolt survival to the outer array located at the outgoing edge of Narraguagus Bay.

Year	% of Smolts Making it to Outer Array
2002	36
2003	44
2004	43

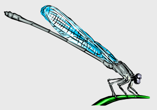
5. Recent observations of smolt-migration behavior using a telemetry-driven model indicates that upon first encountering salt wedges, smolts may perform many reversals

up and down stream during tidal cycles rather than going out to sea directly. Smolts may repeat these reversals several times before finally going to sea.

6. The mortality and the cyclic emigration patterns may suggest that the smolts are compromised by environmental factors such as acidity or aluminum toxicity, etc. Other issues being reviewed by biologists include predation, marine-derived nutrients, genetic variability, and the effects of liming on survival.

2.6 Habitat for Other Fisheries

The Narraguagus River Watershed supports important inland sport fisheries of brook trout, smallmouth bass, and pickerel, as well as lesser fisheries for rainbow smelt and yellow perch. Trout habitat is particularly notable in Shorey, Sinclair, Upper Little Narraguagus, Baker, and Rocky brooks and some portions of the upper mainstem. The West Branch is considered one of the premier wild brook trout fisheries in eastern Maine.



Chapter 3
Water Quality Monitoring History

3.1 Overview

The Narraguagus River Watershed is currently, or has recently been, monitored as part of 18 programs managed by at least ten different agencies/organizations. Several agencies monitor the river as part of multiple programs or studies (e.g., UMSGMC has 5 different studies in the watershed). Table 3.1 provides an overview of monitoring in the watershed and lists by agency, the project name, sampling dates, sampling frequency, objective, data contact, data storage location, and indicators measured.

3.2 Water Quality Monitoring Index

The information in Table 3.1 is a summary of a more-comprehensive Excel spreadsheet, titled the Narraguagus WQM Data Index, which is available online at: http://www.salmonhabitat.org/projects.htm. The Index was created specifically for this project and its purpose is to catalogue the details of current and recent WQM efforts and to provide the background information, or metadata, for developing GIS Maps 1-4 (Appendix A). The reader is encouraged to use the Index when reviewing the text and maps of this report. Each map icon corresponds to sites listed in the Index. The Index is arranged by agency and lists each parameter the agency monitors. It can be sorted by parameter so that the user can determine which agency is monitoring each parameter. For instance, sorting by aluminum (Al) will indicate all of the agencies monitoring for Al.

Although the Index is currently in an Excel spreadsheet, it could easily be imported into other databases and integrated into the PEARL database/website: http://pearl.maine.edu/windows/salmon/Asc_BrowseDataSets.htm. This would facilitate searches and queries of the database.

3.3 Data Collection Objectives

Each of the 18 programs currently collecting WQ/WC data maintains a different objective for based on the mission of the agency. Although the term "Water Quality Monitoring" is used loosely throughout this document, review of the various programs reveals that there are generally three types of data collection occurring in the NRW:

1. Monitoring. True water quality monitoring programs observe specific indicators over a period of time to identify long-range environmental changes. Monitoring can also be used to understand responses to a short-term change, such as before and after a specific land-use change. In

addition, monitoring is often used in watershed surveys to get a better understanding of how the system functions and to indicate the need for further investigation. Examples of programs currently using this type of data collection are MDEP/NRWC, MASC Temperature Program, MDMR Shellfish Sanitation Program, and USGS Streamflow Gage.

As part of their program objectives, some agencies monitor trends in both the mainstem and tributaries (MDEP/NRWC), while other programs monitor only the lakes (VLMP), only the estuary (MDMR) or primarily the mainstem (MASC). After an agency has monitored a specific indicator for many years, staffing and cost often dictate that the program reduce the number of sites and shift to the use of Index Sites, whereby a few sites are monitored in the long term with the results used as a model of response at other sites.

2. Studies. Water quality/chemistry studies are generally designed to answer very specific questions and are conducted in a defined geographic location over a finite period of time using strictly controlled and replicable protocols. The study often originates from questions raised in response to data gathered from a previously established monitoring program. Examples of agencies/programs currently conducting studies in the NRW include the UMSGMC Artificial Acidification Study and MASC pH Survey.

3. Assessment. Data collection in which an agency conducts a one-time sampling and analysis for the presence, absence, and level (lethal limits, index of biological indicators, etc) of specific indicators is generally referred to as an assessment. This form of data collection may develop into continued long-term monitoring or a more detailed, specific study. MDEP Biomonitoring Program for Class Attainment, USFWS Contaminant Assessment (primarily metals and organchlorides), and the USEPA Wadeable Streams Program (full chemistry analysis) are examples of assessments.

3.4 Monitoring Indicators

There is a wide range of parameters currently monitored in the watershed. Stream flow has been measured by USGS for over 50 years in the MS at the Cherryfield Gage Station just north of downtown. Continuous temperature (using loggers) has been monitored for the last 40 years by the MASC (1960s and from 1990–2005) and USGS (1968-1994; 2004-2005). MDMR, MDEPAS, MDEP Biom, and the NRWC currently take one-time field measurements of temperature when monitoring for other indicators. Field pH has been measured using loggers by NOAA (1999-2005) and USGS (1968-2005) and by use of pH pens by MDEPAS (1999-2005). Lab pH and water chemistry including DOC, ANC, specific conductivity, Ca, Mg, Na, K, Cl, NO_3, SO_4, and Al have been measured by

UMSGMC since 2003. Blueberry pesticides have been monitored by the MBPC since 1999 and biotoxins (i.e., red tide, etc) and *E. coli* have been measured by MDMR since the late 1980s.

3.5 Monitoring Locations

Maps 1-4 (Appendix A) illustrate all of the sites that are currently monitored or have been monitored in the past 5 years. Monitoring in the watershed is primarily focused in the mainstem from the Stud Mill Road to the bay. Different agencies focus their monitoring efforts in different reaches/drainages based on agency objectives. Furthermore some agencies maintain multiple study sites (MASC, UMSGMC, MDEP/NRWC, MBPC, and NOAA,) while some agencies maintain only a few index sites (VLMP, USGS, MDMR and NBCWC).

The MASC focuses their temperature and pH monitoring efforts on Priority Subwatersheds 1, 2, and 3 (Stud Mill Road to the Cherryfield Dam). The UMSGMC have water chemistry projects in Priority Subwatershed 1. The MDEPAS/NRWC focus their efforts in Priority Subwatersheds 6 (downtown Cherryfield, and Milbridge), 3, and 1. The MBPC monitor sites associated with blueberry cultivation in Priority Subwatersheds 2, 3, and 5. NOAA temperature and chemistry monitoring efforts focus on smolt migration routes in the MS from Little Falls in Cherryfield to the bay. Finally, the VLMP monitors Spruce Mountain and Schoodic Lakes.

The following areas are not currently monitored and should be considered for monitoring:
- most of the lakes and ponds (Beddington Lake, Bog Brook Flowage, Narraguagus L)
- the headwaters of the MS (above Stud Mill Road)

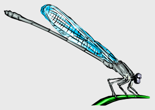
The following areas have some monitoring but should be considered for additional sites:
- Gould, Humpback, Pork, Schoodic, and lower Bear brooks
- MS Subwatersheds 2 (middle stratum) and 3 (lower stratum)
- much of the West Branch

Table 3.1. Overview of WQ Monitoring History in the Narraguagus River Watershed.

Investigating Agency	Project Name	Sample Dates	Sample Freq	Objective	Agency Contact	Data Storage	WQ Indicator
Maine Atlantic Salmon Commission	Water Temperature Monitoring	1960s-2005	spring, summer, fall	Basin wide temperature monitoring, salmon management	Richard Dill, MASC	http://pearl.maine.edu/windows/salmon/Asc_BrowseDataSets.htm	Digital data loggers, and Taylor Chart Recorders for historic data
Maine Atlantic Salmon Commission	ASC pH survey	2003-2004	3 times/year, spring, summer, fall	Investigation of pH and related water chemistry in Maine salmon drainages	Richard Dill, MASC	http://pearl.maine.edu/windows/salmon/Asc_BrowseDataSets.htm	Lab pH and various analytes (ANC, color, DOC, Ca, AL, Mg, NO, SO, etc)
Maine Board of Pesticides Control	Blueberry Pesticides Drift Study	1999-2004	Approx. 2 times per summer	Monitor Pesticide Drift	Heather Jackson	Augusta BPC office, Access database	Blueberry pesticides (phosmet, fenbucanzole, hexazinone, etc)
NOAA-Fisheries Service	Smolt Project	1999-present	15 min-hourly	Monitoring of Juvenile Salmon Habitat	Jim Hawkes	NOAA Field Station, Orono	Temperature, pH (loggers), YSI data sondes
US Geological Survey	Maine Water Resources	1948-present	Hourly	Monitor Streamflow	Jim Caldwell, USGS	http://nwis.waterdata.usgs.gov/me/nwis/qwdata?site_no=01022500&agency_cd=USGS&format=inventory	Streamflow
US Geological Survey	Maine Water Resources	1968-1994	Grab, throughout season	Narraguagus Water Quality	Jim Caldwell, USGS	http://nwis.waterdata.usgs.gov/me/nwis/qwdata?site_no=01022500&agency_cd=USGS&format=qw_sample_por_table&begin_date=&end_date=&inventory_output=0&rdb_inventory_output=file&date_format=YYYY-MM-DD&rdb_compression=file&qw_sample_wide=0&submitted_form=brief_l	pH, Temperature, Specific conductivity

Maine Department of Environmental Protection	Biomonitoring Program	1984-present	Once per summer in year(s) specified	Aquatic life attainment determination	Leon Tsomides, MDEP	MDEP BioME database	Field Temperature, DO, and macroinvertebrates
Maine Department of Environmental Protection/ Narraguagus River Watershed Council	Atlantic Salmon River WQM Program	1999-present	Biweekly-seasonal	Public Health, WQ Profiles	Mark Whiting DEP	DEP Bangor	Field Temperature, DO, and pH. Some lab chemistry
UM Senator George Mitchell Center	ASC Watersheds UMSGMC, ASC	2003-pres	monthly + episodes	Land Use Water Chemistry	Ken Johnson, UMSGMC	UMSGMC	Lab pH and various analytes (ANC, color, DOC, Ca, AL, Mg, NO, SO, etc)
UM Senator George Mitchell Center	Atlantic Salmon Acidity Project, Haines, UMSGMC	2002-03	monthly + episodes	Land Use Water Chemistry	Ken Johnson, UMSGMC	UMSGMC	Lab pH and various analytes (ANC, color, DOC, Ca, AL, Mg, NO, SO, etc)
UM Senator George Mitchell Center	Rt. 9 Salt, UMSGMC, NOAA FS	2004-05	episodes	Assess road salt effects on water chemistry	Ken Johnson, UMSGMC	UMSGMC	Lab pH and various analytes (ANC, color, DOC, Ca, AL, Mg, NO, SO, etc)
UM Senator George Mitchell Center	Bear Brook Watershed, UMSGMC, EPA	1987-pres	weekly + episodes	Artificial Acidification, long-term precipitation chemistry	Ken Johnson, UMSGMC	UMSGMC	Lab pH and various analytes (ANC, color, DOC, Ca, AL, Mg, NO, SO, etc)
UM Senator George Mitchell Center	Calcium Assessment	2004	bi-monthly for 4 months	Calcium Differences Between up and downstream	Ken Johnson, UMSGMC	USGS website for chemistry data: http://nwis.waterdata.usgs.gov/nwis/qwdata?state_cd=23&format=station T	Lab pH, ANC, and Ca, Mg, Na, K

Maine Dept of Marine Resources	Public Health Division	1989 to present	6+ samples yearly	Classification of shellfish harvesting areas	John Fendl, MDMR, Lamoine	Central Oracle Database	E. coli, temperature, salinity, biotoxins
Narraguagus Bay Clean Water Coalition	Clamflat Closure Project	2005	1x week with focus on rain events	Clamflat Pollution Source ID	Lewis Pinkham, Milbridge Town Manager	Narraguagus High School	E. coli, temperature, salinity
Volunteer Lake Monitoring Program	Volunteer Lake Monitoring Program	1974-present	1-2/season	Lake Nutrification	Scott Williams/ VLMP	http://pearl.maine.edu	DO, chl a, transparency, pH, color, TP
USFWS	Contaminant Assessment	2003 & 2005	Once for tissue, once for blood	Residue analysis & blood biomarkers	Steve Mierzykowski	USFWS Field Office, Old Town	Organochlorines, trace elements, endocrine disruption
US EPA	Wadeable Streams Project	2001	Once	Water Chemistry	EPA	http://www.epa.gov/region01/lab/reportsdocuments/wadeable/sites/naraguagus/index.html	DO, temperature, streamflow, turbidity, pH, full chemistry, macroinvertebrates, fish



Chapter 4
Water Quality Trends

4.1 Summary of WQ Trends

Table 4.1 and Map 5 (Appendix A) summarizes those areas in the watershed for which there are data to suggest some form of diminished water quality. The sites and indicators listed in the table correspond to those listed in the Narraguagus WQM Data Index (see Section 3.2). The indicators are described as high or low relative to either state water classification standards for A/AA waters (See Chapter 2) or life stage thresholds of Atlantic salmon (described below). Water quality indicators monitored in the NRW and discussed in this chapter include:

- Temperature
- pH and related analytes (Ca and Al)
- Dissolved Oxygen
- Nutrients
- Bacteria
- Macroinvertebrates
- Pesticides
- Streamflow
- Embeddedness
- Lake Productivity

Sections 4.2–4.12 provide an explanation of salmon requirements and a brief review of existing datasets by agency. The datasets and graphics discussed in these sections were presented (usually via Power Point Presentations) to the NRWQMP Workgroup between January and September 2005. The reader is encouraged to contact agencies directly if there are further questions regarding the data presented herein.

The purpose of this plan is to review existing WQ data and to make recommendations regarding their use in restoration and management decisions and future monitoring plans. Several recommendations regarding the addition of new sites, new studies, expansion of monitoring season, and restoration activities are made for each indicator. The recommendations for each indicator are listed in Table 5.1.

Finally, when attempting to interpret results and determine follow-up actions, agencies and organizations should carefully consider whether the occurrence of diminished WQ in a specific reach or waterbody is naturally occurring or the result of landuse activity. If the cause is determined to be naturally occurring, then no further action should be taken other than general monitoring. If a landuse activity is associated with poor WQ, then appropriate restorations measures should be pursued. There are several restoration-related action items presented in Chapter 5.

Table 4.1. Areas in NRW with Data Suggesting Diminished WQ. See Appendix A, Map 5.

	High Summer Temperatures	**Low pH**	**Low Ca**	**Low DO**	**High Nutrients**	**Bacteria**	**Macroinvertebrates**	**Pesticides**	**Altered Streamflow**	**High Embeddedness**
Schoodic L				√	√					
Beddinton L				√						
Spruce Mntn L				√						
Schoodic B	√	√		√						
Lawrence B	√	√		√						
Rocky B		√								
Baker B		√								
Sinclair B		√	√		√					
McCoy B		√								
Pork Brook								√		
Great Falls Branch		√						√		
Cranberry B		√								
Bog Brook Flowage			√		√			√		
Shorey B					√					
MS @ Cherryfield					√	√	√		√	√
MS @ Little Falls (km 11.08)	√		√							
MS @ Burnt Camp (km 22.43)	√									
MS @ Honeymooners Camp (km 30.86)	√									
MS @ Beddington L Outlet	√									
Ms @ Deblois Index Site (Rt 193)	√									
MS @ Rt 9	√									
Ms @ 28 Pond (km 55.55)	√									
MS @ 31-00-0 Road	√									
WB @ Sprague Falls	√	√	√							
Spring River (WB)	√									
Estuary						√				

4.2 Temperature

4.2.1 Temperature Requirements of Atlantic Salmon

Each life stage of the salmon life cycle responds to a specific range of water temperature and extremes in these ranges can cause abnormalities in behavior. Juvenile salmon and adult spawning salmon experience stress at 22.5 °C and may die when temperatures reach 27-28 °C for extended periods of time (Danie et al, 1984, Elliott, 1991, Garside, 1973, Huntsman, 1942). Extreme temperatures can profoundly affect spawning, hatching, parr growth, and smolt migration (Table 4.2, adapted from Institute for Fisheries Resources and Sheepscot Valley Conservation Association, 2005). Water temperature can also affect the ability of salmon to survive environmental challenges, such as disease and aluminum toxicity (Poleo et al, 1991).

Spawning and early development
The literature suggests that spawning will occur between 4.4-10 °C, with an optimum temperature for fertilization and incubation of 6 °C (Danie et al, 1984; McLaughlin and Knight, 1987; Power, 1990); egg/embryo mortality occurs if temperatures rise above 12 °C (Danie et al, 1984). Hatching time occurs earlier in the spring in warmer reaches of streams, indicating that development time for eggs is related to temperature (Webb and McLay, 1996). Optimum temperatures for alevin occur between 4-7.2 °C, with lethality occurring at temperatures above 12 °C (Institute for Fisheries Resources and Sheepscot Valley Conservation Association, 2005).

Parr growth and survival
Parr remain in freshwater streams for up to 3 years and experience maximum growth when temperatures are between 12-19 °C (Danie et al 1984; Power, 1990). Although parr can tolerate brief exposure to temperatures as high as 32 °C, long-term exposure to 27 °C will cause mortality (Danie et al 1984). Parr survive minimum temperatures close to 0 °C (Elliott, 1991). Temperature limits for feeding ranged from lower limits of 4-7 °C to an upper limit of 22.5 °C (Elliott, 1991).

Table 4.2. Effect of water temperature on Atlantic salmon survival at different life stages (Institute for Fisheries Resources and Sheepscot Valley Conservation Association, 2005).

Life Stage	**Optimum Temp Range (°C)**	**Minimum Temp (°C)**	**Maximum Temp (°C)**
Spawning	5-8	4.0° C	10-12° C
Egg/Alevin	4-7.2	0.5	12
Early Fry	8-19	0.5	23.5-27.7
Parr: Feeding	15-19	3.8	22.5
Survival	0.5-20	0	27-32
Smolt (migrating)	7-14.3	5	19
Adult (migrating)	14-20	8	23

Smoltification and migration

Once parr have matured sufficiently to migrate, smoltification is triggered by increasing day length and spring water temperatures of 5 °C (Sigholt et al, 1998), with emigration peaking at 8-9 °C (McLaughlin and Knight, 1987; Whalen et al, 1999). Smolt that are delayed in migration and experience increased water temperatures may undergo desmoltification, thereby decreasing the number of salmon migrating to salt water successfully (Whalen et al, 1999).

Water temperature: indirect effects

Temperature interacts with flow and depth to determine suitable sites for spawning and parr residence. Redd sites are characterized by flows averaging 53 cm/sec, depths that average 38 cm, and temperatures of 8.3-10.5 °C (Beland et al, 1982). Parr overwinter under cobble with velocities of 38.7-45.7 cm/sec and mean water depth of 40.9-48.9 cm with winter temperatures of 0.5-7 °C (Cunjak, 1988).

Groundwater volume and runoff have significant influence on stream temperature and flow except in spring when snowmelt governs temp and flow variation (Constantz, 1998). Where land has been logged, investigators in Oregon have documented increases in average daily maximum temperatures of 6 °C and in average daily minimum temperatures of 2 °C (Beschta and Taylor, 1988).

4.2.2 Review of Recent Temperature Data

MASC

All information contained in this section was obtained from the MASC Presentation to the NRWQMP Workgroup, February 2005.

The MASC monitors temperature using digital temperature data loggers, which are generally deployed from May through October or early November and record temperature every 60 minutes. The agency maintained 10 sites in 2004 but has historic data on 16 sites on the MS and one on the WB at Sprague Falls. The MASC has been monitoring in the NRW since the 1960s and has data for 1960-1969 and 1991-2004 (See Data Index).

The majority of flow in NRW is base flow; sand aquifers contribute cold water. The purpose of the program is to:

1) Evaluate temperature affect on productivity, growth, and survival of juvenile Atlantic salmon.
2) Investigate water temperature at the reach level and identify river reaches susceptible to critical summer water temperatures.
3) Maintain a time series of temperature index sites and monitor temperatures at ASC weir and fishway trapping facilities.
4) Monitor the Upper Reach of the Narraguagus River, in particular the section from Hemlock Dam to Beddington Lake, which represents one-sixth of the potential rearing habitat of the entire main stem.

The MASC is proposing to integrate temperature as a component of habitat. Although a reach may contain 5,000 units of physical habitat (size of substrate, water depth, and gradient) and be capable of producing 35,000 parr or 11, 725 smolts (33.5% survival - Legault PVA model), diminished water quality and high summer temperature may limit salmon production to 22,400 parr or 7,504 smolts. The agency proposes the following scheme, which classifies temperature according to range and average. Figures 4.1 and 4.2 illustrate how the scheme would be implemented with actual data. For example in Figure 4.1, Cove Brook 2002 temperatures would be classified as cool/stable to cool/moderate, while Kenduskeag's 2002 temperatures would be classified as warm/moderate to warm/extreme. Likewise, Figure 4.5 illustrates how the scheme can be used to compare annual trends. In 2001 July/August NRW temperatures were warm/extreme compared to 2000, which were cool/extreme-cool/moderate.

Figure 4.1. Temperature Averages and Ranges for Several Streams for July 2002.

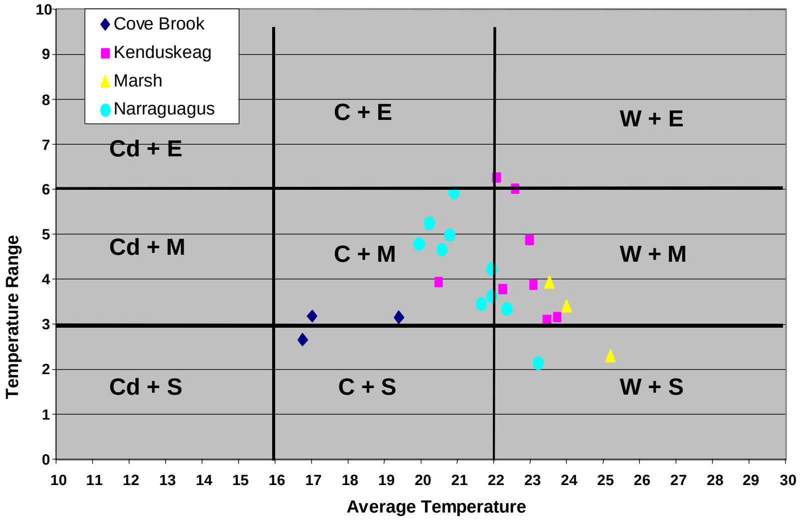


Figure 4.2. Temperature Averages and Ranges for NRW Monitoring Sites for the Last Two Weeks of July and First Two Weeks of August, 2000-2004.

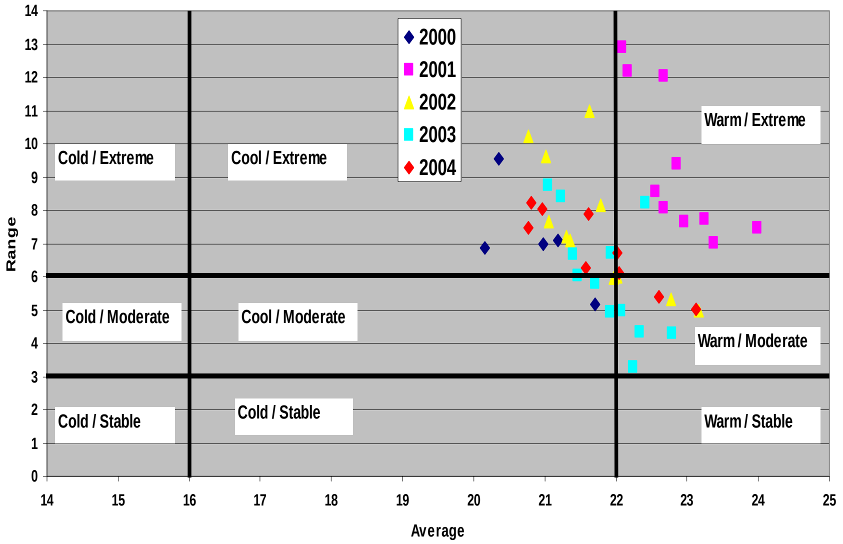
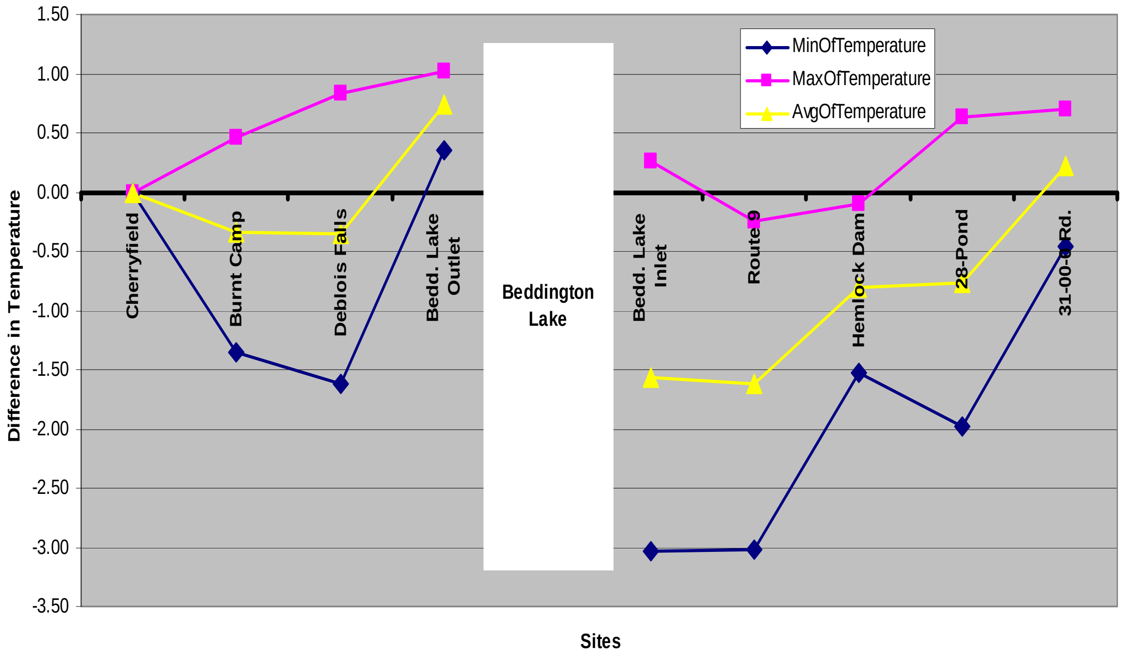


Figure 4.3 illustrates 2004 July/August minimum, maximum, and average temperatures of MS sites as compared to the Cherryfield Index Site, a site which has been monitored on and off since 1963. This method of comparison indicates that temperatures of the MS above Hemlock Dam are generally warmer than the index site and the range of temperature variability at the 31-00-0 and Hemlock Dam is relatively small as compared to other reaches. Below Rt. 9 and at the Beddington Lake Inlet, temperatures are relatively much cooler and the range of variability is quite high suggesting ground water input. The most significant temperature change in the MS is that which occurs at the Beddington Lake. Outlet water temperature is significantly warmer and has a much smaller range of temperature variability when compared to inlet water temperatures. Furthermore the effects of the lake outlet are experienced throughout the lower portion of the MS; higher maximum and average temperatures occur throughout.

Table 4.3 lists several sites that experienced minimum temperatures above 22.5 °C during 2004 (MS at Burnt Camp, Honeymooners Camp, Deblois Falls, Beddington Lake Outlet, 28 Pond, 31-00-0 Road and the West Branch at Sprague Falls). Furthermore, Honeymooners, Deblois, Beddington Lake Outlet, and 31-00-0 Road sites also experienced several days in which the maximum temperature was above 27 °C. No sites experienced temperatures above 30 °C during 2004. This method of classifying temperatures suggests that several sites in the watershed may not experience ample nocturnal relief for salmon recovery.

Figure 4.3. NRW Average, Minimum, Maximum, and Mean Temperatures for the Last Two Weeks of July and First Two Weeks of August, 2004.



Using data from the Cherryfield Index Site (Figures 4.4 and 4.5), the MASC looked at decadal comparisons of average daily minimum and maximum temperatures and found a recent trend toward warmer daily river temperatures. The increase in temperature is approximately +0.1 to 4.0 ^{o}C. Furthermore, it appears that late summer temperatures are warmer now than in the 1960s.

Table 4.3. MASC NRW Temperature Monitoring Results, 2004.

Narraguagus River water temperature monitoring results, 2004.

Site	River Kilometer	# Sample Days	Days minimum >22.5	Days maximum >27	Days maximum >30
Stillwater Dam	1.85	140	0	0	0
Burnt Camp	22.43	261	4	0	0
Honeymooners Camp	30.86	224	2	2	0
Deblois Temperature Monitoring Index Site*	33.26	0	1*	3*	0*
Beddington Lake Outlet	41.79	153	11	3	0
Beddington Lake Inlet	46.29	166	0	0	0
Route 9 Index Site	47.62	166	0	1	0
Hemlock Dam	49.69	271	0	0	0
28 Pond	55.55	166	3	0	0
31-00-0 Road Crossing	62.50	158	1	3	0
Sprague Falls	7.70	113	8	0	0

* Due to logger manfunction estimated 2004 by comparing previous years data to logger at Deblois Falls.

Figure 4.4 Comparison of Decadal Average Daily Minimum Water Temperature for the NRW at Stillwater Dam in Cherryfield, ME (1960s vs 1990s).

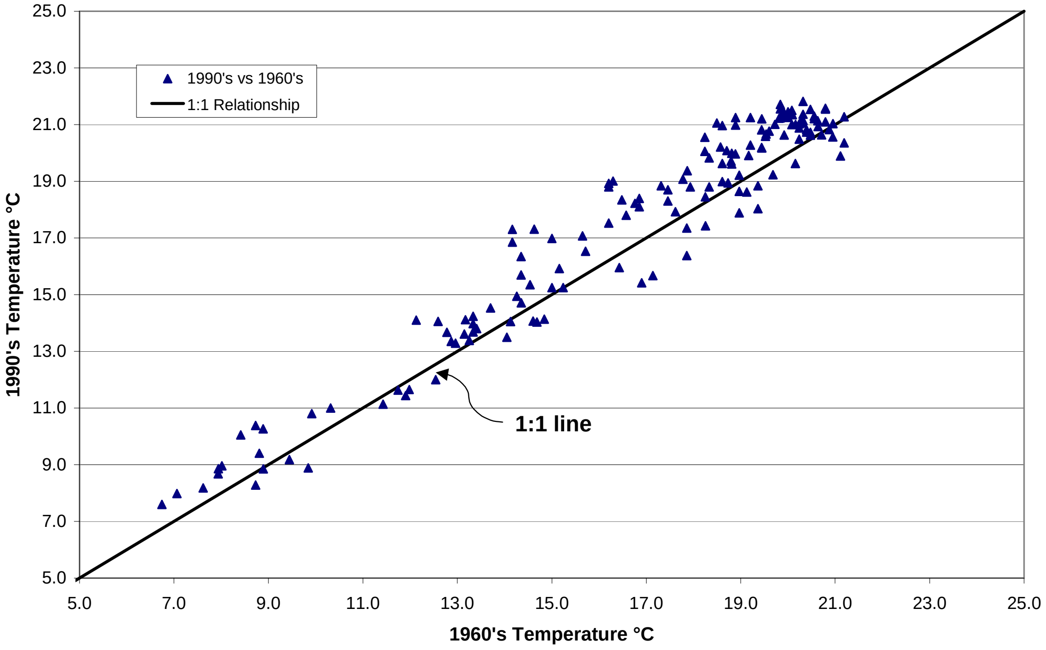
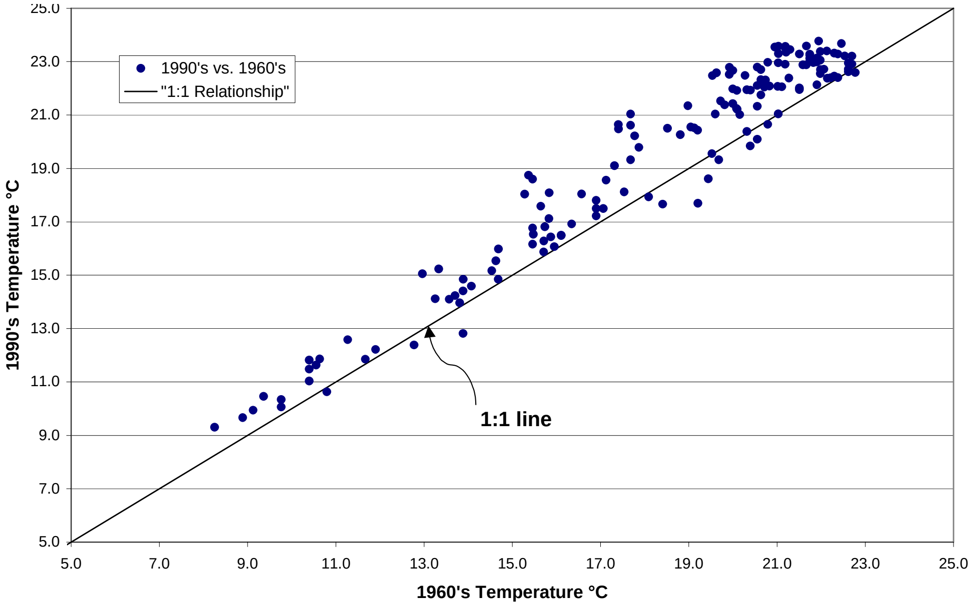


Figure 4.5 Comparison of Decadal Average Daily Maximum Water Temperature for the NRW at Stillwater Dam in Cherryfield, ME (1960s vs 1990s).



MDEP Atlantic Salmon Rivers Program

All information contained in this section was obtained from the MDEPAS Presentation to the NRWQMP Workgroup, February 2005.

The MDEP Atlantic Salmon Rivers Program (MDEPAS) and volunteers from the NRWC monitor water temperature in the tributaries using Onset *Tidbit* temperature loggers. The MDEP/NRWC does not monitor any sites on the MS. The objective of the program is to monitor summer high temperatures that may be stressful or lethal to salmon and other cold-water species.

Data from 2003 and 2004 (Tables 4.4 and 4.5) indicate that most of the tributaries experience zero to very few days when the minimum temperature is above 22.5 ^{o}C or when the maximum temperature is above 27 ^{o}C. No tributaries experienced daily maximum temperatures over 30 ^{o}C which is the imminent lethal temperature. This suggests that salmon can feed most of the time and that many of these tributaries may serve as refuge from the warmer water in the MS. Only Lawrence and Schoodic brooks and Spring River experienced some days when water temperatures were compromising. These streams are lower in the watershed and may be warmer because they are third order streams (wider and deeper). Furthermore, both Lawrence and Schoodic brooks have beaver activity that may increase water temperatures.

Other Temperature Concerns

Both Cherryfield Foods and Wyman and Son blueberry processing plants, located on the MS in Cherryfield, have MDEP discharge permits that allow them a combined discharge of 0.370 million gallons of water per day (MGD) of non-contact cooling water that cannot exceed a temperature of 27 °C. It is unknown if those standards are being met and if that temperature level is harmful to migrating salmon.

Table 4.4. Temperature Thresholds for NRW Tributaries, 2004.

Watershed	Date	Trib	Site	Days min ≥ 22.5 C	Days max ≥ 27C	Days max ≥ 30 C
Narraguagus R	08/03/04	35 Brook	43 040 Rd	0	0	0
Narraguagus R	08/03/04	Humpback Brook	CC Rd	0	0	0
Narraguagus R	08/03/04	Great Falls Branch	Rt 193	0	0	0
Narraguagus R	08/03/04	Schoodic L outlet		4	0	0
Narraguagus R	08/03/04	Schoodic Brook	Rt 193	0	5	0
Narraguagus R	08/03/04	Lawrence Brook	Rt 193	7	3	0

Table 4.5 Temperature Thresholds for NRW Tributaries, 2003.

Watershed	Date	Tributary	Site	Days Min > 22.5 C	Days Max > 27 C	Days Max > 30 C
West Branch	8/21	Pork Brook		0	0	0
West Branch	8/21	Spring River	Sugar Hill Rd	1	3	0
Narraguagus	8/21	Gould Brook	CC Road	0	1	0
Narraguagus	8/21	Bog Brook	65000 Rd	0	0	0
Narraguagus	8/21	Great Falls Branch	Rt 193	0	0	0
Narraguagus	8/21	Schoodic Brook	Rt 193	2	0	0
Narraguagus	7/4	Lawrence Brook	Rt 193	3	4	0

NOAA

All information contained in this section was obtained from the NOAA Presentation to the NRWQMP Workgroup, February 2005.

NOAA monitors temperature in association with spring smolt migration using long-term YSI and Optic Stow-Away loggers that record hourly temperatures. Temperature data from Crane Camp and Little Falls RST indicate that temperatures approach 10 °C (the temperature of peak smolt migration) in late April and early May. Temperatures stay between 10 and 17 °C until late June when they generally rise above 20 °C.

Daily maximum temperature data (Table 4.6) at Little Falls from 2000-2004 indicate that prior to June the temperature rarely exceeds 22.5 °C. However, all years experienced summer high temperatures above 22.5 °C and in 2001-2003 several days were above 27°C. No years experienced temperatures greater than 30 °C. Most years experience peaks of high temperatures in late June/early July and in late August/early September.

Daily maximum temperature data from Shorey Brook from 2001-2004 indicate that summer high temperatures rarely go above 20 °C. Shorey is generally colder than other tributaries and mainstem due to groundwater input, gradient, and shading. In general, temperatures in Shorey remain cool and stable throughout the summer but often rise significantly in autumn with leaf drop.

Table 4.6. Daily Maximum Temperatures from 2000-2004 for Little Falls and Shorey Brook.

Site	Year	# Sample Days	Days Minimum ≥22.5 °C	Days Maximum ≥27 °C	Days Maximum ≥30 °C	Maximum Temperature °C
Little Falls	2000	366	36	0	0	25.06
Little Falls	2001	365	59	6	0	28.01
Little Falls	2002	365	53	5	0	27.49
Little Falls	2003	310	48	2	0	27.31
Little Falls	2004	319	29	0	0	26.41
Shorey	2001	306	2	0	0	22.73
Shorey	2002	350	1	0	0	22.69
Shorey	2003	365	0	0	0	22.01
Shorey	2004	366	0	0	0	20.55

USGS

All information contained in this section was obtained from the USGS Presentation to the NRWQMP Workgroup, February 2005.

The USGS has maintained a continuous-temperature and specific-conductance logger at the USGS flow gage on the MS in Cherryfield at the Cherryfield streamflow-gaging station (near the Cable Pool, USGS station number 01022500) since 2004 on a trial basis. While real-time data are continuous (15-minute) raw data, the USGS data are typically summarized into daily statistics such as minimum, maximum, and mean temperature. USGS data sets can be used for a variety projects. Since temperature data can be cumbersome, users are encouraged to request specific data sets from USGS in order to integrate the data with their own data sets or to answer specific research questions. For example, USGS data may be used to integrate WQ data with climate data to determine trends, or to develop WS models and water budgets. Subwatersheds can be analyzed in the same way assuming there is a gage.

4.3 pH and Related Analytes

4.3.1 pH Effects and Requirements of Atlantic Salmon

Although most salmon rivers have long-term pH values of 6.0 or above, many are subject to episodic decreases in pH due to snowmelt events in winter and spring and rainfall runoff events in summer and fall (Clair et al., 2001; Haines and Akielaszek, 1984; Whiting, 2004). Furthermore, the lack of naturally occurring base cations (calcium, magnesium, etc) in many of the salmon rivers contributes to an overall lack of buffering capacity (Johnson and Kahl, 2005). Tolerance of acidity varies with the life stage in Atlantic salmon (Table 4.7). Vulnerability to low pH increases in the following pattern (Farmer, 2000): Egg < alevin <large parr < small parr < smolt < fry. Although, Farmer's research also found that in laboratory environments, fry suffered substantial mortality when pH dropped below 5.0, while smolt and parr both died at pH below 4.6. Moreover, hatching was delayed at pH 4.5-5.0 and prevented entirely at pH 4.0-4.2. It should be noted, however, that there is great variability in these threshold levels in situ and among watersheds depending on base cation and dissolved organic carbon levels.

Table 4.7. Effect of acidity on Atlantic salmon survival at different life stages.

Life Stage	**Optimum Range**	**Lower Lethal Range**	**Negative Effect Range**	**Reference**
Embryo	6.6-6.8	3.1-3.5	4.0-5.5	Peterson et al, 1980
		4.0-4.2	4.5-5.0	Farmer, 2000
Alevin/Fry		4.0		Daye and Garside, 1977
		<5.0		Farmer, 2000
Parr:	>5.4	4.7	4.7-5.0	Watt et al., 1983
			4.4-6.1	Magee et al., 2003
	>6.5-6.9		5.8	Kroglund and Finstad, 2003
Smolt		4.6-4.7		Farmer, 2000
			<6.2	Kroglund and Staurnes, 1999

Effects of aluminum toxicity

Low pH may also increase the concentration of heavy metal ions in the water column, particularly toxic monomeric aluminum (also known as exchangeable Al). This form of aluminum accumulates on and in gill tissue, disrupting ion regulation and impairing gas exchange. This will ultimately affect the ability of the smolt to transition from freshwater to saltwater. Values greater than 200 µg /L total Al exceed Maine's water quality standard and values greater than 5µg /L exchangeable Al are considered harmful to cold-water fish (Brocksen et al., 1992). Even when Al concentration is fairly low (6 µg/L), exposure to freshwater of pH 5.8 raised gill-Al concentration from 10 µg/g gill dry weight to 30 µg/g gill dry weight (Kroglund and Finstad, 2003).

Physiological effects of chronic and episodic exposure to low pH

Magee et al (2003) investigated the effects of both chronic and episodic acidification on smolt physiology and survival in freshwater (FW) and seawater (SW). When held in FW of pH 4.4-6.1 for 31 days, smolts fed poorly, did not grow, showed substantial changes in blood plasma ion concentrations and hematocrit, and experienced significant mortality when transferred to 34 ‰ SW. Smolts exposed to episodic pulses of low pH (pH 5.2 for 48 hr once each week for 31 days) fed poorly while in acidified FW, but did not show substantial changes in plasma ion concentrations or hematocrit until transferred to SW. The physiological effects and mortality when exposed to SW were less severe for episodically exposed smolts than for chronically exposed smolts. Kroglund and Finstad

(2003) found similar results for presmolts exposed to pH 5.8 for 3 months: growth was poorer, migration was delayed after release to streams, and marine survival was 20-30% lower.

4.3.2 Review of pH, Calcium, and Aluminum Data

Information contained in this section was obtained from the MDEPAS, NOAA, and UMSGMC Presentations to the NRWQMP Workgroup, March 2005.

pH

Mainstem

The MASC and UMSGMC conducted a Systematic Water Chemistry Survey of several salmon streams in the state between 2003 and 2004. The results of the survey indicate fundamental differences in closed cell pH (ClpH), Ca, and DOC between the rivers east and west of the Penobscot River (Figure 4.6). (Closed cell pH is a measurement of pH in a sample of water sealed from atmospheric contact and is thought to represent the pH of the water without the influence of respiration and photosynthesis.) The five Downeast (DE) rivers (Narraguagus, Pleasant, Machias, E Machias and Dennys) experienced lower Ca, ANC, and pH and higher DOC when compared to those west of the Penobscot River. In 2003-2004, the median pH of the DE rivers was 6-6.4 and the range was 4.75-7.3. The median of the other salmon rivers was 7-7.5 with a range of 6.5-8.0. The depressed Ca and acid neutralizing capacity and elevated DOC make the DE rivers more susceptible to event-driven pH depressions than those rivers west of the Penobscot River (Johnson and Kahl, 2005).

The same study indicates that within the NRW the pH ranged between approximately 5.3 and 7.5 (Figure 4.7). Rocky, Sinclair, and the WB at Sprague Falls experience the lowest mean pH (5.3). The MS at Rt.9 experienced the highest mean pH (7.5). Baker, Rocky, and Sinclair brooks, the WB, and the MS at the 31-00-0 Road and Rt. 9 experience large variation in pH most likely in association with stormwater events. Gould Brook and the MS at Little Falls and Rt.193 in Deblois experience less variation.

Five years (2000-2004) of data from the NOAA logger on the MS at Little Falls indicate that pH is generally consistent and ranges between 6.0 and 6.5 between January and April (Figure 4.8). The pH occasionally dropped below 6.0 as a result of spring snowmelt and precipitation events. These drops in pH may be problematic for smolt migration, which occurs at the same time (April-June). During the summer and early fall months (July-September) of low-precipitation years (2001-2003), pH generally rises to approximately 7.0 or greater as a function of diminished streamflow. Years with high flow or many rain events, such as August 2004 and November 2003, experienced sharp declines in pH (<6.0).

Figure 4.6. ClpH, Ca, and DOC for ASC pH Survey Sites East and West of the Penobscot River.

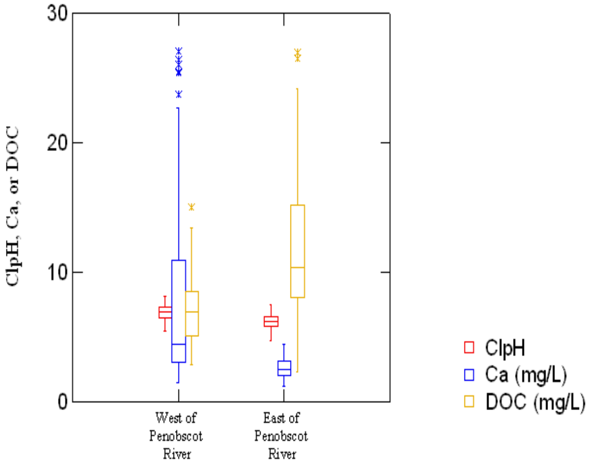


Figure 4.7. ClpH for ASC pH Survey Sites in the NRW.

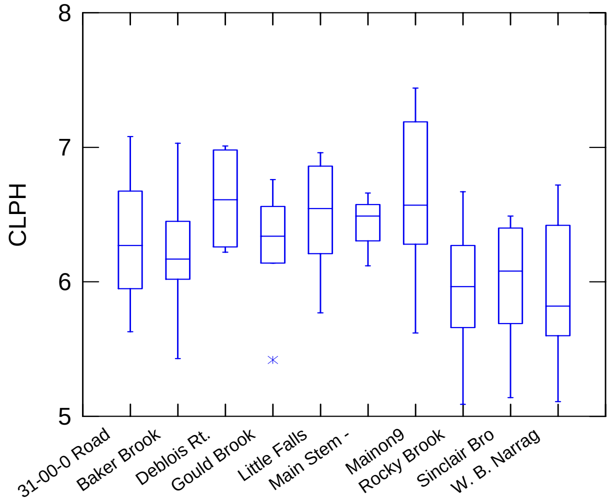
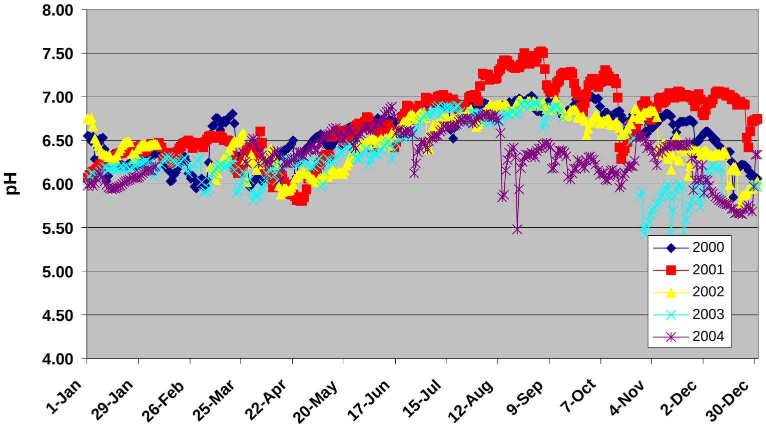


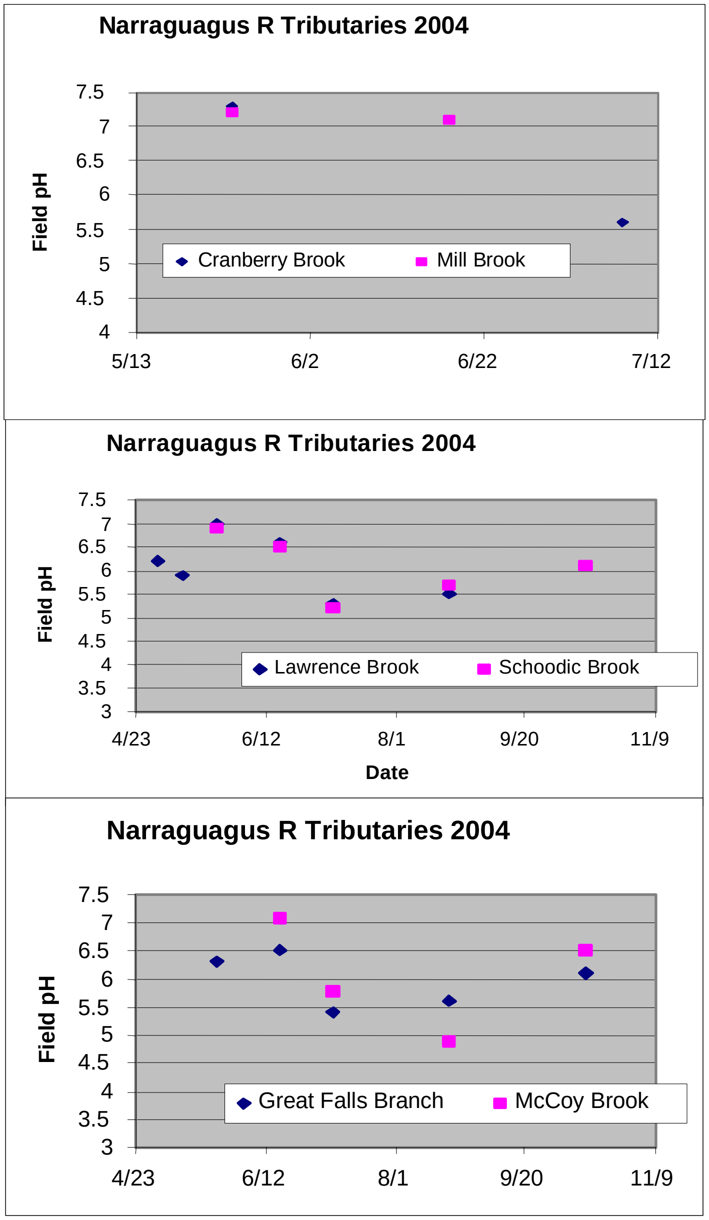
Figure 4.8. Average Daily pH (NOAA Logger) on the MS of the Narraguagus River at Little Falls, 2000-2004.



Tributaries

The MDEPAS/NRWC program monitors field pH on the MS and many of the tributaries. Tributaries draining wetlands or peatlands may contribute acidic water to the mainstem. Data from 2004 indicate that the West Branch is generally more acidic than the mainstem; pH in the WB ranged between 4.8 and 6.1 during 2004. Low pH is the result of inputs from boggy wetlands, acidic forest soils, lower buffering capacity of the WB, and greater sensitivity to acid rain occurring in the drainage. Lawrence, Schoodic, Cranberry, and McCoy brooks, Great Falls Branch and the WB all experience drops in pH (some as low as 5.5) in response to precipitation events (Figure 4.9). Mill Stream, which is in the lower portion of the watershed and enters the mainstem near head of tide, is relatively neutral (pH above 7.0).

Figure 4.9. Field pH of Tributaries in the Narraguagus.



Calcium

Mainstem

The amount of base cations, such as Ca^{+2} and Mg^{+2}, in surface water is primarily a function of the composition of local soils and underlying bedrock with minimal contributions from atmospheric deposition. Calcium measurements from the mainstem at the Cherryfield USGS gage over a ten-year period, 1978-1986, indicate that the average calcium level during that time was approximately 2.1 mg/L and average pH was 6.72 (Figure 4.10). This level is significantly lower than those levels found in the rivers west of the Penobscot (1-28 mg/L). The graph also illustrates the link between pH and calcium. As the amount of cations (Ca) decreases in the system, acid-neutralizing capacity decreases, and therefore pH increases (see Figure 4.10 at 6/18/1982).

Data collected on the MS at Rt. 9 from 2002 - 2003 (UMSGMC) was compared to historical data. This comparison suggests that there has been no significant change in calcium over the 25-year period (1978-2003). Calcium at this site ranged from 1 to 4 mg/L with an average Ca of approximately 2.2 mg/L (Figure 4.11).

Figure 4.10. Calcium and pH Measurements of the MS at the Cherryfield USGS Gage, 1978-1986..

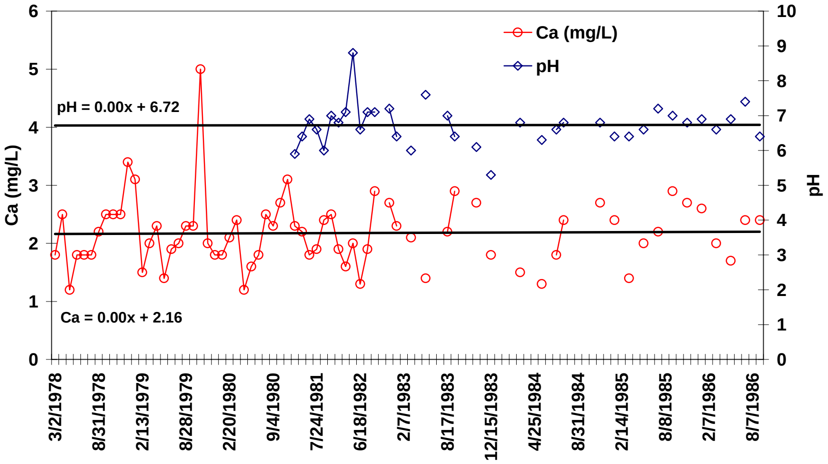
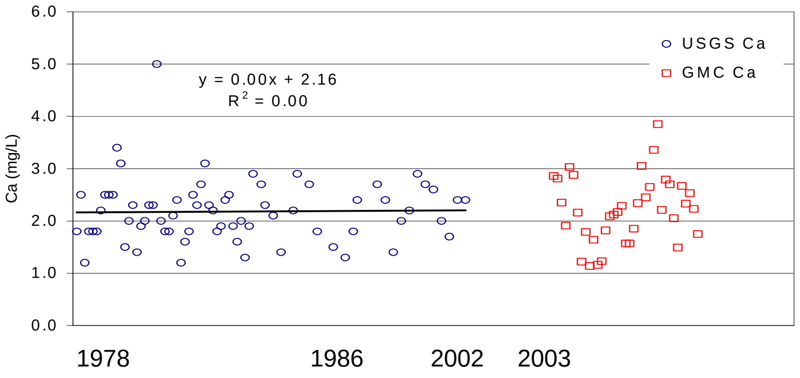


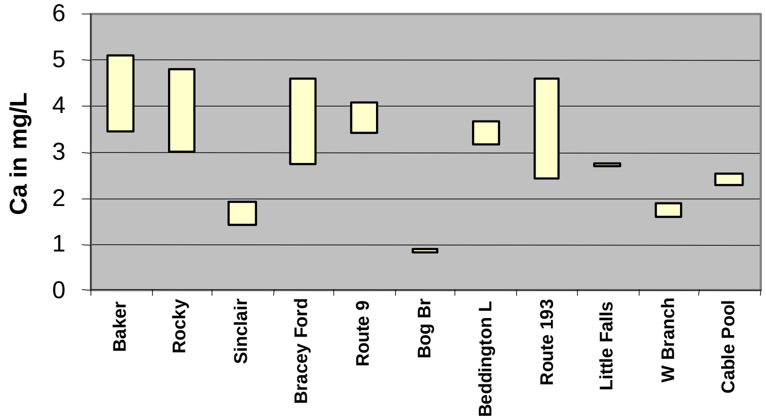
Figure 4.11. Calcium Measurements of the MS at Cherryfield Gage (USGS) and Route 9 (UMSGMC), 1978-1986 and 2002-2003. (UMSGMC, 2005).



Tributaries

Baseflow calcium concentrations in tributaries measured in 1999 and 2000 vary greatly within the watershed and range from as low as 1 mg/L in Bog Brook to as high as 5 mg/L in Baker Brook (Figure 4.12). In addition to Bog Brook, Sinclair Brook, the West Branch, and MS at Little Falls and Cable Pool had values below 3 mg/L. The data suggests that those tributaries with higher calcium (Baker and Rocky) may have bedrock or till deposits with more carbonate rock than those with low calcium. Wetlands like those in Bog Brook Flowage may have no sources of calcium other than atmospheric deposition. MS sites generally have higher calcium because they drain larger areas with more soil and therefore more exported calcium. If calcium is originally present in soils and bedrock, it may be lost from forest soils by acid rain, agricultural harvests, and timber harvesting. This loss of cations may have an acidifying effect on the soil and on surface water runoff.

Figure 4.12. Range of Baseflow Calcium levels in NRW MS and Tributaries, 1999-2000.



Aluminum

The MASC/UMSGMC Systematic Water Chemistry Survey data indicate that in 2004 both total and organically bound Al in the Narraguagus differed very little and were between 45.1 and 250.4 µg/L and 38.5 and 262.1 µg/L respectively (Table 4.8). The Narraguagus, as with all drainages to the east of the Penobscot, has higher Al concentrations than drainages to the west primarily due to a combination of soil type, lower pH, and higher DOC (Johnson and Kahl, 2005).

Table 4.8. Total Dissolved and Organically Bound Aluminum Results from 2004 Surveys. (Johnson and Kahl, 2005)

Drainage	**Analysis (µg/L)**	**# of cases**	**Min.**	**Max.**	**Median**	**Mean**	**Standard Deviation**
Narraguagus	Total Al	26	45.1	250.4	144.9	144.7	55.6
Narraguagus	Al-org	26	38.5	262.1	109.0	133.1	58.8

The amount of time fish are exposed to diminished pH also subjects them to high levels of soluble organic aluminum. Below pH of 6.2, aluminum becomes soluble in water and may become attached to gills and diminish the salmon's ability to undergo smoltification. Table 4.9 indicates that the number of hours that pH levels were depressed (≤ 6.0) was greatest in 2003 and 2004. Furthermore 2003 experienced 81 hours in which the pH was < 5.5 and salmon may have been exposed to potentially harmful Al levels.

Table 4.9. Hours of Depressed pH in Narraguagus River, 2000-2004.

	2000	**2001**	**2002**	**2003**	**2004**
pH < 6.0	143	319	456	1253	1090
pH < 5.5	0	0	2	81	15

4.4 Dissolved Oxygen

4.4.1 Dissolved Oxygen Requirements of Atlantic Salmon

Adequate dissolved oxygen (DO) is necessary for all aquatic life. As mentioned in Chapter 2, Maine state DO standards for Class AA, A, and B waters shall not be less than 7 ppm or 75% saturation, whichever is higher. Below 5 mg/L aquatic life becomes stressed and levels of 2 mg/L can result in large fish kills. Depressed DO is often the result in elevated productivity and nutrification; see Section 4.5 for discussion of nutrients. Likewise DO concentrations should not exceed 100 percent. Fish in waters containing excessive dissolved gases may suffer from "gas bubble disease"; however, this is a very rare occurrence (Kentucky Water Watch, 2005).

Suboptimal DO levels may have sublethal effects on various life stages of coldwater fish species. According to USEPA (1986) reports, production impairment for salmonid embryo and larval stages may occur when DO limits are less than 9 mg/L (Table 4.10). Other sublethal life stage effects may occur between 4 and 6 mg/L. Reiser and Bjornn (1979) report that low dissolved oxygen concentrations during egg incubation may delay hatching, increase anomalous development, stimulate premature hatching, and ultimately lead to weaker, smaller fry. Low oxygen levels can also increase toxicity of contaminants to anadromous fish, including ammonia, zinc, lead, and copper (Colt et al 1979, Davis 1975). Behaviorally, fish may avoid low or high dissolved oxygen conditions by physically moving out of an area.

Table 4.10. Instream Dissolved Oxygen Limits for Salmonid Life Stages (USEPA, 1986).

I. SALMONID WATERS	**Dissolved Oxygen**
A. Embryo and larval stages	
No production impairment	11
Slight production impairment	9
Moderate production impairment	8
Severe production impairment	7
Limit to avoid acute mortality	6
B. Other life stages	
No production impairment	8
Slight production impairment	6
Moderate production impairment	5
Severe production impairment	4
Limit to avoid acute mortality	3

4.4.2 Review of Dissolved Oxygen Data

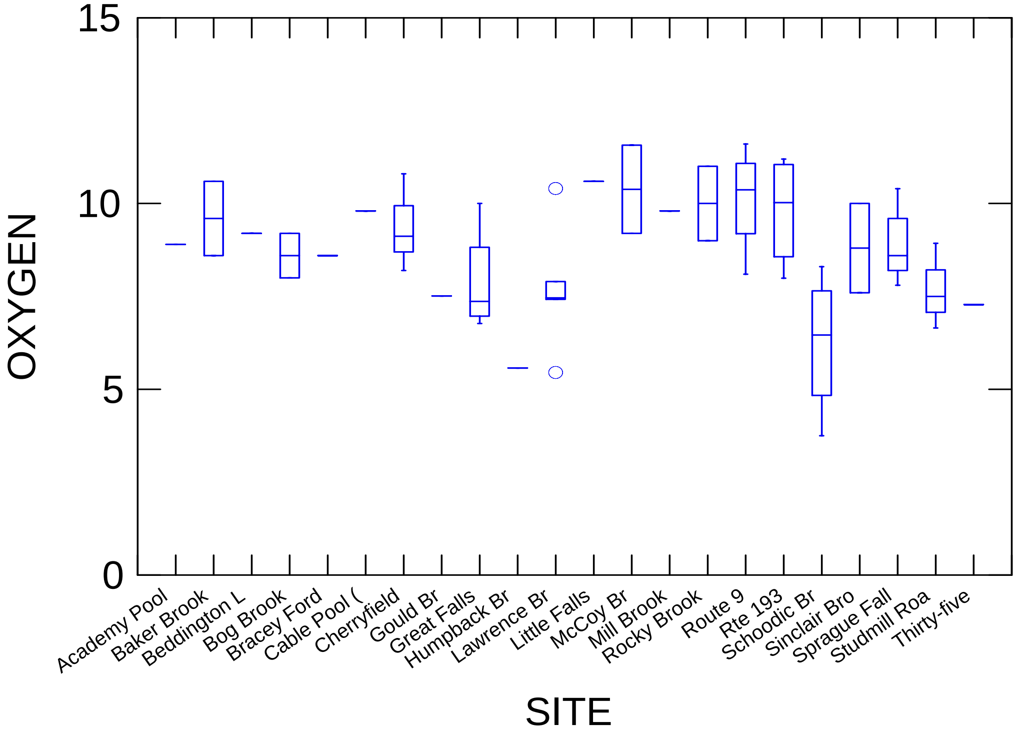
Lake DO is discussed in Section 4.12 Lake WQ.

Information contained in this section was obtained from the MDEPAS Presentations to the NRWQMP Workgroup, June 2005.

The MDEPAS/NRWC measured dissolved oxygen (DO) at several sites (MS, tributaries, and lakes) during 1999-2005. DO ranged from 12 mg/L at McCoy B to 4 mg/L in Schoodic Brook (Figure 4.13). The average for most sites is between 7 and 10 mg/L (75% saturation for Class AA/A Standard). Only Lawrence and Schoodic brooks fall below the Class AA/A standards at 5 and 4 mg/L respectively. Both of these streams are impacted by beaver flowages and therefore the depressed DO may be considered naturally occurring.

The grab samples were taken at various times (morning and afternoon) during the day. There were no night samples and few if any early morning samples. Therefore there is no information on diurnal patterns or overnight DO depletion due to nocturnal respiration.

Figure 4.13. Dissolved Oxygen for MS and tributary sites on the NRW, 1999-2005.



4.5 Nutrients

4.5.1 Nutrients Effecting Water Qaulity

Major and minor nutrients important to coldwater ecosystems include carbon, nitrogen, phosphorus, silicon, calcium, magnesium, sodium, potassium, and sulfur. In general, balanced nutrient levels are required to ensure productivity of all community levels in the ecosystem (algae, zooplankton, macroinvertebrates, etc). Problems can occur when nutrient levels fall above or below specific ranges. Low calcium, for example, may influence pH and cause bone loss in fish while elevated nitrogen and phosphorus (nutrification) may cause excessive algal growth and DO depletion.

Although algal blooms usually pose no direct health effects, certain species produce endotoxins or exotoxins that may be harmful to aquatic life. In addition to algal toxicity, excessive shading of the non-surface waters, the subsequent reduction in photosynthetic activity, and impacts on temperature, dissolved oxygen, and nutrient cycling, may, in turn, affect other aspects of the ecosystem upon which salmonids depend (Institute for Fisheries Resources and Sheepscot Valley Conservation Association, 2005). Algal growth can also have an adverse impact on salmon if a rich nutrient supply causes an algal bloom which leads to a reduction in dissolved oxygen due to nighttime respiration by live algae and decomposition of dead algae (Deas and Orlob, 1999).

4.5.2 Review of Nutrient Data

Lake Nutrients are discussed in Section 4.12 Lake WQ.

Information contained in this section was obtained from the MDEPAS Presentations to the NRWQMP Workgroup, June 2005.

Nitrates

The state average for nitrates (NO3) is 4 μeq/L (Smith et al., 2003) and the DE rivers are generally lower due to the oligotrophic nature of the watersheds and soils. Nitrates in rainwater are often as high as 20 μeq/L, but this is absorbed immediately by nutrient-poor soils and vegetation and is therefore not found in the surface waters except during high runoff storm events.

The MDEP/NRWC is the only program monitoring for nutrients in the NRW. They collected grab samples from the MS and several tributaries for nutrient analysis at the UMSGMC from 1999-2002. Most of the samples were taken during baseflow (i.e., when rivers are mainly supported by groundwater flows, defined here as when there has been no significant rainfall in the last 7 days; these samples are largely summer samples) but a few were taken during stormwater events (within 48 hours of a storm of 1.0 inches or more). Nitrates in baseflow samples (Figure 4.14) were generally very low (1-2 μeq/L) throughout the watershed with the exception of Shorey Brook, which had significantly higher nitrates (0-20 μeq/L). The source of elevated nitrate levels in this brook is not well understood but could possibly be attributed to localized geology and/or vegetation.

Stormwater nitrate measurements were also very low (<3 μeq/L) with the exception of the Cherryfield site, which had levels ranging from 1-17 μeq/L. This wide range is not unrealistic as they reflect the accumulation of nutrients that often occurs at the mouth of high order streams draining large watersheds.

Total Phosphorus

Total phosphorus is composed of both organic (bound to organic matter) and inorganic (bound to soil particles) forms. The Maine state average for total phosphorus (TP) is 13 μeq/L. MDEP/NRWC samples from 1999-2002 had a wide range of baseflow TP levels (5 and 29 μeq/L) but most samples were within the state average (Figure 4.15). A few sites such as Sinclair and Bog brooks had regularly high mean baseline TP levels (25 and 19 μeq/L respectively) suggesting that the source of TP at these sites is bound in a soluble organic complex (with DOC). Furthermore, in all sites except Cherryfield, stormwater TP is lower than baseflow TP suggesting again that TP is mobilized in a soluble form (with DOC) that is diluted in stormwater events. High TP is Cherryfield is most likely the result of several factors including an overall increase in the size of the drainage at the mouth of the river and elevated TP input from the surrounding residential area.

Figure 4.14. MDEP Baseflow and Stormwater Nitrates in MS and tributary sites in the NRW, 1999-2002.

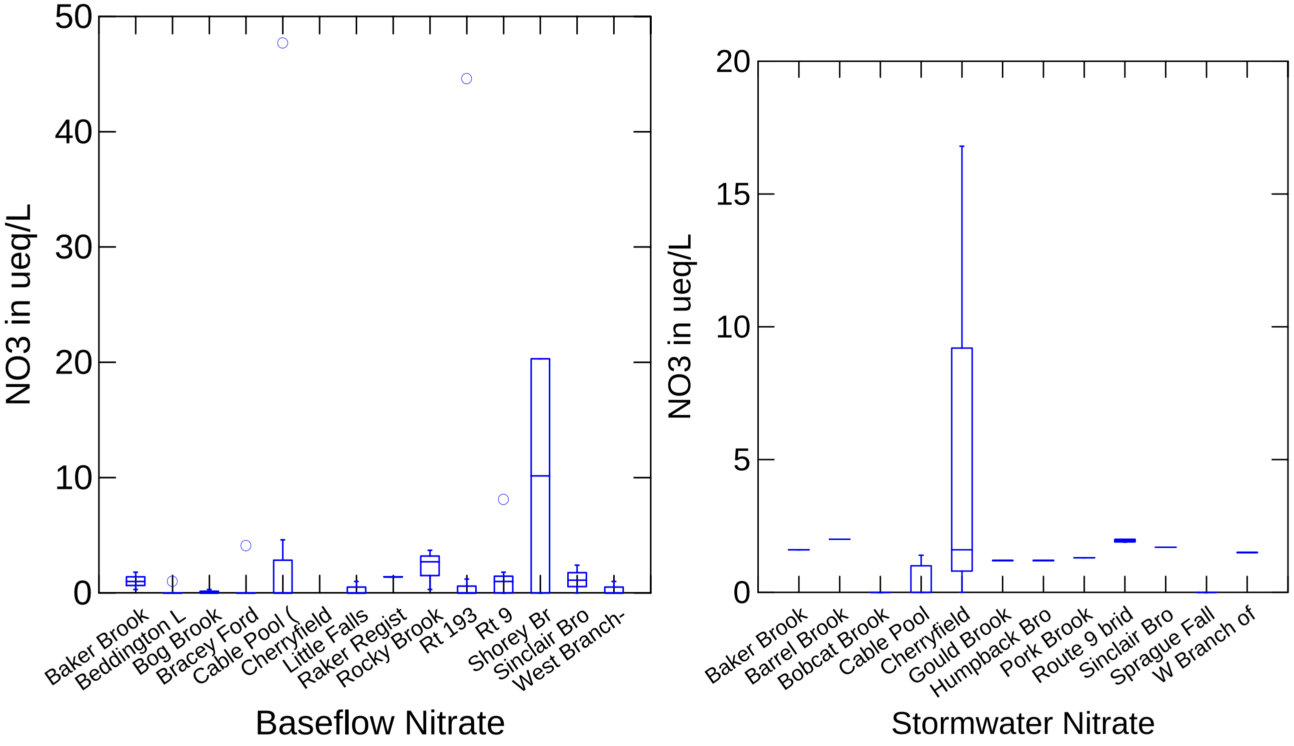


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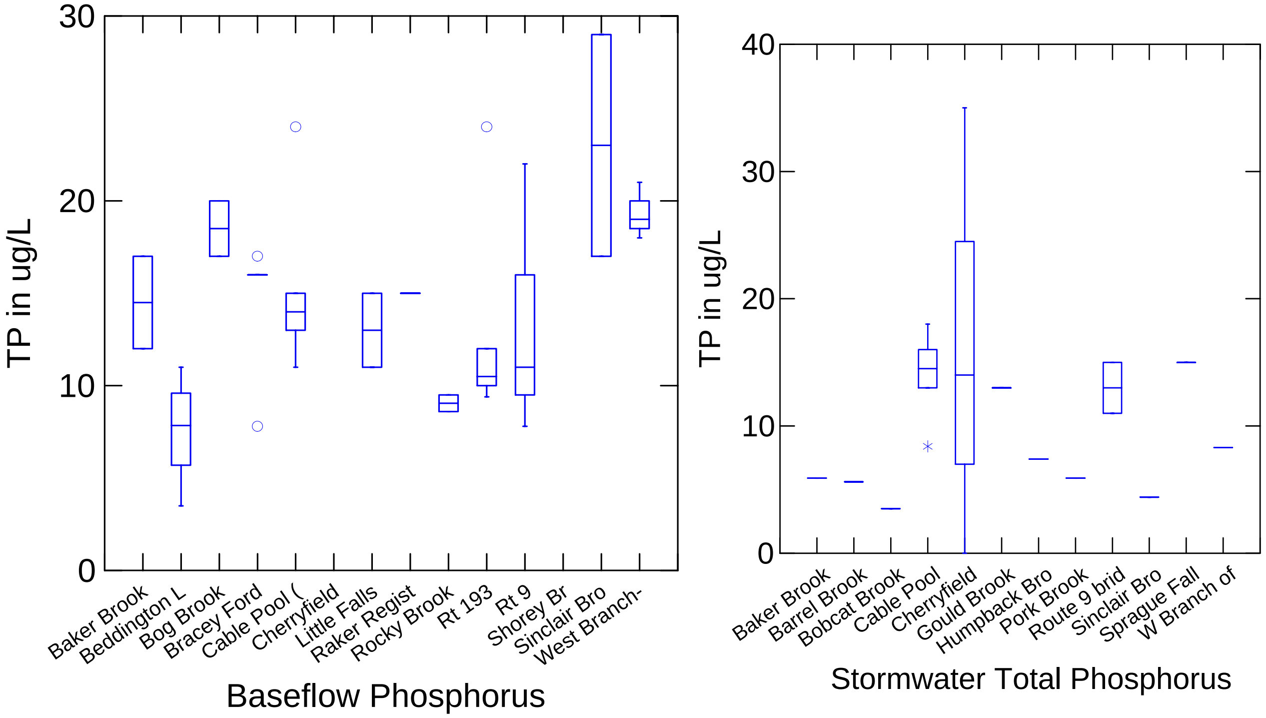
Figure 4.15. MDEP Baseflow and Stormwater Total Phosphorus of Sites in the NRW, 1999-2002.



4.6 Bacteria

4.6.1 Bacteria Effects on Water Quality

Bacteria of greatest concern to water quality are those species that may affect human health. The introduction of disease-causing bacteria and viruses can come from a variety of sources such as failing septic systems and boat discharges, livestock, waterfowl, and pets. Elevated bacteria may contaminate shellfish beds, may close public swimming areas, and diminish drinking water supplies. As mentioned in Chapter 2, Maine state bacteria standards for Class AA and A waters is as naturally occurs and for B waters shall be less than 64/100 ml (geometric mean) or 427/100 ml (instantaneous).

The fecal coliform multiple tube fermentation method is used by several agencies as the indicator of waste from warm-blooded animals. Although it directly measures for the presence of E. coli, it is also an indicator of more lethal pathogens such as typhoid, hepatitis, and cholera. In addition to the direct impacts of the pathogens, elevated bacteria may also cause indirect impacts such as DO depletion, elevated BOD, and elevated temperatures.

4.6.2 Review of Bacteria Data

Information contained in this section was obtained from the MDEPAS and MDMR Presentations to the NRWQMP Workgroup, June 2005.

Both MDMR and MDEPAS have bacteria monitoring programs. While MDEPAS focuses on freshwater sites in the NRW, MDMR monitors sites in the bay. The goal of the MDMR Shellfish Sanitation Program is to protect public health by ensuring that shellfish are harvested from pollution-free areas and are processed and transported under sanitary conditions. The agency maintains approximately 9 sites in the estuary from the Route 1A bridge in Milbridge extending to Fickett Point on the east and Long Point to the west.

A random sampling method is used in order to obtain an understanding of WQ in varying conditions such as seasonal variation, tides, and weather changes. Sites are sampled a minimum of six times per year to maintain open approved status. Classification of a site is based on the statistical average of the 30 most recent samples, the "90th percentile" (P90), or the number of colonies per 100 ml sample. Table 4.11 summarizes the classification standards of the shellfish sanitation program. Sites may also be closed if they are downstream from known discharges regardless of bacteria levels.

Table 4.11. MDMR Water Quality Classification.

Classification	**P90**	**Geometric Mean (gm)**	**Definition**
Approved	<49	<14 mpn*	Open. No sewage pollution or red tide
Conditionally Approved	<49	<14 mpn	Open unless there is > 1 inch rainfall in 24 hour period. Examples include sewage treatment plant or marina.
Restricted	<300	<88 mpn	Depuration harvest only. Slightly polluted area; harvest under strictly regulated conditions by licensed operation that purifies shellfish before sale.
Prohibited	>49	>14 mpn	Closed. Actual or potential sewage or red tide or lack of sufficient data.

* mpn= Most Probable Number

Seven of the nine MDMR sampling sites are closed (prohibited) to shellfish harvesting due to elevated levels of fecal coliform (Table 4.12). Most of these sites have P90s of greater than 49 or are directly downstream of the Milbridge municipal treatment facility. The source of the bacterial contamination is thought to be faulty private septic systems and problems associated with the municipal sewer system. Milbridge town officials have been working to remediate the pollution for several years.

Table 4.12 Fecal Coliform Levels in the Narraguagus Estuary as of June 2005.

Station	Geomean	P90	Approved/Prohibited
EL 20	6.4	27.6	Approved
EL 21	6.9	35.1	Prohibited
EL 23	10.5	63.2	Prohibited
EL 24	112.2	749.0	Prohibited
EL 26	10.3	51.6	Prohibited
EL 31	8.8	56.2	Prohibited
EL 32	10.8	76.6	Prohibited
EL 32.6	8.1	41.9	Prohibited
EL 33	6.4	28.2	Approved

MDEPAS/NRWC monitor 10 sites in Cherryfield Village below the Ice Dam which are Class B waters (Figure 4.16). Most sites have values below 30 colonies, which is below the class AA/A/B (64 g.m.) and public-beach closure (126 g.m.) limits. However, three areas appear to have elevated bacteria: the lower (Rt. 1) bridge, Academy Pool, and the unnamed tributary near the train station. Elevated bacteria at these sites are most likely the result of cumulative effects from the 37 overboard discharge septic systems (OBDs) located on the shores of this portion of the river. If not properly maintained these systems may release bacteria into the river. Elevated bacteria that are not associated with septic systems may be attributed to wildlife (such as occasional samples taken above the Cherryfield ice dam).

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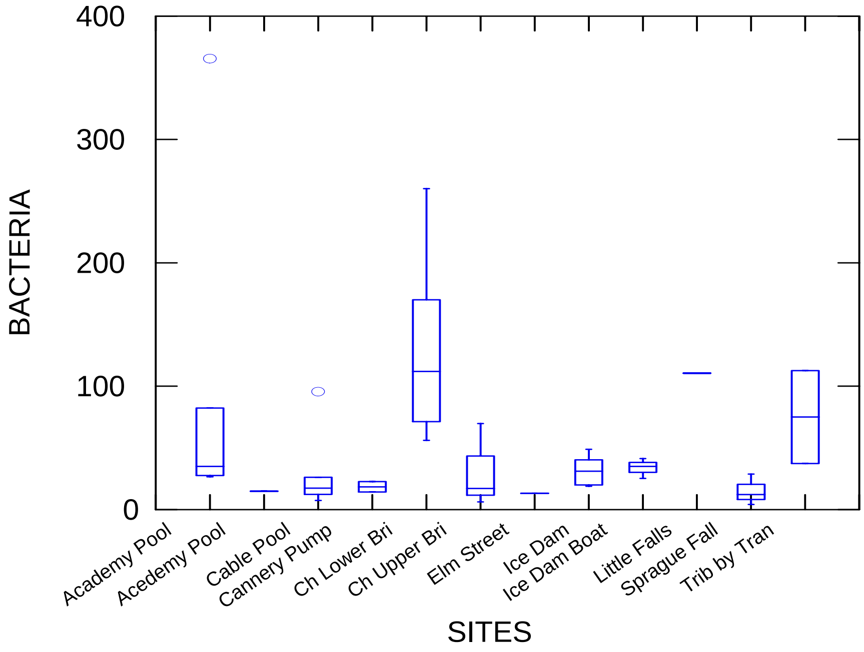
Figure 4.16. Bacteria Levels (colonies/100 ml) in the NRW, 2002-2003 (MDEPAS, 2005).



4.7 Macroinvertebrates

4.7.1 Macroinvertebrates and Productivity

Juvenile Atlantic salmon feed primarily on species of Ephemeroptera, Plecoptera, Diptera, Trichoptera, Coleoptera, and Odonata. Alevin feed on smaller species, and parr feed on increasingly larger species as size increases. Siebenmann (1995) sampled macroinvertebrates at six sites along the main stem of the Narraguagus River from the confluence with Humpback Brook to Cherryfield. She compared samples collected during her 1991-1992 study with those collected by Mingo at the same sites in 1974 (Table 4.13). Siebenmann found that there was no significant difference in abundance at the six sites between the two studies and that the density of macroinvertebrates was greater among the three northern sites than in the three southern sites in both studies.

Ephemeroptera, Diptera, and Trichoptera were the most abundant groups, ranging from 73% to 79% of total individuals collected. Although there was high year-to-year variation in abundance and community composition during the 1991/1992 study, Siebenmann concluded that the macroinvertebrate supply was stable enough and sufficient in species type and abundance to support the population of juvenile salmon. Environmental parameters measured at the same time also showed little change over the 17-year interval (Table 4.14). She concluded that neither water quality nor the food base for immature fish had deteriorated between 1974 and 1991/1992.

Table 4.13. Macroinvertebrate Population Parameters Observed Among Six Study Sites in the Narraguagus River from June through September (data derived from Siebenmann, 1995).

Year	Mean density (#/m^2)	Mean diversity (Shannon-Weaver index)	Number of individuals	Number of taxa	Percent dominants (Ephemeroptera, Trichoptera, Diptera)
1974	6578	3.49	16,327	86	79%
1991	6088	3.54	14,808	108	73%
1992	9461	3.58	23,346	112	74%

Table 4.14. Ranges in environmental parameters observed among six study sites in the Narraguagus River from June through September (data derived from Siebenmann, 1995).

Year	Temperature (°C)	Discharge (m^3/sec)	Velocity (ft/sec)	Dissolved oxygen (mg/L)	pH
1974	16.8 - 23.2	16.1	2.03*	7.6-8.1 to 8.5-9.3	6.1 - 7.2
1991	15.0 - 22.5	14.3	5.7 - 10.1	8.6-9.0 to 9.8-11.8	6.6-7.2 to 6.9-7.3
1992	17.0 - 24.0	12.0	6.7 - 11.5	8.8-9.6 to 9.5-10.1	6.2-7.3 to 6.6-7.3

* Data available for September only

4.7.2 Review of the Macroinvertebrate Data

Information contained in this section was obtained from personal interviews with Leon Tsomides, MDEP Biomonitoring Program and was presented to the NRWQMP Workgroup, June 2005.

MDEP Biomonitoring Program has monitored several sites on the MS between 1984 and 2001 for class attainment. (The next date for sampling the Narraguagus is 2007.) Monitoring includes DO, temperature, and macroinvertebrate sampling using rock bags. Data collected in accordance with Maine's biocriteria protocol are analyzed using statistical models, whose results estimate the association of a sample to four water quality classes defined by Maine's Water Classification Program. Findings of the Biological Monitoring Program are used to document existing conditions, identify problems, set water management goals, assess the progress of water resource management measures, and trigger needed remedial actions. Maine's actual protocol for numeric biocriteria is designed to measure the response of benthic macroinvertebrates to human influences. (MDEP, 2002).

Table 4.15 summarizes the results of macroinvertebrate biomonitoring between 1984 and 2001. The Cherryfield site, which is located above the Rt. 1 Bridge, did not attain class B standards in 1984 and 1993. It did not attain any standards in 1984 but improved to Class C in 1993. In 2001 the site surpassed Class B standards and attained Class A standards. The improvement is most likely due to the removal of effluent discharge from the two blueberry processing plants upstream from the site, which took place in the late 1990s.

Although the site does attained Class A standards in 2001, it should be noted that it still exhibits some enrichment; the statistical model shows that the site has only a 74% probability of meeting Class A standards. This is supported by the fact that the site has a high number of collector feeders (such as Hydropsyche and Cheumatopsyche), a low number of pollution-sensitive Plecoptera (stoneflies), and generally fewer pollution-sensitive species (Ephemeroptera, Plecoptera, Trichoptera) overall.

The Deblois site (MS at Rt. 193) has met Class AA/A standards most years. In 2001, the data indicated a 99% probability of meeting Class A standards. Although there was less total abundance, there were ample numbers of pollution-sensitive species such as Brachycentrus (Caddis). Class AA/A waters are generally less productive and can produce fewer total insects. In 2001, the total abundance of the Deblois site (660) was half that of the Cherryfield site (1465).

Table 4.15. Summary of MDEP Biomonitoring History (MDEP 1999, 2001)

Location	YR	Class	Model	Abundance
Cherryfield	84	B	**NA**	364
	93	B	**C**	1054
	01	B	A	1465
Deblois	87	AA	A	282
	89	AA	A	602
	96	AA	B	542
	01	AA	A	660

NA = did not attain
Model = Class that site attained according to the MDEP Model

4.8 Streamflow

4.8.1 Stream Flow Features of Atlantic Salmon Habitat

Stream flow is influenced by the slope gradient of the streambed, breadth of streambed, and volume of inflow from tributaries and groundwater. Optimal salmon habitat for both spawning and rearing has a 1 to 1.5% gradient, although salmon have been found in streams with 0.5 to 2.0% gradients. Shallower gradients may allow deposition of fine sediments that interfere with spawning, survival of gestating embryos, and the emergence of fry (McHenry et al., 1994, Lisle, 1989). The Narraguagus River has an average slope gradient of only 9 ft/mi; the West Branch is steeper, averaging 19 ft/mi (Kleinschmidt, 1999).

Baum and Jordan (1982) have reported that spawning redds (Table 4.16) for Atlantic salmon in Maine are characterized by flows of 0.9-2.6 ft/sec (27-80 cm/sec); rearing habitat flows range from 0.7 to 2.5 ft/sec (20-75 cm/sec) with the optimal flow between 1.6 and 2.1 ft/sec (50-65 cm/sec). Similar values have been found by Beland, et al. (1982) for redds (53 ± 1.3 cm/sec), by Cunjak (1988) for flow in winter streams supporting salmon juveniles (38.7-45.7 cm/sec), and by Heggenes (1990; 10-60 cm/sec). Heggenes also found that as parr increased in size, they tended to gradually move to portions of a watershed with deeper water, higher velocities, and coarser substratum. Older parr occupy habitats with a wide range of depth, velocities, and substrata, perhaps varying their habitat use in time and space (Heggenes, 1990). However, there is some evidence that alevins avoid feeding during periods of peak river flow (Jensen, et al., 1991), timing the initiation of their feeding to occur either before or after peak flows in the spring. Water depth and velocity can also influence stream temperature and the existence of cool-water refugia. Nielsen, et al. (1994) found that steelhead spent significantly more time in pools that were greater than 3m in depth in streams with flows less than 1 m^3/sec. Stream flow was slow enough to allow the pools to thermally stratify, with the bottom layer up to 7 ^{o}C cooler than surface waters. Such cool-water refugia could also be important to Atlantic salmon.

Table 4.16. Water Velocity in Streams Supporting Atlantic Salmon Juveniles.

Reference	**Water velocity (cm/sec)**	**Comments**
Baum and Jordan (1982)	27-80	spawning redds
	20-75	rearing habitat range
	50-65	rearing habitat optimum
Beland, et al. (1982)	53.0 ± 1.3	
Cunjak (1988)	38.7-45.7	winter stream velocity
Heggenes (1990)	10-60	rearing habitat

Streamflow Alteration

Dams and water withdrawal are two common landuse activities affecting stream flow and WQ. In general, dams diminish water quality and aquatic habitat in the following ways:

- Dams reduce the natural aeration process, increase time of travel, and thereby lower dissolved oxygen content and raise temperatures.
- Dams cause an increase in the settling of sediments and nutrients on the upstream side.
- In some cases, dams may alter flow downstream; in general, water is released and flow is high in the spring, and water is withheld and flow is low in summer.
- Dams change upstream aquatic ecosystems from lotic (fast moving) to lentic (slow moving).
- Dams may obstruct fish passage during low flow and, in some cases, year round.
- Dams may cause increased erosion downstream.

Water withdrawal (for agricultural irrigation) can influence water quality by reducing the cold-water habitat for fishes and reducing the wetted perimeter available for aquatic invertebrates. Altering tributaries may reduce the amount of cold water entering the main stem (location of priority salmon habitat).

Water withdrawal limits are regulated by LURC in the unorganized territories and by MDEP in towns. Waters in DEP jurisdiction currently do not have withdrawal regulations other that no party may “dewater” a body of water. LURC withdrawal regulations are based on a percentage of the total depth and total volume at high water mark. Table 4.19 lists the water bodies from which the industrial blueberry growers withdrawal water for irrigation purposes.

4.8.2 Review of Stream Flow Data

Information contained in this section was obtained from the USGS, MDEP (Dams) and MASC Presentations to the NRWQMP Workgroup, May 2005.

Scientists in the USGS Maine Water Science Center collect, analyze, and interpret water data in cooperation with other federal, tribal, state, and local agencies: universities; and other research centers. Their areas of data collection and study include hydrology and hydraulics, biology, water-chemistry, and geology and geomorphology. There are two gages in the Narraguagus Watershed (245 mi^2). Table 4.17 lists the locations of the gages and their watershed size.

Table 4.17. USGS Gages in the NRW.

Gage	**Location**	**Watershed Size**
Cherryfield	MS at the Cable Pool	227 mi^2
Deblois	MS above the Rt 193 Bridge	96.5 mi^2

Climate directly affects hydrology within a watershed. The climate of the NRW can be characterized as follows:

- 51in/yr precipitationMean annual temperature 43 °F
- Mean monthly temperature range:

  18 °F January

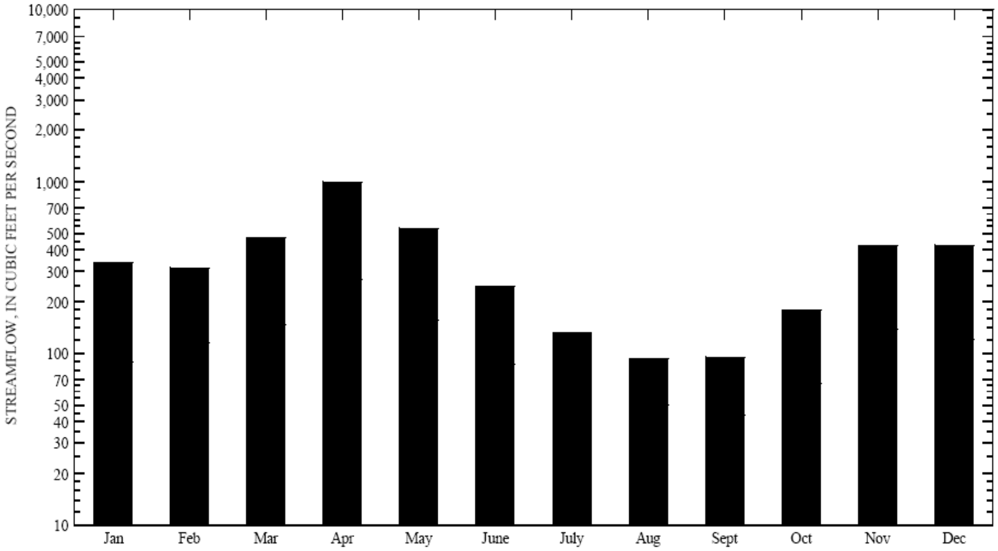
  65 °F July
- 19 in/yr evapotranspiration
- 30 in/yr runoff

Stream flow in the Narraguagus River watershed

In 1999, Kleinschmidt Associates determined the following annual flow patterns on the Narraguagus as part of the Instream Flow Studies. These patterns are consistent with USGS average monthly stream flow data (Figure 4.17).

- Peak flows in April due to snowmelt and spring rainfall
  (1010 cfs average in Narraguagus)
- Decreasing flows from spring runoff through late August
  (June 250 cfs to August 90 cfs in Narraguagus)
- Lowest flows from late July to mid-September
  (July 130 cfs to September 91 cfs in Narraguagus)
- Increasing flows in response to typical autumn rains in October, November, December
  (October 172 cfs to December 426 cfs)
- Decreased runoff in January and February when most precipitation remains on ground
  as snow (January 340 cfs to March 480 cfs)

Figure 4.17. Median Monthly Streamflows in the Narraguagus, 1948-1992 (USGS, 2000).



Mean flow between 1946 and 2004 ranged from 256 cfs (in 2001) to 761 cfs (in 1973), with an overall mean of 487 cfs. Studies of stream flow at eight sites along the mainstream occurred in 1998 and are consistent with the long-term flows (Table 4.18), as are the means for 2003 (549 cfs) and 2004 (480 cfs; Dudley, 2005).

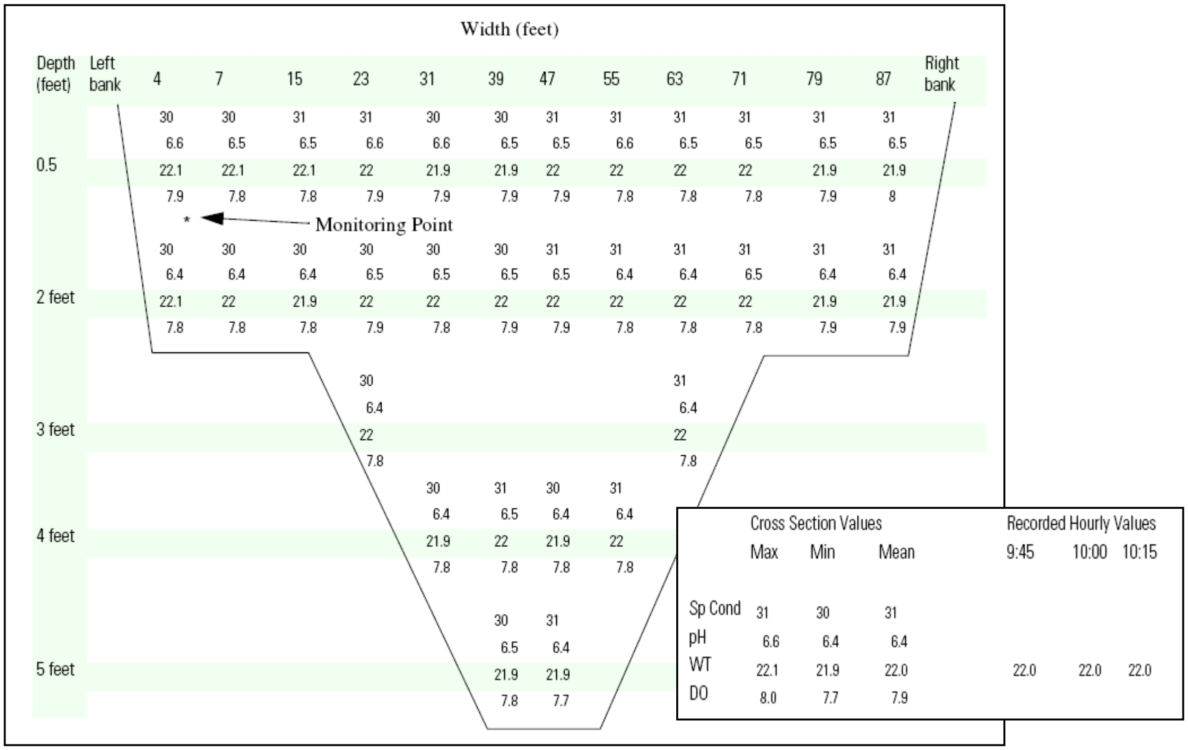
Table 4.18. Water Flow in the Narraguagus River and in the West Branch in 1998 (from Kleinschmidt, 1999).

Flow condition	Flow at Humpback Brook (cfs)	Flow at Cherryfield (cfs)	Flow in West Branch (cfs)
Low flow	7	57	11
Mid flow	40	240	80
High flow	155	790	278

USGS monitored temperature and specific conductance at the Cherryfield gage in 2004 and 2005. Quality assurance checks are typically performed several times throughout the year using the cross sectional profile indicated in Figure 4.18.

The profile indicates that the stream at the gage is well mixed and that readings are fairly consistent throughout the cross section. It is unclear if other portions of the river are as well mixed and what the implications may be if areas of high priority habitat are not well mixed. See ASC temperature protocol.

Figure 4.18. Water-quality Cross Section performed on July 12, 2004 with Field Parameters Displayed in the Following Order: Specific Conductance, pH, Water Temperature, and Dissolved oxygen.



The MASC is actively tracking hydrological data and has created a data catalogue of available hydrologic data that are linked to MASC Maine Salmon database file and contains:

- Ground Water - Surface Water Modeling Possibilities
- Resource for ongoing efforts at MASC

The purpose of the data catalogue is to:

- Link to Existing MASC Databases
- Locate Datasets
- Define Attributes: Spatial, Temporal, Purpose
- Match Model Inputs.

Impacts on stream flow

Water is removed from the watershed to irrigate blueberry fields at 10 sites in addition to irrigation ponds (Table 4.19). Water withdrawal limits exist for all of these sites except the man-made irrigation ponds. Water withdrawal can influence water quality by reducing the cold-water habitat for fishes and by reducing the wetted perimeter available for aquatic invertebrates. Withdrawal of water from tributaries can reduce the amount of cold water entering the main stem, which is the location of priority salmon habitat.

Table 4.19. Sources of Agricultural Surface Water Withdrawal

Location	**Landowner**	**Regulatory Agency**	**Withdrawal Limit**
Schoodic Lake	CFI	LURC	1 ft for season
West Branch, Bill Hill	CFI	LURC	No longer withdrawaling
East Pike Brook Pond	CFI	LURC	1 ft thru 7/15; 2 ft thru 9/30
West Pike Brook Pond	CFI	LURC	1 ft thru 7/15; 2 ft thru 9/30
Horseshoe Pond	CFI	LURC	1 ft thru 7/15; 2 ft thru 9/30
Pike Brook Well	CFI	LURC	2400 gpm (May-Sept) – peak instantaneous
Spring Hole Pond	CFI	LURC	1 ft thru 7/15; 2 ft thru 9/30
Pork Brook	Wymans	LURC	No longer withdrawaling[1]
Schoodic Lake	Wymans	MDEP	Voluntary[2, 3]
Pineo Pond	Wymans	MDEP	Voluntary[2]
Spectacle Pond	Wymans	MDEP	Voluntary[2]
Flynn Pond	Wymans	MDEP	1 foot
East Branch, Jr. Grant	Wymans	MDEP, USFWS	89 cfs[4]
Man-Made Irrigation Ponds See Dam List	Wymans	MDEP	None

[1] Withdrawal took place from Pork Brook prior to 2004 but has since ceased.
[2] Subject to MDEP policy regarding dewatering.
[3] Schoodic Lake lies in both LURC (CFI) and MDEP (Wymans) jurisdiction. The withdrawal limit from Schoodic on the LURC side is 1-2 inches while the MDEP is side is unregulated. CFI and Wymans have an agreement that states that both companies will stop withdrawal at that LURC limit.
[4] As measured at the USGS Cherryfield Gauging Station. MDEP 1998 PBR 19684 withdrawal. Only used for spring frost protection.

There are currently 10 dams in the watershed (Table 4.20). Only one of the dams occurs in the mainstem, the Cherryfield Ice Control Dam; the remaining dams occur in association with ponds on tributaries or kettle hole ponds. The outlet of Beddington Lake has the remnants of a dam that does not appear to be altering flow downstream or impounding the lake significantly. Beddington Lake is primarily a naturally occurring impoundment.

None of these dams create impoundments that serve as reservoirs for energy purposes nor are they manipulated to augment flow (e.g., flood control, etc). Most of the dams are "run of the river" in which headpond input equals output (except for evaporative losses). In this case, the natural flow downstream is generally not affected; the flow increases during rain events and decreases during dry periods.

None of the dams appear to be interfering with fish passage. The only dam that might impede passage is the Cherryfield Ice control Dam but that is equipped with a Denil fishway, which is used by salmon and other species. At this time USFWS is working to enhance the operation of this dam and fishway.

Most of the dams are owned by Jasper Wyman and Son Blueberry Company and are used primarily for irrigation purposes. There is no evidence that the dams maintained at any of the ponds are augmenting flow downstream. In most of the dams, flow comes from the bottom, which generally will be of good quality. Inflow from groundwater is generally zero during most summers and recharge is usually negligible. Most of the water comes from runoff, spring snowmelt, and precipitation.

Table 4.20. Location/ownership Information on the Dams in the NRW.

Dam	**Location**	**Owner & Address**
Narraguagus River Flood Control Dam	Cherryfield	Town of Cherryfield
Bog Brook Flowage Dam	Beddington	MIFW
Farm Pond Dam	Cherryfield	Rusty Gay, Cherryfield, ME
Velvet Pond Dam	Deblois	Jasper Wyman & Son
Fox Hole Pond Dam	Deblois	Jasper Wyman & Son
Ethel Smith Pond Dam	Deblois	Jasper Wyman & Son
Jesse's Pond Dam	Deblois	Jasper Wyman & Son
Brook Lot Pond Dam	Deblois	Jasper Wyman & Son
Lower Jr. Grant Pond Dam	Deblois	Jasper Wyman & Son
Popple Hill Pond Dam	Deblois	Jasper Wyman & Son

4.9 Pesticides

4.9.1 Effects of Pesticides on Aquatic Organisms

Information contained in this section was obtained from the MBPC and Adria A. Elskus, Ph.D. USGS Research Fishery Biologist Presentations to the NRWQMP Workgroup, April 2005.

Pesticides may directly affect organisms through lethal effects (death) and/or sublethal effects that alter or stress various life stages. Sublethal effects may influence hatching, growth, development, immune competence, behavior, endocrine function, and metabolism, among other systems. Such sublethal effects can have serious consequences at the population level (e.g. reproductive success may be impaired in animals whose mating behavior is compromised by disrupted hormone function). Pesticides may also have indirect affects on an organism or population by altering habitat (e.g. reducing stream cover via defoliation) or predator/prey composition or abundance.

Table 4.21 indicates the persistence in surface waters of commonly used pesticides used in blueberry cultivation. Table 4.22 lists the lethal doses (LD50) and lethal concentrations (LC50) of some of these pesticides. Some insecticides currently used in the blueberry industry, Guthion and Imidan, are moderately to very highly toxic to fish and invertebrates. Velpar may be less toxic to fish and invertebrates but is highly toxic to plants and algae and may have indirect effects on the ecosystem (Leyhe, 2004). Therefore, when evaluating the effects of pesticide toxicity, the whole ecosystem must be considered. The ecosystem approach considers both direct lethal and sublethal effects as well as indirect effects on habitat, including parameters such as vegetation, prey, predators, nutrient cycling, and water chemistry parameters (DO, pH, nutrients).

Table 4.21. Persistence of Common Pesticides Used in Blueberry Cultivation.

Pesticide Active Ingredient (Trade Name)	**Type**	**Persistence (in surface water)**
Phosmet (Imidan)	Insecticide	hours-days
Hexazinone (Velpar)	Herbicide	months
Fenbuconazole (Indar)	Fungicide	weeks-months
Propiconazole (Orbit)	Fungicide	weeks-months
Chlorothalonil (Bravo)	Fungicide	months

Table 4.22. Lethal doses (LD50) and Lethal Concentrations (LC50) of Blueberry Pesticides.

Pesticide	**Mammals**	**Fish**	**Inverts**	**Algae**
	14 d LD50	*96 h LC50*	*48 h LC50*	*48hLC5*
Azinphos-methyl (Guthion)	V. High	Moderate- V. High	V. High	?
Phosmet (Imidan)	Moderate	Moderate - V. High	V. High	?
Hexazinone (Velpar)	Low	Low	Low	V. High
Propiconazole (Orbit)	Low	Moderate	Low - Moderate	?
Chlorothalonil (Bravo)	Low	V. High	V. High	?

Hexazinone, listed above, has contaminated the groundwater and is constantly present at low concentrations, year-round, in the Pleasant River (see below), a DE river containing wild Atlantic salmon. Two studies have examined the effects of hexazinone on Atlantic salmon, one in which smolts and larvae were exposed (24 h or 21 days) to low concentrations of hexazinone. Studies in which Atlantic salmon smolts were subjected to 100 ppb hexazinone for 21 days indicate that there was no effect on smolt plasma ions or saltwater tolerance (Nieves-Puigdoller et al., 2004). Furthermore, there were no observed effects on larval survival or size although there was an increase in larval respiratory rate. A study conducted by Spaulding (2005) indicates that a 24-hour exposure to Hexazinone (100 ppb), Phosmet (1 -20 ppb), Propiconazole (200-600 ppb),Terbacil (300-500 ppb), or 2,4-D (200–450 ppb) had no effect on saltwater tolerance, gill Na/K+ATPase activity (a measure of the ability of the gill to regulate plasma ion composition in fish subjected to saltwater), or plasma ions in pre-smolts/smolts.

While these studies suggest there are no effects of hexazinone on salmon, neither study examined chronic, life-time exposure, from egg through smolt, or in the context of multiple stressors, as would be experienced by salmon in hexazinone-contaminated rivers. Studies on additional sublethal endpoints, particularly behavior, in the context of multiple stressors that can exist simultaneously with pesticides (e.g. low pH, high aluminum) are needed before pesticide effects on salmon can be fully ascertained.

4.9.2 Review of the Data

The Maine Board of Pesticides Control (MBPC) has been monitoring blueberry pesticides in the Downeast Atlantic salmon rivers since 1997 and in area ground water since 1994. Currently, MBPC monitors for blueberry pesticides in the Pleasant and Narraguagus Rivers most summers, and monitors ground water every four years.

Hexazinone has been the only blueberry pesticide detected in MBPC ground water studies. Between 1994 and 2002, approximately 42-75 % of wells sampled (wells within ¼ mile downgradient of active blueberry fields) contained hexazinone. The concentrations of hexazinone found are almost always below 10 ppb and usually below 2 ppb. The health advisory level (HAL) for hexazinone is 400 ppb, which according to EPA, is neither lethal nor sublethal to humans. Hexazinone can also be found in surface waters at very low levels (see the Pleasant River Times Series Study available at the MBPC).

The MBPC also conducted drift card studies between 1999 and 2004. Drift cards were placed next to water between the river/stream and blueberry fields during the time of aerial pesticide application to determine the extent to which pesticides enter the waterways. The studies, conducted between 1999 and 2004, showed some pesticide drifting to water resources at 1000’ from target areas (low levels) in four of six years. In addition, of the pesticides aerially applied, phosmet was most commonly found (and most frequently looked for). For the Narraguagus River Watershed, fenbuconazole was found in Bog Brook Flowage while phosmet was found in Pork Brook, Great Falls, and on the MS at the gravel pit (Table 4.23). Not shown in the table below are the non detects for propiconazole and the three positive detections of propiconazole on drift cards: 0.54 ug at Great Falls, 0.47 ug at Crotch Camp Brook, and 0.41 ug at the MS near the gravel pit. A detailed report for each year a drift study was conducted is available at the MBPC.

Table 4.23. Fenbuconazole and Phosmet Levels Found in Drift Card Studies in the NRW, 1999-2004.

SITE	**YEAR**	**Fenbuconazole**	**Phosmet**
Bog Brook Flowage Above Dam	2004	ND	ND
Bog Brook Flowage Near Dam	2004	0.11 ppb water	ND
Bog Brook Flowage Below Dam	2004	ND	ND
Pork Bk NW	2004	ND	0.44 ppb water 3.79 µg card
Pork Bk SE	2004	ND	0.97 ppb water 2.06 µg card
Great Falls	’00-03	-----	0.54-1.70 µg card
MS gravel pit	01	-----	3.50 µg card

Table 4.24 compares the levels of several pesticides found in the Narraguagus River (MBPC, 2000-2004) with known LC50 ranges for aquatic organisms (EPA, 2003). The data clearly suggest that current pesticide levels in Narraguagus are 100 to 1,000,000 times lower than levels known to cause death.While the current pesticide levels found in the Narraguagus River are well below lethal levels, the effects of low levels and/or prolonged exposure to pesticides on Atlantic salmon and macroinvertebrates in this system are currently unknown. Longer exposure and/or additional stressors can greatly increase pesticide toxicity (Reylea et al., 2001).

In studies with the pesticide carbaryl, Reylea et al. (2001) found that even very low, sublethal concentrations could become lethal if exposure time was increased, and/or additional stressors were present. By increasing exposure time from 4 days (the time used to calculate the 4 day LC50) to 10-16 days, carbaryl concentrations of only 3 to 4% of the 4-day LC50 killed 10–60% of gray treefrog tadpoles. When predatory cues were present, carbaryl toxicity increased still further (2 to 4 times) killing 60–98% of the tadpoles. Very low concentrations of pesticides can also have devastating sublethal effects with population-level consequences. Hayes et al. (2002) found that extraordinarily low, environmentally relevant levels of atrazine (0.1 ppb) can cause hermaphrodism in frogs.

Table 4.24. LC50s and Current Detections Levels of MBPC Sampling Sites in the NRW.

Pesticide	LC50 (ppb) All organisms	Surface water (ppb)	LC50/ [Water]
Propiconazole	300–100,000	ND	-
Hexazinone	150,000-350,000	0.22 – 3.20	10^{5}-10^{6}
Phosmet	58–37,000	ND – 0.52	$10^{2-}10^{4}$
Chlorthalonil	24–430	ND	-

4.10 Metals, Chlorine, and Other Toxins

Information contained in this section was obtained from the MDEPAS Presentations to the NRWQMP Workgroup, June 2005 and personal Communication with USFWS, October 2005.

There are currently few data on metals, chlorine, or other toxins (PCBs, etc) in the NRW, however, inputs of these compounds into the watershed are well known. The lack of data represents the type of data/information gap that should be addressed in planning.

Metals

The presence of metals in waterbodies is strongly influenced by atmospheric deposition, soil processes, and by NPS pollution. The presence of metals such as aluminum and mercury are well documented so it is not unlikely that other metals with similar behavior would be present. Gulfwatch is a program that monitors mussel tissue for the presence of metals, PCBs, and other toxins, and this program has data for the St Croix, Union, and Penobscot rivers but none for the DE salmon rivers. In addition, USFWS has tested mussel tissue from the Dennys River in connection with the Eastern Surplus Superfund Site. In all cases some toxins have been found. If samples could be taken from the other DE salmon rivers, these data could be compared to existing data sets. EPA does recommend that trace metal surveys be part of watershed monitoring.

The Narraguagus River is included in an ongoing USFWS/MASC/USGS screening-level contaminant assessment of the eight DPS Atlantic salmon rivers. In the assessment, composite samples of wholebody white suckers are being analyzed for 22 organochlorine compounds (e.g., Total PCBs, DDT metabolites, etc.) and 19 trace elements (e.g., mercury, copper, etc.). Plasma is being analyzed for sex steroids (estradiol and 11-ketotestosterone) and gonad histological examinations are being conducted.

In 2003, white suckers were collected from five locations on the Narraguagus River for the residue analysis portion of the study. In 2005, additional suckers were collected at two locations on the river for the blood biomarker (sex steroid) and intersex (gonad) portions of the assessment.

Preliminary reviews of the tissue residue data do not indicate highly elevated levels of organochlorine compounds in Narraguagus River white suckers. Of the 22 organochlorine compounds in the analytical scan, only the DDT metabolite, DDE (DDT metabolite), was detected and at it occurred at low levels (< 5 ppb, wet weight). All other compounds were below detection. Several trace elements were detected in sucker tissue. Mean levels of trace elements detected in sucker composite samples were: cadmium 0.03 ppm (all expressed as wet weight), chromium 2.20 ppm, copper 1.26 ppm, mercury 0.18 ppm, selenium, 0.57 ppm, and zinc 20.5 ppm. With the exception of chromium, which tends to be higher in omnivorous species than piscivorous species, trace element levels in Narraguagus River white suckers do not appear elevated compared to concentrations reported in Maine, regional, and national biomonitoring programs. The chromium levels in Narraguagus River suckers are being reviewed, and additional sampling may be required to confirm the results of the screening-level assessment.

The plasma and gonad analyses for the Narraguagus River samples should be completed in 2006. Once all laboratory work is completed and the data analyzed for the eight DPS Atlantic salmon rivers, a final report will be prepared and posted on the USFWS Maine Field Office contaminants web site (http://mainecontaminants.fws.gov). The projected report date is December 2007. If samples could be taken from the other DE salmon rivers, these data could be compared to existing data sets. EPA does recommend that trace metal survey be part of watershed monitoring.

Chlorine

Although there are 37 OBD systems within a one-mile reach of the MS, there has been no chlorine monitoring. Chlorine ($Cl2$), chlorite (OCl^-) and hypochlorite ($HOCl^-$) are strong oxidants that are used for disinfection. Chlorine may also form toxic compounds when in contact with ammonia, phenols, and organic material:

- Chlorine + ammonia forms chloramines
- Chlorine + phenols form chlorophenols (including dioxins)
- Chlorine + organic matter forms dioxin and trihalomethanes (including chloroform)

Toxicity is measured in ppb, and varies with pH and temperature and among species. The chlorine residual allowed in drinking water (4 ppm) will kill fish. EPA Acute Toxicity Levels for total residual chlorine are as follows:

- Daphnia - 28 ppb
- Fathead minnow - 105 ppb
- Brook trout - 117 ppb
- Bluegill - 246 ppb

In addition to residential OBDs, there are two industrial discharge permits for the blueberry processing plants. Wyman's OBD discharges treated sanitary wastewater for up to 150 employees; it receives "secondary treatment" in a sand bed and discharges up to 3,000 gallons per day "more than 6 months per year." Cherryfield Foods discontinued their OBD in 2003 and now pumps to storage lagoons and spray-irrigate their wastewater on land. Wyman fruit processing water permit allows for 0.1 mgd, total residual chlorine (TRC) limit 0.1 ppm (winter and spring) and a cooling water flow of 0.27 million gallons per day and TRC limit of 0.1 ppm. Cherryfield Foods permit allows a flow of 0.1 mgd and a TRC limit of 0.1 ppm. Furthermore, the Milbridge Wastewater Treatment Plant discharges some chlorine and bisulfite.

Since chlorine compounds are highly toxic, highly reactive, and a strong irritant of delicate tissue (eyes and gills), monitors should consider chlorine sampling. Measurement of total residual chlorine is difficult since is it highly reactive; EPA suggests that holding time for samples is approximately 15 minutes and that measuring should take place in the field. Some kits can measure to 50 ppb while some electronic probes are sensitive to 10 ppb.

4.11 Sedimentation and Embeddedness

4.11.1 Effects of Sedimentation on Salmon Habitat

Summarized from "Sediment and Atlantic Salmon Habitat," Institute for Fisheries Resources and Sheepscot Valley Conservation Association, 2005.

Excess stream sediments can directly impact salmon productivity especially when fine sediments embed larger gravel and cobble. Atlantic salmon fry prefer to hold in stations over gravel substrate (1.6-6.4 cm), while older parr prefer cobble or boulder substrate larger than 26 cm (Danie et al., 1984). In a healthy stream, young salmon and trout hide in the interstitial spaces between cobbles and boulders to avoid predation and to avoid the extreme cold of winter surface flows (Heggenes, 1990). Waters (1995) found that excess fine sediment diminished Atlantic salmon habitat and also reduced food resources. Sediment caused a loss of pool depth, where both adults and juveniles may reside, and filled interstitial spaces between stream cobble and gravel blocking juvenile use of that area for cover, and decreased aquatic invertebrate production.

In addition, high turbidity impacts the feeding ability of juvenile salmon, although it may also provide them some cover from predation if it occurs during periods of smolt migration (Danie et al., 1984). Newcomb and Jensen (1996) noted that more than 6 days of exposure to total suspended solids (TSS) greater than 10 mg/l is a moderate stress for juvenile and adult salmonids. A single day of exposure to TSS in excess of 50 mg/l is also a moderate stress.

4.11.2 Review of the Data

Information contained in this section was obtained from a MASC presentation to the NRWQMP Workgroup, July2005.

In 1993, the MASC conducted a study that measures the embeddedness as a way to monitor salmon habitat degradation or improvement. The study also determined the interstitial space index (ISI), which provides an index of the volume of interstitial space available. Cobble embeddedness is a measure of the average proportion of rocks in a stream that is buried in fine sediments. The measurement serves as an estimate of interstitial space within cobble streambeds which is used as invertebrate/food habitat and juvenile and egg shelter during winter months.

The study compared the upper, middle, and lower strata of the river and found that there were significant differences between strata for interstitial space, embeddedness, and percent fines (Figure 4.19). The lower stratum had the highest level of embeddedness and percent fines and subsequently had the lowest ISI. These values are not uncommon in the lower reaches of high order streams where fines would naturally accumulate over time. The middle stratum had significantly less fines and embeddedness and a higher ISI, possibly as a result of less development and fewer roads in this region. Surprisingly, the upper stratum had slightly higher fines and embeddedness than the middle stratum that may be the result of the extensive network of unpaved logging roads in the region. The study also found that there was no difference for any variables by habitat type (run vs riffle) except water velocity and water depth. The study also suggests that embedded habitat may limit parr production. Further work directed at the interaction between parr densities and embeddedness levels is forthcoming.

Within any watershed, the source of embeddedness and fine material is generally nonpoint source erosion and sedimentation from a variety of sources. In 2003, the Narraguagus Watershed Council and Project SHARE created a Nonpoint Source Pollution Management Plan (Arter 2003) that documented 175 known sites contributing eroded materials to the MS and its tributaries. The majority of sites were located in the upper stratum of the MS or the stratum of highest priority habitat (See section 2.6) and some elevated embeddedness and fines (Table 4.25).

The plan also states that the greatest source of nonpoint source (NPS) eroded materials is from faulty culverts, unstable shoulders, inadequate ditching, road runoff, and unstable bridge abutments associated with unpaved roads. Furthermore, the landuse associated with 37% of the sites is unpaved logging roads (Figure 4.20), which occur primarily in the upper stratum.

Figure 4.19. Mean ISI, Embeddedness (WEMB), and Percent Fines in the MS.

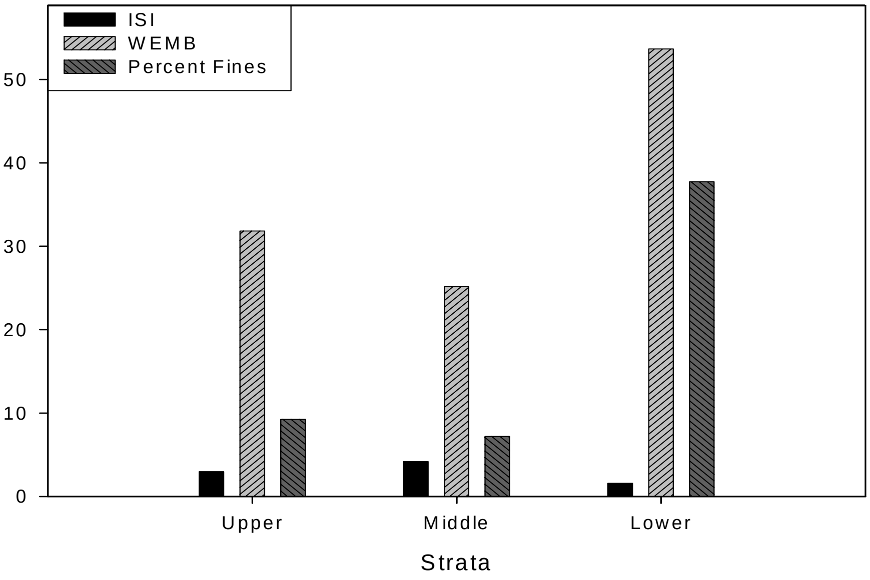
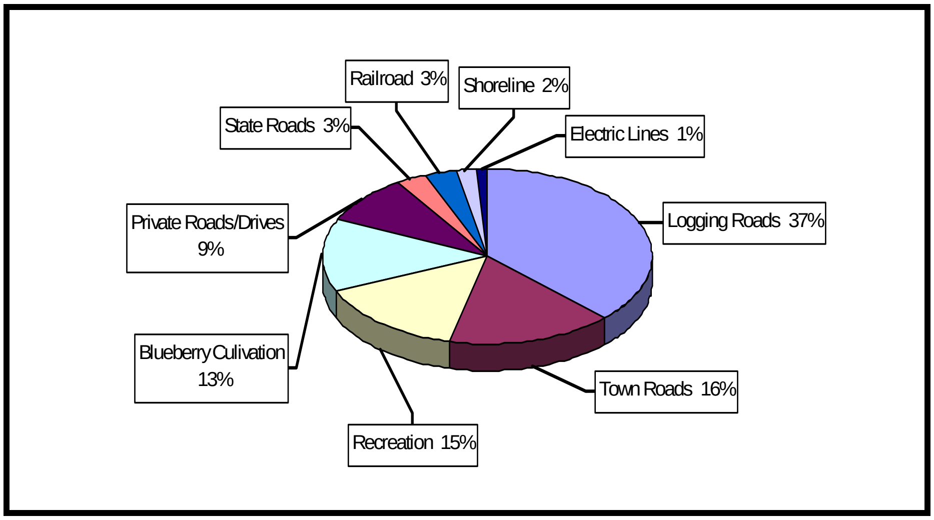


Table 4.25. Nonpoint Source Pollution Sites and Priority Salmon Habitat in the NRW (Arter, 2003).

SUBWATERSHED LOCATION	PRIORITY	PERCENT OF NPS SITES
Deer Lk. Outlet to Beddington Lk. Outlet	1	33%
Beddington Lk. Outlet to Deblois Falls	2	11%
Deblois Falls to Little Falls	3	13%
Rock Dam to Sprague Falls	4	14%
Other Freshwater	5	11%
Estuary	6	18%

Figure 4.20. Landuse Associated with Nonpoint Source Pollution Sites in the NRW (Arter, 2003).



4.12 Lake WQ

4.12.1 Lake Influences

Information contained in this section was obtained from a VLMP presentation to the NRWQMP Workgroup, April 2005.

Lakes and ponds may influence river WQ in a variety of ways:

- Lakes and ponds in the river watershed may be viewed as pollutant "traps."
- However, as nutrients, sediment, and algae concentrations rise in these waterbodies, there is a proportional export of pollutants to the river downstream. "Lake outlet effect" occurs when poor-quality lake water enters the river and subsequently diminishes river water quality.
- Salmon often pass through in-stream lakes in order to access upstream habitat. Poor lake WQ could act as an obstacle to passage. The use of these lakes by Atlantic salmon is not fully understood.
- Untreated runoff from watershed development is a common threat to both lake and riverine systems

The greatest threat to lake and river WQ is elevated productivity in lakes and ponds. Elevated productivity can reduce in clarity/transparency, alter ecosystem balance and stability, reduce DO, reduce coldwater fishery habitat, and lead to the export of algae, nutrients, and sediment to downstream waters. In general all fish will move up to lake layers that have higher DO. In lakes with good DO in deeper layers, adult salmon will hold in the colder, deeper layers. Juvenile salmon will hold in lakes to avoid anchor ice and exposure to extreme cold temperatures in the rivers.

Lakes in Maine are classified into five attainment categories 305(b):

- Category 1: Not attaining all standards
- Category 2: According to the data, the lake attains some of its standards, and there is no reason to believe that it does not attain others.
- Category 3: Possibility of a persistent WQ issue
- Category 4: TMDL Complete
- Category 5: Regional TMDL Needed. All Maine lakes listed because of statewide fish advisory for mercury.

4.12.2 Review of the Lake Data

The NRW contains five lakes (Beddington, Narraguagus, Eagle, Schoodic, and Spruce Mountain) that are greater than 200 acres in addition to numerous ponds (Table 4.26). Beddington Lake is the deepest lake (59 ft) and drains the largest watershed (62 mi^2) while Schoodic Lake has the largest surface area (882 acres) and drains the smallest watershed (1.08 mi^2). Beddington Lake is the only instream lake on the mainstem and occurs between two reaches of high priority salmon habitat. Beddington, Eagle, and Spruce Mountain lakes are managed as warmwater fisheries; Narraguagus is managed as coldwater; and Schoodic is managed as both (Table 4.27).

The MDEP Lakes Program and the Volunteer Lakes Monitoring Program (VLMP) collaborate in the collection of lake data to evaluate water quality, track algal blooms, and determine water quality trends. The VLMP has been collecting WQ data on Maine lakes since the 1970s. The primary focus of their monitoring program is cultural eutrophication, or nutrification, as a result of human activity.

Table 4.26 Morphometry and Hydrology of Lakes in the NRW (VLMP, 2005).

Lake	**Depth: Max/Avg**	**Surface (Acres)**	**Flush/yr**	**Watershed Sq Miles**
Beddington L	59/19	403	14.18	62
Eagle Lake	24/10	250	2.82	4
Narraguagus	34/16	425	2.9	8.5
Schoodic	37/23	882	0.4	1.08
Spruce Mtn. L	43/18	410	1.13	2.68

Table 4.27. Fishery Management of Lakes in the NRW.

Lake/Pond	**IF&W Fishery Management**
Beddington	Warmwater species
Eagle	Warmwater species
Narraguagus	Coldwater species
Schoodic	Cold and Warmwater Species*
Spruce Mtn	Warmwater species

Although there are twelve lakes and ponds in the NRW, only five lakes (Beddington, Eagle, Narraguagus, Schoodic, and Spruce Mountain) have been monitored and only Schoodic, and Spruce Mountain are currently monitored (Table 4.28).

MDEP and VLMP measure the following productivity indicators: transparency, DO, pH, alkalinity, TP, and chlorophyll a (chl a). Transparency, TP, and chl a are sometimes referred to as “trophic state” indicators. Transparency, DO, and pH are performed in the field, while TP and chl a are analyzed at the MDEP lab.

Beddington, Schoodic, and Spruce Mountain lakes experience some loss of DO during summer months. This could be a problem for all fish species and macroinvertebrates. There is high quality salmon habitat above Beddington Lake but this lake loses DO especially during summer months and is being managed for warmwater fish species. The loss of DO and the competition with warmwater species may be stressful to salmon as they migrate through the lake to and from upstream salmon habitat. MIFW and MASC should conduct a lake survey to determine the effects of predacious and competitive species on salmon.

Table 4.28. Monitoring Record of lakes and ponds in the NRW.

Lake	Yrs Data	Active Vol?
Allen	None	
Beddington	7 (74-03)	No
Bracer	None	
Bog Brook	None	
Deer	None	
Eagle	1 (1990)	No
E. Pike	None	
W. Pike	None	
Narraguagus	1 (2001)	No
Schoodic	9 (1977-	Yes
Spruce Mtn.	29 (1976-	Yes
Twenty	None	

Schoodic Lake has near or above state average TP and chl a, which indicate some productivity or nutrification. However, transparency in Schoodic (Figure 4.29) has been improving in recent years so TP and chl a may not be threatening the lake. AN NPS survey should be conducted in order to remediate sources of nutrification.

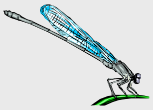
Table 4.29. Productivity Averages of lakes in the NRW (VLMP, 2005).

Lake/Pond	Secchi (m) Ave= 4.8 m	TP (ppb) Ave=12ppb	Chl a (ppb) Ave=4.7ppb	Color (spu) Ave=27spu	D.O. Loss?
Beddington	3.5	8	2.8	44	Depressed
Eagle	3.5 (1)		3.7 (1)		
Narraguagus	3.5 (1)			35	
Schoodic	5.8	10	4.9	8	Moderate
Spruce Mtn	5.6	5	2.9	22	Mod/ Severe

MDEP/VLMP rates lake WQ based on the productiivty data (Table 4.30) and for the NRW found that for the three lakes having suffiecient data, all were considered to have average WQ and that they al fall into attainment categories 2 (attaining standard) and 5 (TMDL required for mercury).

Table 4.30. DEP/VLMP WQ Rating and Attainment Category

Lake/Pond	**DEP/VLMP WQ Rating**	**Attainment Category (DEP/EPA)**
Beddington	Average	Category 2, 5
Eagle	Insufficient Data	Category 2, 5
Narraguagus	Insufficient Data	Category 2, 5
Schoodic	Average*	Category 2, 5
Spruce Mtn	Average*	Category 2, 5



Chapter 5
Strategies and Action Plan

5.1 Action Items

Chapter 4 provided a review of the current water quality trends based on existing monitoring programs and data. Table 5.1 lists all of the recommendations generated from workgroup discussions for future monitoring based on those trends. The Workgroup reviewed and discussed each recommendation and assigned lead and partnering agencies and priority levels thus transforming each recommendation into an action item.

The Action Items are prioritized as high, medium, or low based on how soon each agency/organization thought each action could be achieved or at least initiated:

Priority:	**High**	1-2 years	2006-2007
	Medium	3-4 years	2008-2009
	Low	5-6 years	2010-2011

Lead, Partners:	**Lead**	The lead agency(s) is the agency that will initiate the action item and oversee its progress. The lead agency may provide staff/funding or seek outside funding.
	Partners	Partnering agencies are those agencies that provide input, data, technical assistance, support, etc. Partners may or may not provide financial assistance.

5.2 Plan Strategies

The recommendations/action items fall into five distinct categories each with a specific objective or strategy (listed below). The first three categories/strategies address overall administration, experimental design, and quality control/quality assurance (QA/QC). There is one strategy addressing all of the details of each WQ parameter and finally one strategy addressing the application of WQ data to restoration and management. The action items are grouped by the following strategies and objectives:

1. **ADMINISTRATION:**
   OBJECTIVE: Strengthen communication and coordination among WQ agencies and improve dissemination of information.

2. **QUALITY ASSURANCE AND QUALITY CONTROL**
   OBJECTIVE: Improve quality assurance and quality control measures in order to strengthen data correlation and interagency trust.

3. **PLANNING AND EXPERIMENTAL DESIGN AND ANALYSIS**
   OBJECTIVE: Improve experimental design, project planning, and analysis in order to achieve effective experimental results.

4. **WQ INDICATORS**
   OBJECTIVE: Identify and fill appropriate gaps in spatial and temporal data and develop new studies where appropriate.

5. **RESTORATION AND MANAGEMENT**
   OBJECTIVE: Connect Restoration and Management Activities with WQ Findings

Table 5.1. Narraguagus River WQM Plan Action Items

ITEM #	**ACTION ITEM**	**PRIORITY**	**LEAD,** PARTNERS
1	**ADMINISTRATION AND COORDINATION**		
	OBJECTIVE: Strengthen communication and coordination among WQ agencies and improve dissemination of information.		
1.1	All stakeholders agree to fulfill the action items in this plan to the best of their ability. This will include incorporating the items into individual agency/staff workplans, coordinating activities with other agencies and organizations, and consulting the plan regularly before and during monitoring	High	**All Stakeholders**
1.2	Agencies should come together annually to review and evaluate the success of the plan and its action items and to use the plan to guide upcoming monitoring.	High	**NRWC,** All Stakeholders
1.3	An Atlantic Salmon Scientific Review Committee (possibly a sub-committee of the TAC or Recovery Team) should be established for the purpose of central coordination and direction of research projects and WQM. The committee should be composed of representatives from the biological, ecological, and environmental sciences and would be charged with establishing the research/management priorities most importance to salmon (temperature, water chemistry, habitat, prey, fishing).	Medium	**MASC, All Stakeholders**
1.4	WQ data and related information should be integrated with GIS mapping technology in order to better understand WQ-geographic relationships. As such, watershed councils and other area conservation organizations should establish a GIS program with dedicated staff and technology (GIS technician, software, printer, etc).	High	**DSF, NRWC,** SHARE, MDEP, WCSWCD
1.5	WQ-GIS data should be used to assign relative 'habitat quality' designations for different reaches of the NR and tributaries. These analyses should include both biotic (e.g. IBI) and abiotic (e.g. water flow, pH, temperature, embeddedness) data to produce a predictive model that provides reach-specific 'habitat quality' designations relevant to all organisms (not salmon-specific).	High	**All Stakeholders,** PEARL

1.6	Since the PEARL Website is currently being used by the MASC and NOAA for storage and dissemination of agency biological, temperature and water chemistry data (http://pearl.maine.edu/windows/salmon/Asc_BrowseDataSets.htm), all other WQM agencies should store their data on the site as well in order to establish a central site for data storage.	High	**All Stakeholders,** PEARL
1.7	In order to encourage the proper use of PEARL as a central WQ data storage database/website, PEARL staff should conduct training for all watershed councils and WQM agency staff.	High	**PEARL,** all stakeholders
1.8	Although the WQM Data Index is currently in an Excel spreadsheet, it could easily be imported into an Access database and integrated into the PEARL database/website: http://pearl.maine.edu/windows/salmon/Asc_BrowseDataSets.htm. This would facilitate searches and queries of the database.	Medium	**PEARL,** all stakeholders
1.9	All agencies should use these WQ recommendations to help achieve Recovery Plan Objectives	High	**All Stakeholders,**
2	**QUALITY CONTROL & QUALITY ASSURANCE**		
	OBJECTIVE: Improve quality assurance and quality control measures in order to strengthen data correlation and interagency trust.		
2.1	In order for data to be correlated with other data, shared among agencies, and ultimately placed into a shared database, all agencies should work together to ensure appropriate QA/QC. As such, agencies should work together to create an Atlantic Salmon Rivers WQM QA/QC Initiative that includes the following:		
	a. Each agency should develop a Quality Assurance Project Plan (QAPP) that addresses study design, monitoring protocols, and data analysis and that is peer reviewed and officially adopted by each agency.	High	**All Stakeholders,** MDEP
	b. Update the existing Project SHARE WQM Protocol for Salmon Rivers (http://salmonhabitat.org/Salmon%20Rivers%20WQM%20Protocol%20Manual.pdf) by reviewing and standardizing existing protocols and making them available to all agencies.	Medium	**All Stakeholders,** MDEP

	c. Once QAPPs and protocols are updated and adopted, a QA/QC training program should be established.	Medium	**All Stakeholders,** MDEP
	d. Once QAPPs and protocols are updated and adopted and training has been established, QA/QC protocols should be reviewed and updated annually.	Medium	**All Stakeholders,** MDEP
	e. Once QAPPs and protocols are updated and adopted, agencies should ensure that the protocols for individual data sets are properly referenced when placing them in shared databases or websites.	High	**All Stakeholders,** MDEP, PEARL
3	**PLANNING AND EXPERIMENTAL DESIGN AND ANALYSIS**		
	OBJECTIVE: Improve experimental design, project planning, and analysis in order to achieve effective experimental results.		
3.1	When developing a monitoring plan, choosing new sites, and designing new studies, the following should be considered:		
	a. Identify the type of habitat to be assessed and ensure that it coincides with the program objective: salmon spawning and rearing habitat reaches, smolt migration routes, or non-essential salmon habitat that contribute to overall watershed health (e.g., lakes, tributaries, estuary, etc)	High	**All Stakeholders**
	b. WQM studies should identify the question that needs to be answered or the information that is needed and design the study accordingly: long-term index site monitoring, baseline monitoring, high resolution sampling, or experimental studies focused on answering a specific question.	High	**All Stakeholders**
	c. Review baseline data and pre-existing studies to identify gaps and to determine future study needs; design new studies to fill relevant gaps.	High	**All Stakeholders**
3.2	Continue baseline monitoring where needed (e.g., tributaries, lakes) but once baseline data are well understood, long-term permanent index sites in key sensitive areas should be established in order to reduce costs and staff time.	High	**All Stakeholders**
3.3	All monitoring agencies should adopt an "ecosystem approach" to monitoring in which all native coldwater species and overall watershed health are considered.	High	**All Stakeholders**

3.4	In order to gain a better understanding of the relationship between water quality and streamflow, agencies should correlate data (especially temperature and pH) with continuous streamflow and climate data (available from USGS) when analyzing WQM and study results.	High	**All Stakeholders**, USGS
	WQ INDICATORS		
	OBJECTIVE: Identify and fill appropriate gaps in spatial and temporal data and develop new studies where appropriate.		
4	**TEMPERATURE**		
4.1	Agencies should work together to establish an Atlantic Salmon Water Temperature Initiative (similar in process to the Liming Committee) in which a multi-agency, multi-organizational task force reviews existing literature and data, identifies relevant questions, designs appropriate studies and proposes restoration measures as needed.	High	**MASC**
4.2	The MASC has an extensive summer high temperature database therefore, the temperature monitoring program should be adjusted as follows:		
	a. Reduce the number of temperature monitoring sites from 10-12 to 2-4 and ensure that historic index sites in Deblois (km 33.26) and at Stillwater Dam (km 1.85) are maintained.	High (Ongoing)	**MASC**
	b. Investigate low winter temperatures and how they may affect overwinter survival of juvenile salmon and consider potential restoration efforts, if needed.	High	**MASC**
4.3	The extensive MASC database is continually updated and analyzed; future analysis should include:		
	a. The proposed MASC Temperature Classification Scheme and the use of temperature as an attribute of salmon “habitat” should be peer reviewed, officially adopted by the state and federal fisheries agencies, and integrated into management and stocking decisions.	Ongoing	**MASC**
	b. When assessing summer high temperatures, the MASC should develop a summer severity index that focuses on the warmest days for each year rather than a predefined time period.	Ongoing	**MASC**

	c. Data from river reaches that regularly exceed 27 ^{o}C should be analyzed in greater detail in order to determine how many minutes/hours per day the temperature reaches sublethal or stressful levels.	Low	**MASC**
	d. The MASC, with the assistance of USGS, should correlate temperature data with climate data, such as snow, air temperature, precipitation, etc.	Medium	**MASC**, USGS
	e. Using existing temperature data from the Deblois Index Site, work with USF&WS to develop a model that predicts the temperature at other locations.	Ongoing	**MASC**, USF&WS
4.4	The MASC Temperature Database contains over 1 million records and should be modified into a more user-friendly database that can be used for management purposes:		
	a. Store/query temperature data sets by region according to an agreed upon time series, such as pre-2000, 2000 through 2004, 2005 through 2008 etc.	Ongoing	**MASC,** UMSGMC, NOAA
	b. Develop Summary Tables for: · Deployment Information Summary: to keep track of method and purpose · Index of Temp. Records: where, when, how, location of raw data · Daily Summary Table: Min, Max, Mean; would reduce amount of data by 1/24th · Weekly Summary Table: Min, Max, Mean; ASC/ICES weekly approach	In progress	**MASC,** UMSGMC
	c. Create easy-to-use canned queries for agency/organization report writing	In progress	**MASC,** UMSGMC
4.5	The MDEP/NRWC program should continue the established tributary temperature monitoring in order to develop long-term comparisons among tributaries and to compare with MS data. Once a trend is established it may be possible to reduce the number of sites in order to reduce costs or add sites that are currently not monitored.	High	**MDEP,** NRWC
4.6	Since tributaries are highly influenced by groundwater seepage, MDEP/NRWC temperature site selection should be aware of locations of known input and focus on areas that become warm due to lack of groundwater influence.	High	**MDEP**, NRWC

4.7	Since both blueberry processing plants in Cherryfield have MDEP permits for the discharge of process water, an above/below study should be conducted to determine the effects of the thermal discharge on all organisms and on summer high temperatures in the rearing habitat. Review MDEP data to monitor enforcement. Review permit for appropriateness related to salmon.	Low	**MDEP**, MASC
4.8	Develop a Habitat Suitability Index (HSI) that uses temperature and discharge parameters to describe favorable conditions for smolt emigration and includes indices such as median emigration temperature, % exceedance of 20 ^{o}C, median emigration discharge, and % over/under baseline.	Ongoing	**NOAA,** MASC
4.9	Analyze NOAA temperature data and review cumulative degree-days annually from January 1 in order to better understand pre-smolt growing conditions and to determine relationship with median run time.	Ongoing	**NOAA,** MASC
4.1	Using NOAA temperature data, develop a freshwater/saltwater differential index in order to estimate the magnitude and direction of thermal challenges during smolt emigration.	Ongoing	**NOAA,** MASC
4.1	Conduct literature search/review to determine thresholds and/or actual direct measurements of thermal parameters occurring pre-smolt or during smolt migration and use these values to develop thermal suitability/favorability indices.	Ongoing	**NOAA,** MASC
4.11	Conduct study to determine correlation between thermistor-based temperature data (loggers, etc) in estuaries and marine locations with data obtained from satellite imagery.	Ongoing	**NOAA,** MASC
4.12	Temperature protocols should include the regular use of cross-sectional thermal profiles so that data can be correlated with stream structure, channel/flow dynamics, multiple parameters, and mixing patterns. Profiles should be conducted several times throughout the year to account for seasonal flow variation and should include a winter profile to capture ice and thaw conditions.	Medium	**All stakeholders,** USGS
4.13	Since all temperature monitoring is conducted using loggers, the data is continuous and should be correlated with other instantaneous monitoring such as DO, nutrient cycling, and electrofishing.	Medium	**All stakeholders,** USGS
5	**PH AND RELATED ANALYTES**		

5.1	Future monitoring should include those areas for which there is currently insufficient data: the MS below the confluence with the WB and Spring River	High	**MASC,** MDEP, NOAA
5.2	Since the MASC/UMSGMC have two years of baseline and event data from the pH surveys, future monitoring should shift to long-term index sites, especially those sites known to be acidic.	Ongoing	**MASC, NOAA,** UMSGMC
5.3	Since pH and analytes such as Ca, Al, and DOC are known to fluctuate in response to precipitation/high flow events, these data sets should be correlated (graphed and analyzed) with discharge data to determine the nature and timing of response.	Ongoing	**NOAA,** USGS, UMSGMC
5.4	Assess the condition of Mainstem, West Branch and the confluence to see if there are any water chemistry conditions that may compromise emigrating smolts; conduct monitoring or a study if needed.	High	**NOAA, MASC,** UMSGMC
5.5	Although there are Ca data for late spring, summer, and fall, more water chemistry data are needed for winter and early spring in order to capture snowmelt and early rain events that may effect parr survival and smoltification.	Ongoing	MASC, NOAA, GMC
5.6	Stream Side rearing studies should be performed in order to get a better understanding of the effects of moderate pH and calcium levels (which are found on the Narraguagus) on fish physiology.	Ongoing	**NOAA,** USGS
5.7	Use findings from the UMSGMC/ASC Watersheds Study (Rocky, Baker, Sinclair Study) to better understand relationships between long-term landscape changes and salmon population dynamics. Results may also suggest the need for changes in landuse management decisions and policies.	Medium	**MASC, UMSGMC**, USGS
5.8	Based on the results of the UMSGMC/MASC Rocky, Baker, Sinclair Watersheds Study, agencies should consider conducting a stream study that monitors fish responses to applied buffering.	High	**NOAA,** MASC, UMSGMC
5.9	A classification scheme based on the format and intent of the proposed MASC Temperature Classification Scheme should be developed for pH. The pH scheme and data should be peer reviewed as an attribute of ‘habitat’, officially adopted by the state and federal fisheries agencies and integrated into management and stocking decisions.	Medium	**MASC,** NOAA, UMSGMC

6	**LAKES**		
6.1	At the request of the MASC, MIFW should conduct a fish and WQ survey of Beddington Lake to determine the effects of predacious and competitive fish species on salmon.	High	**IFW,** MASC
6.2	Several lakes do not have monitoring currently; seek volunteers to gather data on unmonitored lakes and ponds in the Narraguagus watershed; VLMP will provide training, equipment, and support.	High	**NRWC, VLMP,** MDEP
6.3	Conduct watershed survey(s) to identify and resolve nonpoint source threats and baseline aquatic plant survey in order to monitor for the introduction of invasive plant and animal species.	High	**NRWC, VLMP,** MDEP
7	**PESTICIDES**		
7.1	MBPC pesticide sampling has been conducted yearly since 1997 however no sampling was conducted in 2005. Agencies should petition the Board to conduct sampling in 2006 and emphasize the importance of sampling during this time of changing pesticide applications (aerial vs ground spraying).	High	**All Stakeholders,**
7.2	The Time Series Study on the Pleasant River indicates the presence of hexazinone in the river throughout the year. The MBPC should consider a similar time series study in the Narraguagus River in order to better understand the presence of hexazinone in the river system.	Low	**MBPC,** UM
7.3	A study should be conducted to ascertain if the new ground application of pesticides is reducing the amount of pesticide entering the water. This could be done as a university study or by MDEP with NRWC volunteers if landowner permission is granted.	High	**MBPC, UM**
7.4	New pesticides are introduced into the blueberry industry regularly. The MBPC should continue to monitor for the presence of these new chemicals in order to understand their movements and actions.	Medium	**MBPC, UM**
7.5	Continue ground water and surface water monitoring, while comparing new data with past results to detect any trends.	Medium	**MBPC, UM**
7.6	As the MBPC plans its sampling in 2006, several factors should be considered:		

	a. Expand the use of passive samplers in order to facilitate sampling without use of staff/mileage.	Medium	**MBPC**
	b. The MBPC should consider adding additional and/or more appropriate sites to their studies.	High	**MBPC**
	c. Continue to evaluate risks from other pesticide use sites, such as forestry, residential, and right of way.	Low	**MBPC**
7.7	UM researchers, with the assistance of MBPC, should conduct a study using passive samplers supported with monthly grab samples to monitor the year-round presence of pesticides whose long-term persistence is suspected (e.g. hexazinone). In addition, use grab samples and passive samplers after application of short-lived pesticides (e.g. phosmet) and during precipitation events to determine presence of short-lived pesticides.	Medium	**UM,** USGS, NOAA, MASC, MDEP
7.8	The following studies are recommended to determine pesticide effects on salmon:		
	a. Conduct studies to determine the effects of multiple stressors, such as occur in the Downeast Rivers. For example, simultaneous, chronic exposure to low pH, high Al, altered temperature profiles, DO, and pesticides with and without the presence of additional stressors, such as predators, and/or low food density.	High	**UM,** USGS, NOAA, MASC, MDEP
	b. Conduct studies to determine sublethal effects of pesticides on growth, behavior, immune function, and endocrine function of salmon and their prey.	Medium	**UM,** USGS, NOAA, MASC, MDEP
	c. Conduct studies to determine the sublethal effects of chronic exposure to pesticides in all salmon life stages (larval, parr, smolt). For example, does exposure to low pH and elevated aluminum + hexazinone affect development of larvae to the parr stage?	High	**UM,** USGS, NOAA, MASC, MDEP
	d. Conduct test of candidate alternative pesticides. Mesotrione and spinosad are two pesticides proposed as alternatives to replace hexazinone and phosmet. Such candidate pesticides should be evaluated for their effects on salmon and salmon habitat (prey, predators, plant cover, etc) prior to being used on blueberry fields that border salmon rivers.	Medium	**UM,** USGS, NOAA, MASC, MDEP

8	**STREAMFLOW AND WITHDRAWAL**		
8.1	Use discharge data to indicate when and where to sample. Some specific examples might include storm-water sampling before, during, and after storm-runoff events and seasonal sampling, such as during low-flow conditions, or spring-runoff conditions. Seepage runs (field work involving high-density, high-frequency measurements of streamflow) can be done to aid in the identification of gaining and losing (groundwater inflow and outflow) reaches to help target sampling locations specific to the effects of groundwater.	High	**All Stakeholders,** USGS
8.2	Break out surface runoff vs. ground water (baseflow). There are models and statistical methods to determine how much of flow is surface and how much is ground water input.	Low	**MASC, MDEP,** USGS
8.3	Conduct geomorphology study to determine locations that require restoration. Some initial studies underway on Narraguagus – SHARE	High	**All Stakeholders,** USGS
8.5	Maine Geological Survey has mapped significant sand and gravel aquifers throughout most of the state. The data are available through the Maine Office of GIS (MEGIS) at http://apollo.ogis.state.me.us/catalog/. This information should be utilized when conducting groundwater and flow studies and data analysis and correlation.	Medium	**All Stakeholders,** USGS
8.6	While the area of the river at the gage appears to be well mixed, other areas may not be well mixed. Need to look at priority salmon habitat and possibly do a cross sectional profile assessing the effects of springs and mixing on that habitat.	Medium	**MASC, MDEP,** USGS
8.7	Investigate the possibility of managing beaver in specific situations (like Black Stream on the Machias) to deliver more and colder water to mainstem.	Medium	**MASC, MDEP, SHARE,** WCSWCD
8.8	Water chemistry and thermal profiles of streams and springs containing priority habitat or which are associated with habitat on the mainstem should be continued and money for lab fees be made available for the purpose from funding agencies.	Medium	**MDEPAS,** MASC,

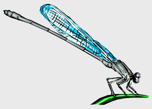
8.9	Evaluate our current knowledge about springs and aquifers, including alluvial ones, and whether we need further studies. Available maps of springs, aquifers and wetlands should be provided to those agencies doing coldwater source management. Previous studies indicate that we only have a handful of spring areas in two rivers (Pleasant and Narraguagus) therefore these coldwater sources are rare and should be better understood and managed.	Low	**MASC, MDEP,** USGS
8.11	Check progress of repair of the Cherryfield Ice Control Dam to ensure that maximum passage is restored.	High	**MASC,** NRWC, USFW
8.12	The composition and work of the Flow Team is currently not well known. The Team should communicate their efforts and the results (documentation) of their work with councils and other major players.	Medium	**MASC, MDEP**
8.13	A study to investigate irrigation well withdrawal (aquifer withdrawal) effects on cold-water springs should be conducted with input from the Flow Team.	Low	**UM, USGS**
9	**NUTRIENTS AND DISSOLVED OXYGEN**		
9.1	Review current nitrate and TP data and gather more data as needed to fill gaps in existing baseline and stormwater datasets.	Medium	**MDEPAS,** NRWC
9.2	Conduct study to assess nitrate and TP levels associated with OBDs located in downtown Cherryfield.	Medium	**MDEPAS,** NRWC
9.3	Dissolved Oxygen monitoring should be expanded to include the following:		**MDEPAS,** NRWC
	a. Conduct DO diurnal profiles in key areas in order to better understand overall water quality an productivity.	Medium	**MDEPAS,** NRWC
	b. Fill in gaps in data to include tributaries such as Lawrence and Schoodic Brooks (especially those areas of apparent diminished WQ)	Medium	**MDEPAS,** NRWC
	c. Correlate DO data with habitat, temperature, embeddedness, and nutrient data.	Medium	**MDEPAS,** NRWC
	d. Conduct BOD sampling in selected areas with pre-existing WQ data and correlate findings.	Medium	**MDEPAS,** NRWC

9.4	Conduct a study that addresses overall nutrient levels and productivity especially as it relates to marine derived nutrients, terrestrially derived nutrients, large woody debris, etc.	Medium	**UM, MASC, USFWS**
10	**BACTERIA**		
10.1	Continue current level of bacteria monitoring. Any additional monitoring should focus only on new problems.	Low	**MDEPAS, NRWC**, DMR
11	**TRACE METALS AND OTHER TOXINS**		
11.1	Conduct sampling for trace metals, PCBs, and chlorinated pesticides using the Gulfwatch Contaminants Monitoring Program protocol which has sample sites in Union, Penobscot, St Croix rivers.	Low	**MDEP,** Gulfwatch, NRWC
11.2	Since chlorine is discharged from most OBDs and municipal waste treatment plants, a comprehensive study should be conducted to determine current levels of chlorine and how these levels may affect salmon health.	Medium	**MDEP,** NRWC, MASC, USFWS
11.3	USFWS has examined organochlorines, trace elements, gonads, and sex steroids in white suckers from all the DPS rivers. A study should be conducted whereby higher trophic level species (e.g., bass, brook trout) would be analyzed for EROD, intersex, OCs and metals in the Narraguagus and other Downeast DPS rivers.	Medium	**USFWS,** MASC, USGS
12	**MACROINVERTEBRATES**		
12.1	Work with MDEP and MASC to determine the most appropriate biomonitoring macroinvertebrate and algal sampling for the 2007 monitoring season.	High	**MDEP Biom, MASC**, UM, NRWC
12.2	Conduct a Comprehensive Productivity study to determine if there are enough nutrients and macroinvertebrate taxa to support salmon. This may also require the establishment of permanent monitoring sites and the monitoring for presence/absence of functional groups.	Medium	**UM, NOAA, MASC**, NRWC, MDEP

12.3	Use existing MDEP Biomonitoring data (macroinvertebrates and periphyton) as an Index of Biological Integrity (IBI) to measure ecosystem health (producers, primary costumers, and decomposers). The data can be used to determine redundancy (the number of species with the same/similar function in the ecosystem), diversity, and the status of tolerant versus sensitive species.	Medium	**UM**/USGS/NOAA/MASC/MDEP
13	**EMBEDDEDNESS AND NPS**		
13.1	Continue embeddedness studies (especially 2005 results) and correlate data to NPS sites and parr densities as well as temperature and nutrient data.	Medium	**MASC**
13.2	Connect embeddedness data with frazzle ice and other overwintering habitat findings; apply to restoration projects.	High	**MASC**
14	**MULTIPLE STRESSORS**		
14.1	Aquatic organisms continuously cope with environmental stressors. Recent studies with amphibians demonstrate that the deleterious effects of combined stressors are far greater than any single stressor alone.		
	a. As a first step towards devising a scale by which to assess multiple stressor conditions, a classification scheme based on the format and intent of the proposed MASC Temperature Classification Scheme should be developed that combines pH and temperature, as they relate to Atlantic salmon. Initially, this would involve literature searches to determine what data, if any, exist on the effects of a range of pH/temperature combinations.	Medium	**All Stakeholders**
	b. Once developed, additional stressors could be added to the Multiple Stressor Classification Scheme (e.g. pH, temperature and pesticides).	Medium	**All Stakeholders**
15	**RESTORATION AND MANAGEMENT**		
	OBJECTIVE: Connect Restoration and Management Activities with WQ Findings		
15.1	All restoration projects (large woody debris, culvert repair, stream bank stabilization, etc) should include an assessment component that includes before and after geomorphology assessment, sediment budget, WQM, embeddedness analysis, and parr density evaluation.	High	**USFWS, SHARE,** MASC, NRWC, UMSGMC

15.2	The ASC and USFWS should investigate which life stages are affected by summer high temperatures occurring in MS at Hemlock Dam, lower Gould, Schoodic and Lawrence brooks, and Spring River.	Medium	**MASC, USFWS**
15.3	Reaches/tributaries that experience stressful high summer temperatures, such as MS at Hemlock Dam, lower Gould, Schoodic and Lawrence brooks, and Spring River, should be considered for restoration efforts (riparian plantings, placement of large woody debris, or other structural restoration efforts).	Medium	**USFWS, SHARE,** MASC, NRWC
15.4	Coldwater inputs should be assessed, monitored, and protected:		
	a. Although the MASC has completed a manual "walk through" to identify springs, all agencies should assess the effectiveness and value of conducting a fly over or some other technique to identify and document springs. The MASC catalogue of springs should be upgraded and shared with other restoration specialists so that coldwater areas can be prioritized, monitored and protected.	Medium	**MASC, USFWS**, SHARE, WCSWCD
	b. USFWS and WCSWCD should identify and manage coldwater sources and integrate existing Best Management Practices, research, and methodologies for councils and other restoration organizations (SHARE) to implement.	Medium	**MASC, USFWS**, SHARE, WCSWCD
15.5	All agencies should work with landowners to follow the recommendations set forth in existing Water Use Management Plans and the MDEP "In-stream Flow Standards for Class AA/A/B Waters". Some examples include farm pond placement and water withdrawal for agricultural or processing use.	Low	**MDEP, WCSWCD**
15.6	MDEP should work with Jasper Wyman & Son Blueberry Growers and encourage them to remove OBDs & switch to pumping or similar treatment.	Low	**MDEP,** NRWC
15.7	Restoration projects should focus on reducing NPS pollution and embeddedness and subsequent improvement of DO, water chemistry, temperature, and sedimentation. Some examples include:		
	a. Placement of large woody debris to improve velocity, shade, shelter, nutrients, etc.	High	**USFWS, SHARE,** MASC, NRWC, UMSGMC
	b. Road improvements including shoulder stabilization, culvert replacement, proper ditching,	High	**USFWS, SHARE,** MASC, NRWC, UMSGMC

	c. Instream restoration such as bank stabilization and channel restoration.	High	**USFWS, SHARE,** MASC, NRWC, UMSGMC
15.8	Investigate if those areas with diminished WQ are naturally occurring or the result of anthropogenic reasons and plan appropriate restoration as needed.	Ongoing	**SHARE,** USFWS
15.9	Use WQ findings to advocate for the removal of discharge inputs such as residential OBDs, processing plant discharges, etc.	Medium	**MDEP, NRWC, MASC,**



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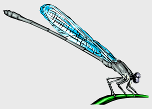


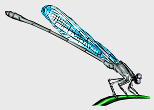
Appendix A

Appendix A

Maps of the Narraguagus Watershed

PDF Maps at
http://salmonhabitat.org/projects.htm

1. NRW WQM Sites (Entire Watershed)
2. NRW WQM Sites – Upper Stratum
3. NRW WQM Sites – Middle & Lower Strata
4. NRW WQM Sites – Cherryfield Village and Estuary
5. NRW Areas of Diminished Water Quality



Appendix B

Appendix B

Water Quality Monitoring Data Index for the Narraguagus River Watershed

Excel Spreadsheet at
http://salmonhabitat.org/projects.htm