3. Freshwater Species and Ecosystems in Maine: An Overview

Glaciation produced much of the physical diversity in Maine's landscape, but left it essentially devoid of plant and animal species. Aquatic habitats were "altered on an unprecedented scale, through the destruction of old systems and the widespread creation of new lakes and rivers (Bernatchez and Wilson 1998). Biological diversity in Maine today is the result of re-colonization of the region by fauna and flora following deglaciation approximately 13,000 years ago. Re-colonization occurred (and continues to occur) from a number of refugia in other parts of North America (e.g. Burian 1990, Hocutt and Wiley 1986). Because of the relatively recent retreat of the glaciers, species richness in many groups is lower in the Northeast than areas to the south. At the same time, however, Maine lies within a transition zone between south and north. This transition is clearly seen in forest types (Gawler et al. 1996) and is also evident in many of the state's floral and faunal groups. The transitional nature of the state contributes to regional biodiversity.

This chapter provides a general introduction to the four major biodiversity groups covered by MABP: vascular plants, fish, amphibians and reptiles, and macro-invertebrates. It focuses on (i) broad patterns of taxonomic diversity, (ii) current knowledge about the composition of aquatic ecological communities, and (iii) "high-value" components of the state's freshwater biodiversity, including threatened and endangered species. Chapter 6 is an In-depth analyses of spatial and temporal patterns in aquatic biodiversity, along with a discussion of status and trends.

3.1 Species Diversity in Maine and the Northeastern U.S.

Amphibians and Reptiles

Maine's amphibians and turtles exhibit a range of habitat requirements. Some are exclusively aquatic while others are intermediate in habitat requirements or primarily terrestrial. Of the 57 species of amphibians and turtles that are found in the Northeast (New England and New York), 28 are found in Maine (Table 3.1). Nine of Maine's amphibian species are salamanders / newts, and nine are frogs / toads. All but one of these species are native to the State (the introduced species is the mudpuppy, *Necturus maculosus*, which is currently restricted to central Maine). Six of the native amphibian species occur statewide, whereas the other two native species (and the mudpuppy) have restricted distributions, probably reflecting specialized habitat requirements (Hunter et al. 1999). Of the 20 reptile species occurring in Maine (10 turtles and 10 snakes – excluding sub-species), six turtles and two snakes are commonly associated with freshwater and/or wetland systems. Three turtle species are marine. Three turtle species are listed as threatened or endangered in Maine: Spotted turtle (*Clemmys guttata*), Blanding's turtle (*Emys blandingii*), and Eastern box turtle (*Terrapene carolina carolina*).

Table 3.1: Amphibians and turtles of the northeastern U.S.

State / Region	Salamanders / Newts	Frogs / Toads	Turtles *
Maine	9	9	10
New Hampshire	12	10	8
Vermont	12	11	7
Massachusetts	11	10	16
Connecticut	12	10	12
New York	18	14	14
Total: Northeast	21	16	20

* Includes marine species. Data source: Hulse et al. 2001

Fish

There are 150 species of freshwater (including diadromous) fish in the northeastern U.S. (the six New England states, New York and New Jersey; Halliwell et al., 1999). These species belong to 70 genera and 26 families (Table 3.2). Of these 150 northeast species, 67 (45%) are known to occur in Maine. Most Maine species are in the carp/minnow family (Cyprinidae). The next two most species-rich families are the trouts (Salmonidae) and the bass/sunfishes (Centrarchidae). The former are primarily cold/cool water forms, whereas the latter includes primarily warm-water species.

Approximately 70% of Maine's fish species are native to the state, i.e. they are thought to have been present in Maine prior to European settlement (Table 3.2). A majority of Maine's non-native fish species are minnows (Cyprinidae) and centrarchids. In comparison to other parts of the U.S., Maine has one of the lower numbers of non-native fish species (Fuller et al., 1999). However, this number is increasing -- several new introductions have occurred over the past 10 years, including the green sunfish (*Lepomis cyanellus*) and central mudminnow (*Umbra limi*) (Schilling, in press; Halliwell 2005). In addition, a number of fish species that are either native to Maine or have been here for a long time continue to be moved to waterbodies in which they were not originally present (e.g. Halliwell 2005; K. Warner, MDIFW, pers. comm.). Common examples include the largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*), black crappie (*Pomoxis nigromaculatus*), white perch (*Morone americana*) and a number of minnow species. Such introductions are likely to reduce fish diversity in many of Maines lakes and streams, in part because of the predatory habits of many of these species. At the same time, species richness insome naturally depauperate systems is increasing as a result of these introductions. Overall, distributions of many of Maine's freshwater fish species have been substantially modified by humans, particularly since colonial times. Today, continued species introductions are leading to a relentless homogenization of fish assemblages throughout the State. Chapters 4 and 6.4 provide more information about fish introductions to Maine.

Several of Maine's fish species inhabit both fresh and salt waters. The American eel (*Anguilla rostrata*)is the only catadromous species in Maine (i.e. it descends rivers to breed in the ocean). Anadromous species ascend rivers to breed in lakes and streams. They include Atlantic salmon (*Salmo salar*), several members of the herring family (e.g. blueback herring [*Alosa aestivalis*], alewife [*A. pseudoharengus*] and American shad [*A. sapidissima*), rainbow smelt (*Osmerus mordax*) and the sea lamprey (*Petromyzon marinus*). Dams and natural barriers restrict the current inland range of most diadromous species (see Chapter 4). Some of the naturally diadromous species have established landlocked populations in Maine. Examples include the landlocked salmon, smelt and alewife. In addition to the truly diadromous species, others may be found in both freshwater, estuaries and, at times, marine waters. Examples include the shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*A. oxyrhynchus*), striped bass (*Morone saxatilis*), mummichog (*Fundulus heteroclitus*) and white perch (*Morone americana*). The latter is an example of a species whose native habitat is coastal systems (estuaries, rivers and lakes with coastal access), but which has been introduced to many inland lakes over the past 100+ years.

Chapter 6.4 provides more detail on Maine's freshwater fish fauna. Species distribution maps are contained in Appendix 11.5.2.

Table 3.2: Freshwater fish diversity in Maine and the northeastern U.S.

FAMILY	NORTHEASTERN U.S. [1]		MAINE	
	# Genera	#Species	# Genera	# Species [2]
Lampreys (Petromyzontidae)	3	6	1	1 (1)
Eels (Anguillidae)	1	1	1	1 (1)
Herrings (Clupeidae) [3]	2	4	2	4 (3)
Trouts (Salmonidae) [4]	5	9	5	8 (6)
Smelts (Osmeridae)	1	1	1	1 (1)
Carps and minnows (Cyprinidae) [5]	21	46	13	21 (13)
Killifishes (Fundulidae)	1	2	1	2 (2)
Sculpins (Cottidae)	1	2	1	1 (1)
Suckers (Catostomidae)	5	11	2	3 (3)
Bullhead catfishes (Ictaluridae)	3	8	1	2 (1)
Sunfishes (Centrarchidae)	6	13	4	8 (2)
Perches (Percidae)	4	20	3	3 (2)
Pikes (Esocidae)	1	5	1	4 (2)
Mudminnows (Umbridae)	1	2	1	1 (0)
Temperate basses (Moronidae)	1	3	1	2 (2)
Sticklebacks (Gasterosteidae)	4	4	4	4 (4)
Cods (Gadidae) [6]	1	1	1	1 (1)
Sturgeons (Acipenseridae)	1	3	1	2 (2)
Trout-perches (Percopsidae)	1	1	--	--
Pirate perches (Aphredoderidae)	1	1	--	--
Livebearers (Poeciliidae)	1	2	--	--
Silversides (Atherinidae)	1	1	--	--
Bowfins (Amiidae)	1	1	--	--
Gars (Lepisosteidae)	1	1	--	--
Drums (Sciaenidae)	1	1	--	--
Soles (Soleidae)	1	1	--	--
TOTALS	**70**	**150**	**44**	**69 (47)**

(1) Based on Halliwell et al. 1993.
(2) Numbers in parentheses are Maine-native species.
(3) Excludes the hickory shad (*Alosa mediocris*) which does not reproduce in New England.
(4) Landlocked and sea-run salmon are counted as a singe species. The hybrid splake is not counted as a separate species.
(5) Excludes goldfish.
(6) Excludes the tomcod (*Microgadus tomcod*).

Macro-invertebrates

Our knowledge of the composition and distribution of aquatic macro-invertebrates in Maine is patchy. Some groups, such as odonates (dragonflies and damselflies), freshwater mussels (Bivalvia) and, to a lesser extent, mayflies (Ephemeroptera), have been well surveyed. For other groups, many parts of the state are under-sampled – for example, caddisflies (Trichoptera), blackflies (Simuliidae), beetles (Coleoptera) and aquatic snails (Gastropoda). This means that we have significantly incomplete knowledge about species distributions and regional patterns of species richness for these groups. It also means that the state species lists will continue to expand as additional collections are made.

While inconsistencies in survey effort make it difficult to provide an adequate summary of macro-invertebrate diversity in Maine, Table 3.3 synthesizes what is known about the fauna of Maine and provides a comparison to the fauna of the northeastern U.S. Maine data were summarized from records in the MABP database, whereas Peckarsy et al. (1990) was used to develop a summary for the northeast. Of the insect groups shown in Table 3.3, five are exclusively aquatic in their larval forms (but are terrestrial as adults): Ephemeroptera, Odonata, Plecoptera, Trichoptera and Megaloptera. In the other insect groups, only some species are aquatic at some stage in their life history. Among the non-insect invertebrates, all the crustacean groups, the mussels and the leeches (Hirudinea) are fully aquatic, completing their entire life cycle in water. Among the other non-insect groups in Table 3.3, only some species are truly aquatic.

In general, genus-level diversity of macro-invertebrates in Maine appears to be similar to that of the broader northeast region (Table 3.3). For insects and crustaceans, similar numbers of genera have been recorded from Maine and the northeast. For molluscs and oligochaetes, there is a greater disparity between Maine and northeast totals. The lower numbers of genera recorded from Maine may reflect the fact that Maine is relatively under-sampled for these species; on the other hand, they may also represent actual differences in regional richness. The first alternative is probably the case for oligochaetes and gastropod molluscs, since these groups have been relatively under-sampled. The second explanation most likely applies to the freshwater mussels, since these have been well-surveyed in Maine. Approximately one half of the northeast's freshwater mussel genera are represented in Maine.

Patterns of genus-level richness in Maine vs. the Northeast provide an interesting comparison with respect to macro-invertebrates and fish (Tables 3.2 and 3.3). In contrast to the broad similarity in numbers of invertebrate genera between Maine and the northeast, only about 60% of the Northeast's fish genera are present in Maine. This may in part reflect differences in the ease with which the various faunal groups have been able to re-colonize northern New England following retreat of the glaciers (e.g. Burian 1990, Peckarsky et al. 1990, Matthews 1998, Schmidt 1986, Taylor 1999). Invertebrates with terrestrial life stages may be able to more readily disperse among watersheds than taxa that are wholly aquatic.

Documented species richness of aquatic macro-invertebrate in Maine is highest in the Diptera (true flies), caddisflies and beetles – note, however, that the number of species listed for the Diptera over-estimates the total number of aquatic species present in the state, since the craneflies (Tipulidae) and the deer flies and horse flies (Tabanidae) were not separated by habitat type.

Chapters 6.5 – 6.9 provides more detail on Maine's invertebrate fauna. Appendix 11.2 summarizes macro-invertebrate diversity by family, comparing Maine data with information compiled from the northeastern U.S. (Chandler and Loose, 2001). Appendix 11.4 provides species lists from the MABP database. Species distribution maps are contained in Appendices 11.5.3 – 11.5.10.

Table 3.3: Diversity of aquatic macro-invertebrates in Maine and the Northeast U.S. [@]
Note that, for some of the groups, the Maine numbers exceed the published equivalents for the Northeast U.S.

Group	Aquatic Stages (insects)	# NE Families	# NE Genera	# Maine Families	# Maine Genera	# Maine Species *
Insects						
Ephemeroptera [(1)]	L	14	45	13	47	170
Odonata [(1)]	L	10	55	9	50	158
Plecoptera [(1)]	L	9	52	9	46	123
Hemiptera [(2, 3)]	L, A	14	35	10	27	54+
Trichoptera [(1)]	L, P	19	87	21	81	342
Lepidoptera [(3)]	L, P	1	9	1	6	6
Coleoptera ([3)]	L, A	13	81	17	83	278
Megaloptera [(1)]	L	2	5	2	4	10
Neuroptera [(3)]	L	1	2	1	2 ?	2 ?
Diptera [(3)]	L, P	24	257 **	21	260 *****	648 *****
Collembola [(4)]	All		5	3	3 ?	3 ?
Crustaceans						
Amphipoda		4	5	3	4	4
Isopoda		1	1	1	2	4
Decapoda		1	4	1	3	8
Mysidacea		1	1	1 ****	1	1
Arachnids						
Hydrachnidia		31	76		27 +	?
Molluscs						
Gastropoda		9	36	7	23	57
Bivalvia ******		4	28	3	11	36
Annelids						
Polychaeta		1	1	1	1	1
Oligochaeta		5	40+ ***	6	22	46
Hirudinea		5	18	4	18	25

[@] Data for Northeastern U.S. are from Peckarsky et al. 1990. Maine data from MABP database.

* Included in species totals are taxa that are identified only to the genus level, i.e. no species identifications available from anywhere in the state.
** Peckarsky et al. provide no genera lists for 4 of the 24 families of Diptera.
*** 2 oligochaete orders are not keyed to genus in Peckarsky et al.
**** Introduced *Mysis relicta* in Moosehead Lake.
***** Includes all Maine genera and species of Tipulidae (crane flies) and Tabanidae (deer flies and horse flies), not all of which are truly aquatic.
****** Freshwater mussels and fingernail/peaclams

? Data are sparse or most or all of taxa are identified only to genus; thus actual genus and species totals are probably higher than numbers given.

(1) All members of order are aquatic in life stage indicated. L = larva, P = pupa, A = adult.
(2) Order contains semi-aquatic species
(3) Some members of order are aquatic in life stage indicated (and defined above).
(4) Semi-aquatic taxa: associated with water surface.

Plants

There are over 2,000 species of vascular plants in Maine, including terrestrial, wetland and truly aquatic forms (Campbell et al. 1995, Haines and Vining 1998). The characterization of a species as truly aquatic is somewhat subjective, depending on what criteria are used to define aquatic habitat and growth form. Based on the habitat characterizations of Haines and Vining (1998), there are approximately 190 species of submerged, floating and emergent "aquatic" vascular plants in Maine. The most recent USFWS list of wetland plants in Maine includes 1,436 species, of which 242 are considered to be submerged, floating or emergent aquatic species (Tiner et al., 1995). The MABP database has compiled records for 173 aquatic plant species, distributed between 33 families (using the habitat designations of Haines and Vining, 1998).

Chapter 6.2 provides more information on vascular plant diversity in Maine. Appendix 11.2 uses data from Crow and Hellquist (2000) to summarize the diversity of aquatic and wetland species from Maine and the northeastern U.S. Appendix 11.4 lists the aquatic macrophyte species contained in the MABP database. Appendices 11.5.1 and 11.6 provide, respectively, plant species distribution maps and elevation / alkalinity plots for selected species.

Statewide Patterns of Biodiversity

By way of an introduction to regional patterns in biodiversity among Maine's plant and animal species, we provide a summary of taxonomic richness for selected floral and faunal groups by major region in the state (Table 3.4). It is important to underscore the fact that documented species richness is a function of sampling effort (see Chapter 5); thus care should be taken in interpreting the data in Table 3.4. There has been extensive fish sampling in lakes across the state and thus there is high confidence that regional patterns of documented species richness reflect true geographic variation. It is also likely that the mussel and crayfish data in Table 3.4 accurately reflect actual diversity across the state because the total number of species in both groups is relatively low; at the regional level, we know what species are present. For other groups, confidence is lower. Odonates, for example, have been surveyed relatively extensively – and mayflies to a lesser extent. However, even for these groups, lower sampling effort in some parts of the state means that documented species occurrences may underestimate actual species richness in some regions.

Relative to other parts of Maine, the northern part of the State has fewer documented species of fish, turtles, crayfish, odonates, mayflies and rare plants and animals. For the other groups shown in Table 3.3, broad spatial patterns in species richness are either not as clear (mussels, amphibians) or are confounded by major variations in survey effort (caddisflies).

Species richness is only one aspect of biodiversity. Of equal importance are the spatial patterns in assemblage composition. Chapter 6 describes these patterns and Chapter 7 presents quantitative comparisons of regional biodiversity.

Table 3.4: Overview of numbers of species for groups of freshwater animals and plants in six regions of Maine.

GROUP	REGION [1]					
	South	Central	Downeast	Northeast	West	Northwest
Fish	45	58	47	39	45	33
Fish: ME natives	37	45	41	35	38	33
Mussels	7	10	8	9	10	4
Mayflies	48	105	111	65	132	61
Stoneflies	16	17	50	16	16	13
Odonates	141	148	140	109	131	91
Caddisflies	46	103	217	92	146	139
Amphibians	16	18	16	15	16	14
Turtles	7	7	5	3	6	2
Aquatic plants	100	110	93	69	80	47
Aquatic plants: Tracked [2]	15	19	14	6	9	7
Fauna: Tracked [2]	28	26	17	11	20	7

(1) See Figure 2.3 for map of regions.
(2) Rare species that are tracked by MDIFW or MNAP in Natural Heritage database.

Data sources: multiple, as compiled in MABP database.

3.2 Freshwater Communities

Characterization of biological communities is central to the “coarse filter” approach to biodiversity conservation (Stein et al. 2000). The composition and distribution of terrestrial plant communities has been integral to the development of ecological and landscape-level classifications developed in the U.S. and elsewhere -- examples include the U.S. National Vegetation Classification, developed by TNC (Grossman et al. 1998, Anderson et al. 1998), as well as several ecoregional frameworks such as those of Bailey, Omernik and, in Maine, McMahon (1990) and Krohn et al. (1999). The classification of freshwater communities is less advanced than terrestrial community classifications, but the scientific literature holds numerous examples of studies designed to define community types. Some community “definitions” are relatively simple characterizations, such as fish species characteristic of warmwater vs. coldwater lakes, large rivers vs. small streams, or stream pool vs. riffle areas. More complex descriptions of species associations (and environmental correlates) are developed using multivariate, clustering and other statistical approaches.

A major constraint to the development of freshwater community classification systems is the frequent inadequacy of biological data – stemming from either insufficient and/or inconsistent survey effort. In response to this general dearth of biological data, TNC has developed a landscape-level, GIS-based classification. This integrates a series of biophysical data layers to produce a framework that can be used (in conservation planning and other management-related activities) as a hypothesized surrogate for the biological communities, themselves (Lammert et al. 1996).

In this section, and in Chapter 6, we summarize efforts to characterize biological assemblages in Maine’s freshwater ecosystems. It is important to underscore at the outset that all classification frameworks are developed for specific purposes. This fact is illustrated by the classification systems described below. For example, MNAP’s vegetation classification aims to characterize the structure of natural communities. In contrast, MDEP’s invertebrate-based classification is used for biomonitoring purposes. Consequently, this classification focuses on human disturbance gradients, evaluating these via the structure of macro-invertebrate assesmblages (Davies and Jackson, in press).

The Maine Natural Areas Program (MNAP) has developed a classification of vegetated natural communities and ecosystems (Gawler 2001) that is currently under revision (A. Cutko, MNAP, pers. comm.). The classification describes just under 100 natural plant communites in Maine, of which 34 are open wetlands. Of these, five are communities that would typically be considered “aquatic” (e.g. macrophyte beds dominated by pickerel weed or water lily). The MNAP classification also defines 24 ecosystems in Maine, of which seven may be considered aquatic (e.g. kettlehole bog-pond, lakeshore, and Appalachian-Acadian rivershore ecosystems). In a related study, Cameron (2000) sampled macrophyte assemblages in 30 lakes and, using an ordination technique, was able to distinguish four vegetation community types – these are described in Chapter 6.2.

Other classifications of Maine freshwater assemblages have focused on macro-invertebrates. Courtemanch (1982) studied the assocation between profundal chironomid (midge) assemblages and lake water quality. Chironomid communities differed across the entire gradient from low to high productivity lakes, but provided a particularly useful tool for discriminating trophic state in the oligotrophic (unproductive) to mesotrophic (moderately productive) ranges. For stream invertebrate communities in Maine, there has been considerable effort dedicated to evaluating the relationships between community structure and water quality (Davies et al. 1999, Courtemanch 1993, Courtemanch et al. 1989, Davies et al. ms.). The classification of stream macro-invertebrate communities is central to the development of a bioassessment methodology for evaluating the degree to which streams meet water quality expectations (Shelton and Blockson 2004). More recently, Hawkins et al. (200x) have extended the approach to community classification by evaluating the extent to which invertebrate assemblages deviate from predicted reference assemblage types.

Few studies have focused on the classification of Maine's freshwater fish communities – at least not beyond the level of warm-water / cold-water and deep water / littoral groupings. Two factors limit the extent to which fish can be used for developing a classification scheme for Maine's freshwater ecosystems. First, most of the available assemblage-level fish data are simply species lists, without adequate measures of species' relative abundance. Second, the fish assemblages of Maine's lakes and streams have been, and continue to be, substantially impacted by stocking and species introductions, making it difficult to evaluate whether or not apparent assemblage groups reflect relatively stable ecological communities or are simply the result of human interventions. Analyses of fish community structure carried out during MABP are discussed in Chapter 6.4

No study in Maine has attempted to classify lakes using multiple taxonomic groups and then evaluate the similarity among the classes produced by the various groups, i.e. how well the different taxa define the same lake classes [7]. Such a study was carried out in Vermont (Langdon et al. 1998). While there were some assocations between resource classes developed from different taxonomic groups, the study's authors caution that it is necessary to "consider each plant or animal group classification individually" (Langdon et al. 1998, p. 32). An overarching conclusion from the Vermont study appears to be that it remains realistic to consider both lake and stream communities from the traditional physico-chemical perspectives (e.g. elevation, trophic class, stream gradient, etc.). This observation reinforces the potential utility of a biophysical-based classification framework.

3.3 Rare, Threatened and Endangered Species

Among *both* terrestrial and aquatic taxa, 34 animal species in Maine are currently listed as threatened or endangered under the Maine Endangered Species Act an additional 13 species (including the Atlantic Salmon Distinct Population Segment) are listed under the Federal Endangered Species Act, but not under Maine legislation. The equivalent number for plants is 186 species. MNAP also lists 72 plant species as possibly extirpated from Maine – they have not been documented or field-verified in the State over the past 20 years. Within the group of freshwater taxa considered by MABP (amphibians, reptiles, fish, invertebrates and plants), 19 species are listed as threatened and 10 species listed as endangered (Table 3.4). An additional 45 species are considered rare and are "tracked" by MDIFW or MNAP in their Natural Heritage database.

Rare species occupy a variety of freshwater habitats ranging from large lakes to vernal pool, and large rivers to mountain streams. A few rare species are endemic to Maine, while others are at either the northern or southern end of their ranges. While Chapter 6 focuses on a more in-depth discussion of rare (and non-rare) faunal and floral groups, we provide here synopses of nine rare species or species groups.

- Freshwater mussels: Maine's two threatened mussel species, yellow lampmussel (*Lampsilis cariosa*) and tidewater mucket (*Leptodea ochracea*), occur in several watersheds in the central and northeastern part of the State. They occur together in about half of these watersheds (Figure 3.1 A). MDIFW lists three mussel species as being of special concern: triangle floater (*Alasmidonta undulata*), brook floater (*A.*

[7] Note, however, that O'Connor et al (2000) and Allen et al. (1999) were able to demonstrate that different taxonomic groups, -- diatoms, benthic macroinvertebrates, zooplankton, fish and birds -- did exhibit some concordance in their responses to environmental stressors in New England lakes, some of which are located in Maine.

varicosa) and creeper (*Strophitus undulata*). Watersheds with two or more special-concern species are concentrated in the central part of the State (Figure 3.1 B).

- Odonates: There are 28 rare odonate species in Maine that are "tracked" by MDIFW. These rare species include both threatened and endangered taxa, as well as other rare species that are not formally listed as threatened or endangered (Table 3.4). Approximately one half (84/177) of Maine's HUC-10 watersheds contain no records for any of the 28 tracked odonate species (Figure 3.2 A and C). In 59 watersheds, there are documented occurrences for one or two tracked species. Tracked species generally comprise <5% of the total number of odonate species recorded from the watershed (Figure 3.2 B) – an observation consistent with the fact that tracked species are rare.

- Mayfly assemblages: Although only two mayfly species are tracked by MDIFW, many others appear to be rare in the State. We define "rare species" here as those that have been documented from ten or fewer HUC-10 watersheds in Maine. While this value of ten watersheds is subjective, it is based on species-frequency distribution data (see Figure 6.7.2 in Chapter 6). In most watersheds, fewer than five rare species have been recorded. However, there are several watersheds in which the number of rare species exceeds 15 (Figure 3.3 A). In many of the HUC-10 units, rare species represent over 20% of the total number of mayflies recorded from the watershed. In some watersheds, however, rare species comprise >40% of total species – and these watersheds include some with relatively high species counts (Figure 3.3 B). It is unclear to what extent inadequate survey effort contributes to this pattern of rare mayfly species richness.

- Tomah mayfly: *Siphlonisca aerodromia* has some characteristics that are reminiscent of fossil mayflies from the Carboniferous period (McCollough et al. 2003). This threatened species was first discovered about 100 years ago in northern New York, but this population was apparently extirpated following construction of a dam in the 1930s. Once considered extinct, it was rediscovered in 1978 at Tomah Stream in eastern Maine (Gibbs 1993). Since that time, surveys have recorded this species from a number of sites, primarily in Maine (Figure 3.4), but also in New York and Quebec (Gibbs et al. 2001). Within Maine, the Tomah mayfly has been observed at just over 15% of the sites at which it has been searched for (Figure 3.4). It inhabits small rivers and streams fringed by extensive areas of sedge meadow. Its patchy distribution in Maine and elsewhere is likely a consequence of its habitat requirements. Dam construction on rivers and streams, leading to destruction of sedge meadows, may be a primary cause of this species' limited distribution in the state (Gibbs 1993). Sex ratios of late-instar nymphs are female-biased. In addition, studies have shown that up to 94% of the eggs from unmated females hatch or display embryonic development. Both these observations suggest that parthenogenesis (reproduction without fertilization) may occur in this species (Gibbs and Siebenmann 1996).

- Roaring Brook mayfly: *Epeorus frisoni* is Maine's only endangered mayfly species. It is endemic to Maine, found only on Mt. Katahdin. Since its first discovery in 1939, there had been uncertaintly about whether it still existed on Katahdin and even about its validity as a distinct species. Recent (2003) surveys by MDIFW have confirmed that (i) it is a valid species, (ii) it still exists in an apparently highly restricted area of Baxter State Park -- although not in Roaring Brook, itself, it seems (Swartz et al. 2004). Its habitat is a high-gradient mountain stream characterized by large boulders and coarse granite bottom (McCollough et al. 2003). Although this type of habitat exists in other parts of Maine, the species has so far not been found outside of Baxter State Park.

- Arctic charr: Maine and Alaska have the only native populations of *Salvelinus alpinus* in the United States, although it is widely distributed in Canada and other circum-polar regions. It is one of two fish species listed as being of Special Concern in Maine (Table 3.5). Two color variants of this species are known as Sunapee trout and Blueback trout. In the past, they were considered separate species (Everhart 1966). The Arctic charr has the most northerly distribution of any North American fish species (Page and Burr 1991). It was extirpated from the Rangeley Lakes in the early 1900s, probably as a result of over-harvesting and competition from introduced landlocked salmon (Kendall 1918). Today, eleven lakes and ponds have native char populations and there are introduced populations in several others (Figure 3.8). This species inhabits well oxygenated, cold, deep lakes.

- Shortnose sturgeon: *Acipenser brevirostrum* was originally listed as federally endangered in 1967. The National Marine Fisheries Service (NMFS) recognizes 19 distinct population segments, including two in Maine (Penobscot River and the Sheepscot, Kennebec and Androscoggin Rivers). No individuals have been reported from the Penobscot River since 1978, but it is thought that they still exist in this river. The primary shortnose sturgeon populations in Maine are in the Kennebec and Androscoggin estuaries (NMFS 1998). The St. John River in New Brunswick supports one of the largest populations of shortnose sturgeons in North America.

- Atlantic salmon: In 1999, the USFWS listed the Atlantic salmon as endangered in eight Maine rivers, five of which are in the Downeast region of the State (Figure 3.5). Fish in these rivers comprise the Distinct Population Segment – see below and Chapter 6.

- Blanding's turtle: *Emydoidea blandingii* is restricted to the southernmost part of the State (Figure 6.3.1, Chapter 6), frequenting small acidic wetlands and vernal pools. It is one of two state-listed endangered turtle species in Maine (Table 3.5). In the 1990s, less than 1000 individuals were estimated to occur in southern Maine. Habitat fragmentation, isolating wetland habitat from upland nesting habitat, is one of the greatest threats to this species (McCollough et al, 2003). Blanding's turtle populations are particularly vulnerable to all sources of adult mortality because of late age of first reproduction and high nest mortality. Road kill is the primary source of adult mortality (McCollough et al., 2003).

- Aquatic plants: Although records for the group of 27 rare aquatic plant species tracked by MNAP span the State, most small watersheds (HUC-12) have only one documented species (as of early 2004; Figure 3.6). A few watersheds, particularly in the more heavily sampled southern region of the State, have records of up to 15 species. Many of the rare species appear to have relatively restricted distributions, although a few, such as the water awlwort (*Subularia acuatica*), are found throughout a much broader region (Figure 3.7).

3.4 Unique and High-Value Systems: Some Examples.

There are many approaches to determining value for Maine's freshwater resources, ecosystems and species (rarity, itself, generally confers high value to a species). Frequently, "valuable" will depend on the perspective of the person assigning values and/or the objectives of the valuation exercise. Here, we introduce seven examples of high-value and/or relatively unique systems and biological assemblages. These (and other) high-value components of Maine's aquatic biodiversity will be further discussed in Chapter 6.

- Wild brook trout and lake trout populations: While brook trout have been stocked throughout Maine for many decades, MDIFW estimates that there are almost 600 lakes which contain wild brook trout populations (i.e. the lakes have never been stocked with this species and thus contain native, self-sustaining, populations). Similarly, there are an estimated 28 lakes that contain wild lake trout populations. The vast majority of these lakes occur in the western and northern parts of the State, with a few being in the Downeast region (Figure 3.8). It is likely that the number of wild brook trout lakes is actually higher, since many of the smaller systems have never been surveyed. Recent work has documented spatial variations in the genetic structure of Maine's brook trout populations (see below).

- Wild landlocked salmon populations: Since the mid 19th Century, landlocked salmon have been widely stocked in Maine (Warner and Havey 1985). It is thought that the "original" landlocked populations were found in four lake systems: West Grand Lake (Washington County), Green Lake (Hancock County), Sebec Lake (Piscataquis County), and Sebago Lake (Cumberland County). Today, MDIFW estimates that wild (unstocked, self-sustaining) populations exist in 19 of the 304 landlocked salmon lakes across the State (data provided by K. Warner, MDIFW). Note, however, that Kendall and Havey [1985] state that populations are maintained by natural reproduction in 26% of the lakes in which the species occurs. Also, according to MDIFW stocking data in the MABP database (current through 2003), 154 of the 304 lakes have been stocked at some time since 1998. MDIFW's management plan for landlocked salmon for the period 2001-2006 states that its goal is to maintain principal fisheries in about 46 waters based entirely on natural reproduction.

- Dwarf lake whitefish and smelt populations: Lake whitefish, *Coregonus clupeaformis,* is present in 76 of Maine's lakes. In about 30 of these there are (or were) dwarf forms present, with or without normal forms (Figure 3.9). Dwarf lake whitefish are not considered a separate sub-species in Maine, although in Canada the Lake Simcoe whitefish has been shown to be genetically distinct and is protected as a threatened subspecies (Page and Burr 1991). The dwarf forms are characterized not only by a smaller size but also by morphological differences that reflect their ecological role in the community. For example, they have more gill rakers, with finer spacing between the rakers, which means that they are more efficient zooplanktivores (Fenderson 1964). They also mature in 1-2 years, whereas the normal forms typically take 3-5 years. In Cliff Lake (T9 R12, Piscataquis County), the morphological differentiation between the dwarf and normal forms of lake whitefish is especially pronounced (Bernatchez and Wilson 1998, D. Baseley, MDIFW, pers. comm..). It is likely that, historically, dwarf forms were more common than they are currently. Competition with (often introduced) species such as rainbow smelt is probably a major reason for the decline in dwarf lake whitefish populations.

  Rainbow smelt (*Osmerus mordax*) is another species which occasionally exhibits dwarf forms (Taylor and Bentzen 1993, Rupp 1959). As with dwarf whitefish, dwarf smelt have more gill rakers than do normal smelt; they also have larger eyes. At least four lakes in Maine are known to have dwarf smelt populations: Onawa Lake, Green Lake, Floods Pond and Lake George. Onawa Lake supports both dwarf and normal fish. Genetic analyses have shown that the smelt of Green Lake (Ellsworth / Dedham) are distinct from all other populations in Maine, Nova Scotia and Newfoundland. The Green Lake fish belong to the phylogenetic assemblage of populations north of the St. Lawrence River. Current evidence suggests that, in lakes where dwarf and normal populations co-exist (only one lake in Maine, but several outside of the state), these populations have an allopatric origin, i.e. they result from separate "introductions". Dwarf smelt used to be considered a separate species (Rupp 1959), but now are not (Taylor and Bentzen 1993).

- Fishless ponds: As of mid-2004, there were 29 ponds documented as being fishless in Maine, located primarily in the western and Downeast regions of the State (Figure

3.10) – note that some ponds previously thought to be fishless proved not to be so. A few of the fishless systems are >10 acres, but most are smaller. It is well known that fish can have major influences on the structure of plankton, macro-invertebrate and some non-fish vertebrate communities. Because of this and because of their rarity, fishless ponds represent unique ecosystems. Reasons for fishlessness include (i) impeded access (barriers, such as waterfalls or high-gradient stream sections, and the absence of connections to the surface drainage network), (ii) highly acidic water and (iii) extensive anaerobic conditions, either under ice or during summer.

The introduction of fish into previously fishless systems has been shown to impact invertebrate communities by altering species composition, relative abundance and body size structure (McPeek 1998, Post and Cucin 1984, Mallory et al. 1994, Bendell and McNicol 1987, Zimmer et al. 2000, Lamontagne and Schindler 1994). Such introductions may also negatively impact amphibian populations (e.g. Funk and Dunlap 1999, Drake and Naiman 2000) and, via competition for food resources, can decrease waterfowl fledging success (Mallory et al. 1994, Bendell and McNicol 1987, Hanson and Riggs 1995). In Maine, Brett (1985) has shown that nektonic invertebrates are more common in fishless lakes than in lakes with fish. There is some evidence (external to Maine) that the recovery process following removal of introduced fish species from a previously fishless pond may be quite slow, perhaps on the order of decades (Drake and Naiman 2000). Thus, identification and effective conservation of the remaining fishless ponds (or at least a representative selection) is critical for the preservation of this ecosystem type.

The number of fishless ponds used to be greater, but a number have been stocked in recent years, either legally or illegally (MDIFW currently has a moratorium on stocking fishless ponds). Since many smaller lakes and ponds in the State have never been surveyed, it is highly likely that undocumented fishless ponds exist. Two studies currently underway at the University of Maine are focusing on this issue. In one, a landscape-level model is being developed to predict which ponds across the State are likely to be fishless (E. Schilling, University of Maine, pers. comm.). The second study is using sediment cores to determine whether some ponds that might otherwise be expected to be fishless, but currently have fish, were originally fishless.

- Native minnow species: Lakes with high numbers of native minnow species are clustered in the northern and western parts of the State (Figure 3.8). Although elevated minnow species richness does not necessarily indicate more pristine conditions (e.g. "bait-bucket" introductions may be increasing the number of species in naturally depauperate systems), it is likely that introductions of littoral predators such as largemouth and smallmouth bass, chain pickerel (*Esox niger*) and northern pike (*E. lucius*) have caused decreases in minnow diversity (Whittier et al. 1997, Whittier and Kincaid 1999). Pond in the River, between Lake Umbagog and Richardson Lake in western Maine, appears to have the highest diversity of native minnows in Maine (MDIFW data), although it is likely that this diversity is now under threat from encroaching smallmouth bass. See Chapter 6 for added discussion of Maine's native minnows.

- Biodiversity of acidic lakes: Among lakes with water quality data, about ninety are known to be acidic with a pH less than 5.5. Most of these acidic lakes are either at high elevations or are in the Downeast region (Figure 3.11 C). Most of the non-plankton biodiversity data on acidic lakes is for fish. A number of these lakes are fishless. However, for those acidic lakes with fish, their species richness is similar to other lakes of the same size (Figure 3.11 A). Perhaps the most detailed study of a broad range of biodiversity in acidic lakes is that of Hunter et al. (1985). Their study focused on two pairs of ponds in Hancock County; one pond in each pair was naturally acidic (pH < 5.0) whle the other was not. The two acidic ponds were fishless; one circumneutral pond had brook trout and golden shiner, while the other pond had several fish species (current MDIFW data indicate that it has seven species). The acidic ponds had a total of 11 macrophyte species, while the circumneutral ponds had a total of 22 species. Total plant biomass, however, appeared to be controlled more by transparency than by acidity. The lowest biomass was in a circumneutral pond which also had the lowest transparency. Zooplankton communities differed between acidic and non-acidic lakes, and densities of backswimmers were much higher in the fishless, acidic ponds. Benthic invertebrates were sampled in one pair of ponds. Biomass of the benthos was substantially lower in the acidic pond, as was taxon richness in some groups. For example, the acidic pond had two mayfly and nine caddisfly genera, while the circumneutral pond had five and fifteen, respectively. Odonate assemblages, however, were similar in both ponds, although odonate biomass was substantially lower in the acidic pond.

- Biodiversity of high elevation lakes: These lakes are unique and sensitive ecosystems because of their location, their rarity and the fact that their water is generally very dilute (low ionic strength). While the water quality and plankton of these lakes have been extensively studied (Kahl and Scott 1988, Kahl et al. 1991), there is less information on their non-plankton biodiversity. Available fish data show that high-elevation lakes have lower numbers of fish species than would be expected based on their size (Figure 3.11 B). Seven of the surveyed lakes are known to be fishless, while the others have between one and four species. Species richness is independent of lake size. Brook trout (*Salvelinus fontinalis*) is present in most of the lakes with fish. Lake chub (*Couesius plumbeus*) is the next most common species in these high elevation lakes, followed by blacknose dace (*Rhinichthys atratulus*), smelt (*Osmerus mordax*), finescale dace (*Phoxinus neogaeus*) and golden shiner (*Notemigonus crysoleucas*). Illegal fish introductions (including minnow species) are a significant threat to these systems.

- High-value fisheries: Numerous lakes and streams across the State are known to support high-value (outstanding quality) fisheries. In this context, high value often refers to exceptional growth rates or the presence of a good fishery for a species that tends not to be common in a particular region (for example trout in southern Maine). While these high-quality waters are in general not formally documented by MDIFW, some of the relevant information provided to MABP through interviews with regional biologists is provided in Appendix 11.8.

- "High-value" watersheds: As part of its ecoregional planning process, TNC employed a series of approaches to identify watersheds and lakes that rank highly in terms of landscape condition and biodiversity attributes. These watersheds constitute an initial candidate list from which will be selected areas for future conservation efforts. Evaluation of watersheds relied on three broad sources of information:

    - GIS coverages, including land-use and land-cover, dams, pollution sources, roads, and existing conservation lands.
    - Biodiversity data, including: rare species and exemplary community occurrences; representation of native species; other notable biotic assemblages.
    - Expert opinions.

    Following evaluation of all these information sources, a list of priority, high-quality, watersheds was developed (TNC, in prep.).

3.5 Genetic Diversity

Identifying population groups with independent evolutionary histories is a basic prerequisite for managing biodiversity (Bernatchez and Wilson 1998). Within the U.S. Endangered Species Act, the Distinct Population Segment and the Evolutionary Significant Unit are provisions that can afford legal protection for differentiated populations which share the same species name, i.e. separate species status is not required (Taylor 1999). With recent advances in techniques for documenting genetic structure, there are ever increasing opportunities for quantifying levels of among-population diversity. Genetic data are especially important wherever detailed ecological data for different populations is unavailable and where morphological characters provide little resolution among groups. This section provides a synopsis of five studies that have addressed genetic diversity in segments of Maine's freshwater biota.

Tomah mayfly: Gibbs et al. (1998) investigated genetic differentiation among six populations of this rare mayfly species – two from the Kennebec drainage and four from the Penobscot and St. Croix drainages. While mayfly populations only 4 km apart along the same stream showed significant differences in allele frequencies, the level of differentiation among populations that were separated by over 100 km in the St. Croix and Penobscot drainages was minimal. This suggests that adult dispersal may be sufficient to maintain gene flow among populations at this scale. The greatest genetic differentiation was observed between the two western populations (in the Dead River watershed) and the group comprised of the Penobscot and St. Croix populations. The geographic separation between these two groups may promote their genetic divergence. In addition, the two sets of populations are in different climatic regions. Sites in western Maine are cooler relative to the central/eastern sites, perhaps contributing to delayed development of nymphs in the west. Gibbs et al. (1998) suggest that this delay in development translates into an approximately 20-day difference in emergence. Since adults are short-lived, these two groups are isolated temporally, as well as spatially.

Yellow lampmussel: The genetic diversity of freshwater mussel species is of particular interest in view of the substantial array of threats impacting this group in North America (see Chapter 6). Kelly and Rhymer (2005) conducted one of the first studies to examine the genetic structure of freshwater mussel populations in a recently glaciated landscape. They focused on three populations of yellow lampmussel, from the St. George, Kennebec and Penobscot drainages. Populations separated by relatively modest distances, as little as 36 km, exhibited significant differences in genetic structure. Variance explained by differences among populations was similar to differences among drainages, each about 4% of total variance. Genetic variation among yellow lampmussels from these drainages was modest compared to that found in more southern unionid populations, suggesting that glacial history is a significant factor influencing levels of differentiation in populations of the Northeast. There was no detectable influence of the number or height of dams in the various drainages on the level of genetic differentiation in the mussel populations. Another study, currently in progress, is developing a DNA key for ten mussel species and will use this to identify mussel glochidia ("larvae") to species (J. Rhymer, University of Maine, pers. comm.). This should improve our knowledge of the fish hosts of mussel species in Maine.

Brook trout: The influence of historical and contemporary landscape features on genetic diversity in 30 of Maine's brook trout populations was recently studied by Castric et al. (2001). They analyzed samples from the Kennebec, Penobscot and St. John drainages to investigate how (i) habitat (=lake) area, and (ii) altitudinal differences among populations influence genetic diversity. Brook trout from different locations comprised genetically distinct populations. Interestingly, variation among drainages was low relative to the variation between populations within the same drainage. Landscape features had different effects on the Penobscot and St. John populations. In the St. John, variation was strongly associated with differences in altitude among locations, but not associated with the distance between populations. The reverse was the case for the Penobscot populations. Compared to brook trout populations from Quebec, Maine brook trout exhibited less among-population diversity. This was despite the fact that the Maine samples came from a much large geographic scale than did the Quebec samples.

Additional studies of the genetic structure of Maine brook trout populations involves populations from Acadia National Park (T. King, USGS, pers. comm., 12/2004). Using microsatellite data, the level of resolution is such that it is possible to characterize the level of relatedness of among populations of minor drainages and detect the influence of past stocking events. For six populations on Mount Desert Island, four cluster together (Marshall Brook, Jordan Stream, Stanley Brook and Hunters Brook), while two others appear relatively distinct (Lurvey and Hadlock Brooks). Reviewing data from a number of national parks in the U.S., there appears to be as much variation within parks as among parks (each about 15-21%). However, this broader scale variance is small compared to the within-population variance (approximately 68%) (T. King, pers. comm.).

Atlantic salmon: The 2000 listing under the Endangered Species Act covers the wild fish in eight Maine rivers (Figure 3.5) and considers them to be a single Distinct Population Segment (DPS). According to a recent report by the National Research Council (NRC 2002), North American Atlantic salmon are clearly distinct genetically from European salmon. Furthermore, despite extensive stocking of non-native hatchery fish (many of which came from Canada) and mixing with aquaculture fish, the evidence is "surprisingly strong" that wild salmon in Maine are genetically distinct from Canadian populations. There is also significant genetic divergence among populations in the eight Maine rivers – in fact Maine rivers have salmon populations that are "genetically as divergent from Canadian salmon populations and from each other as would be expected in natural populations anywhere else in the Northern Hemisphere" (NRC 2002). In addition to among-river differentiation, there is also significant variation among both tributaries and cohorts within the Penobscot River, although Penobscot fish are not currently within the Maine DPS.

Wood turtle: A recent, unpublished, study has investigated genetic diversity in several wood turtle (*Glyptemys insculpta*) populations in Maine: from the Androscoggin, upper Kennebec, Downeast and Aroostook drainages (J. Rhymer, University of Maine, pers. comm.). There is a problem with illegal "take" of this species in Maine and resource managers would like to know where the removed individuals are coming from. While data are not yet final, it appears that Downeast populations can be identified, based on genetic structure, with an 80% accuracy, whereas the accuracy for the other drainages is 60% or less.

Table 3.5: Freshwater animal and plant species listed as threatened, endangered or of special concern in Maine, as of June, 2004 [(1)]. Data sources: MDIFW, MNAP.

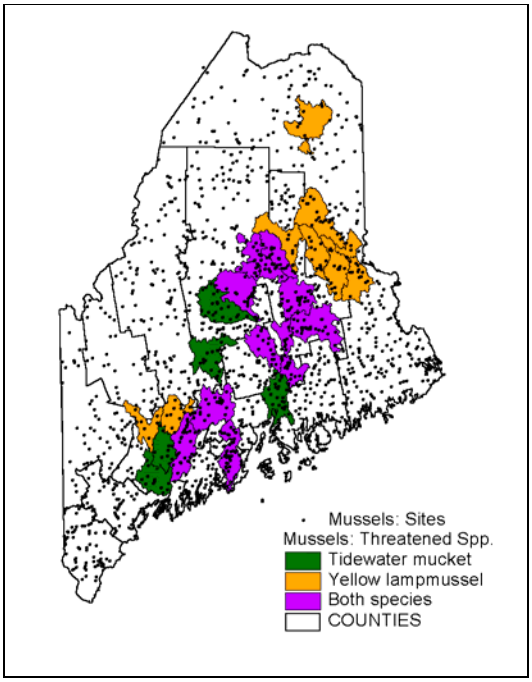
GROUP	SCIENTIFIC NAME	COMMON NAME	STATUS [(2)]
Reptile	***Clemmys guttata***	**Spotted turtle**	**T**
Reptile	*Glyptemys insculpta*	Wood turtle	SC
Reptile	***Emys blandingii***	**Blanding's turtle**	**E**
Reptile	***Terrapene carolina carolina***	**Eastern box turtle**	**E**
Reptile	*Sternotherus odoratus*	Common musk turtle	SC
Amphibian	*Gyrinophilus porphyriticus*	Spring salamander	SC
Fish	*Salvelinus alpinus oquassa*	Landlocked arctic charr	SC
Fish	*Esox americanus americanus*	Redfin pickerel	SC
Fish	***Etheostoma fusiforme***	**Swamp darter**	**T**
Fish	***Salmo salar***	**Atlantic salmon**	**E (fed)**
Fish	***Acipenser brevirostrum***	**Shortnose sturgeon**	**E (fed)**
Mayfly	***Siphlonisca aerodromia***	**Tomah mayfly**	**T**
Mayfly	***Epeorus frisoni***	**Roaring brook mayfly**	**E**
Odonate	***Williamsonia lintneri***	**Ringed boghaunter**	**E**
Odonate	***Enallagma durum***	**Big bluet**	**T**
Odonate	***Gomphus quadricolor***	**Rapids clubtail**	**T**
Odonate	***Gomphus vastus***	**Cobra clubtail**	**T**
Odonate	***Stylurus spiniceps***	**Arrow clubtail**	**T**
Odonate	*Argia translata*	Dusky dancer	SC
Odonate	*Enallagma carunculatum*	Tule bluet	SC
Odonate	*Enallagma laterale* *	New England bluet	SC
Odonate	*Enallagma pictum*	Scarlet bluet	SC
Odonate	*Ischnura hastata*	Citrine forktail	SC
Odonate	*Ischnura ramburii*	Ramburs forktail	SC
Odonate	*Aeshna juncea*	Sedge darner	SC
Odonate	*Anax longipes*	Cornet dancer	SC
Odonate	*Epiaeschna heros*	Swamp darner	SC
Odonate	*Rhionaeschna mutata*	Spatterdock darner	SC
Odonate	*Lanthus vernalis*	Southern pygmy clubtail	SC
Odonate	*Ophiogomphus anomalus*	Extra-striped snaketail	SC
Odonate	*Ophiogomphus colubrinus*	Boreal snaketail	SC
Odonate	*Ophiogomphus howei* *	Pygmy snaketail	SC
Odonate	*Progomphus obscurus*	Common sanddragon	SC
Odonate	*Cordulegaster obliqua*	Arrowhead spiketail	SC
Odonate	*Neurocordulia michaeli* *	Broadtailed shadowdragon	SC
Odonate	*Somatochlora brevicincta*	Quebec emerald	SC
Odonate	*Leucorrhinia patricia*	Canada whiteface	SC
Odonate	*Libellula needhami*	Needhams skimmer	SC
Odonate	*Sympetrum corruptum*	Variegated meadowhawk	SC
Odonate	*Tramea carolina*	Carolina saddlebags	SC

Odonate	*Tramea lacerata*	Black saddlebags	SC
Mussel	*Alasmidonta varicosa*	Brook floater	SC
Mussel	***Lampsilis cariosa***	**Yellow lampmussel**	**T**
Mussel	***Leptodea ochracea***	**Tidewater mucket**	**T**
Mussel	*Strophitus undulatus*	Creeper	SC
Plant	*Callitriche heterophylla*	Water-starwort	SC
Plant	***Hottonia inflata***	**Featherfoil**	**T**
Plant	***Isoetes acadiensis***	**Acadian Quillwort**	**T**
Plant	***Isoetes prototypus***	**Prototype Quillwort**	**T**
Plant	***Isoetes riparia***	**Shore Quillwort**	**PE**
Plant	*Littorella uniflora*	American Shore-grass	SC
Plant	***Nuphar advena***	**Yellow Pond-lily**	**PE**
Plant	***Nymphaea leibergii***	**Pygmy Water-lily**	**T**
Plant	*Potamogeton bicupulatus*	Snail-seed Pondweed	SC
Plant	*Potamogeton confervoides*	Alga-like Pondweed	SC
Plant	***Potamogeton friesii***	**Fries' Pondweed**	**E**
Plant	***Potamogeton pulcher***	**Spotted Pondweed**	**T**
Plant	*Potamogeton strictifolius*	Straight-leaved Pondweed	SC
Plant	***Potamogeton vaseyi***	**Vasey's Pondweed**	**T**
Plant	*Sagittaria calycina*	Spongy Arrow-head	SC
Plant	*Sagittaria filiformis*	Narrow-leaf Arrowhead	SC
Plant	***Sagittaria rigida***	**Stiff Arrow-head**	**T**
Plant	*Samolus valerandi*	Water Pimpernel	SC
Plant	*Stuckenia filiformis ssp. alpinus*	Northern slender pondweed	**T**
Plant	*Stuckenia filiformis ssp. occidentalis*	Slender pondweed	**E**
Plant	*Subularia aquatica*	Water Awlwort	SC
Plant	***Wolffia columbiana***	**Columbia Water-meal**	**T**
Plant	*Zannichellia palustris*	Horned Pondweed	SC
Plant	***Zosterella dubia***	**Water Stargrass**	**T**

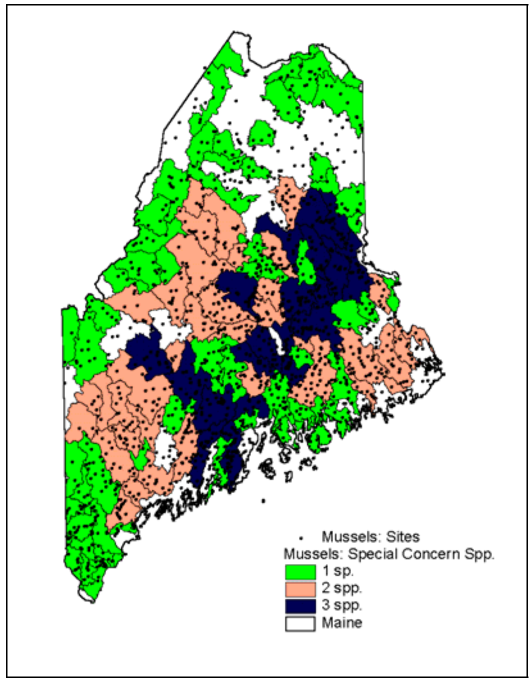
(2) E = endangered; T = threatened. E (fed) = listed as endangered at the federal level. SC = species of special concern; tracked by MDIFW or MNAP in Natural Heritage database.

* Included in Special Concern list on the basis of rare global listing status; these species are not considered endangered or threatened in Maine.

(Table 3.5, continued)



(A)



(B)

Figure 3.1: Distribution of (A) threatened and (B) special-concern mussel species, by watershed (HUC-10). Special-concern species (panel B) are summarized as the number of taxa per watershed.

Sample collection sites are shown as dots and include both lake and stream sites.
Data sources: MDIFW mussel survey and other data in MABP database.

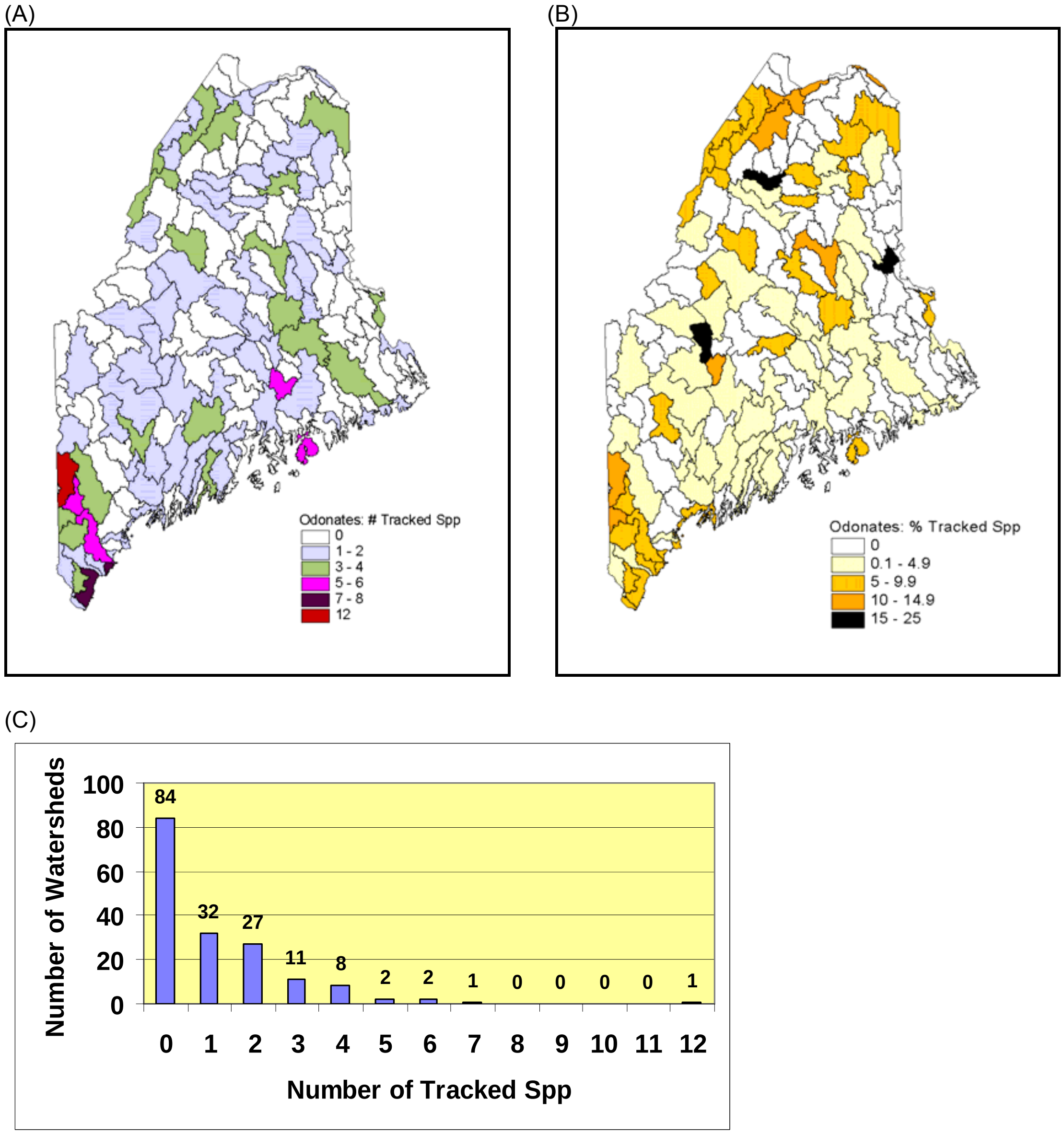
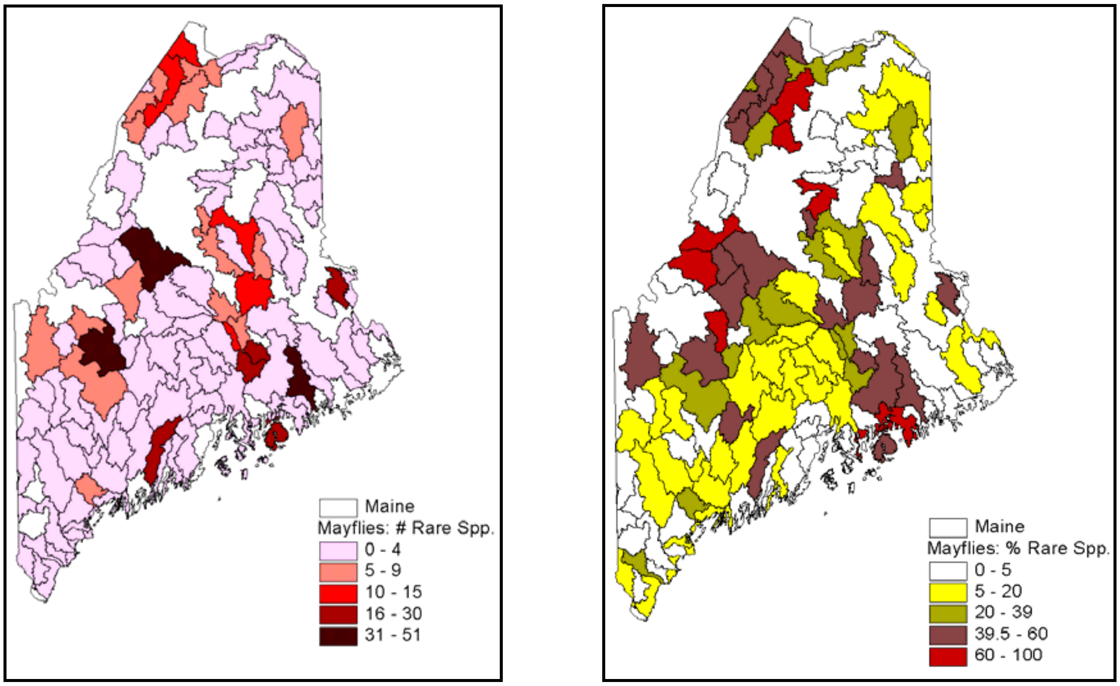


Figure 3.2: "Tracked" odonates: numbers of species by watershed.
(A) Number of "tracked" odonate species by watershed (HUC-10).
(B) Number of tracked odonates expressed as % of total number of species recorded from the watershed.
(C) Frequency of occurrence of tracked odonate species, by HUC-10.

MDIFW tracks (i.e. maintains a database for) a total of 28 rare odonate species (list of tracked taxa revised 2005). There are 177 HUC-10 watersheds in Maine.

Data sources: MDIFW dragonfly and damselfly survey, MDEP stream biomonitoring program, and other sources, as compiled in MABP database.



(A) (B)

Figure 3.3: Relative frequency of rare mayfly species, by watershed.
(A) Number of rare species recorded from each watershed.
(B) Rare species expressed as % of total number of mayfly species recorded from the watershed.
Rare species are defined as those occurring in ten or fewer HUC-10 watersheds across the state. Watersheds without data are not shown. Data are from Burian and Gibbs (1991) and other sources, as compiled in MABP database.

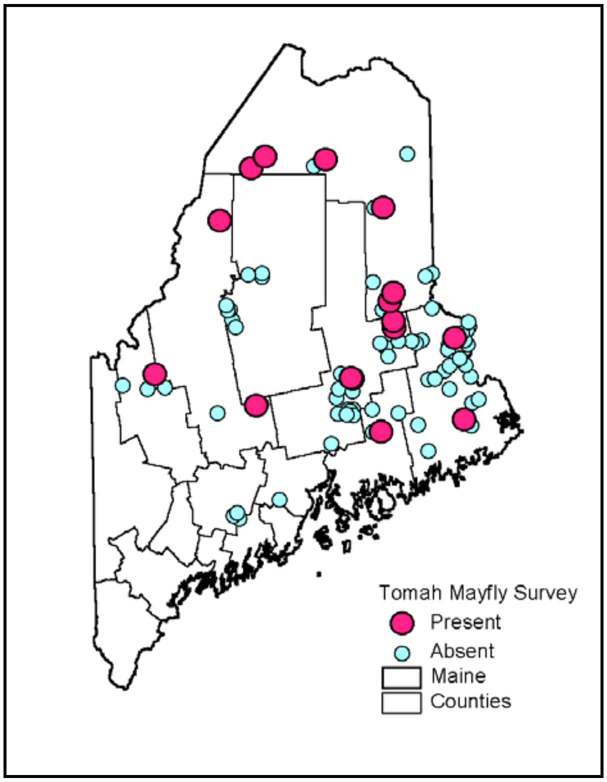


Figure 3.4: Tomah mayfly survey sites, with presence / absence records. Data sources: Gibbs et al. 2001; MDIFW.

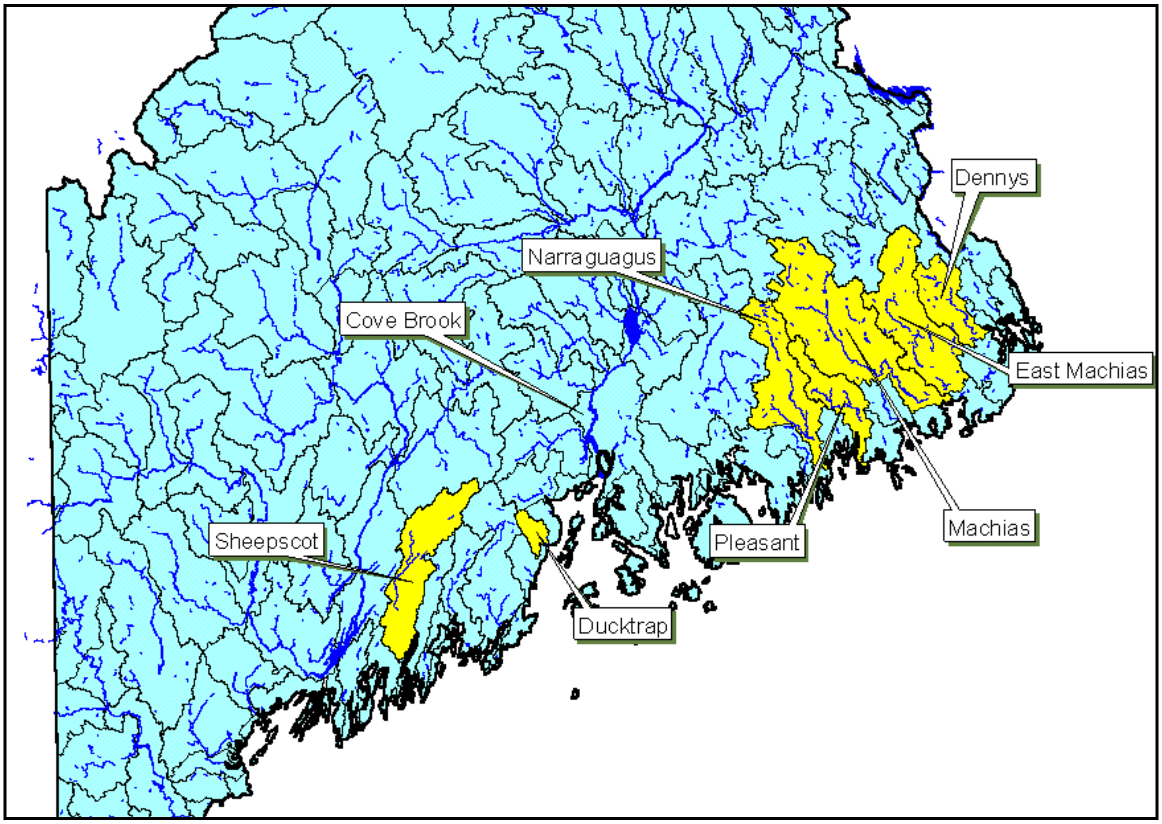


Figure 3.5: Watersheds containing Atlantic salmon distinct population segments. (Note: Cove Brook is not shown as a highlighted watershed because its HUC-10 unit extends beyond the boundaries of this stream's drainage.)

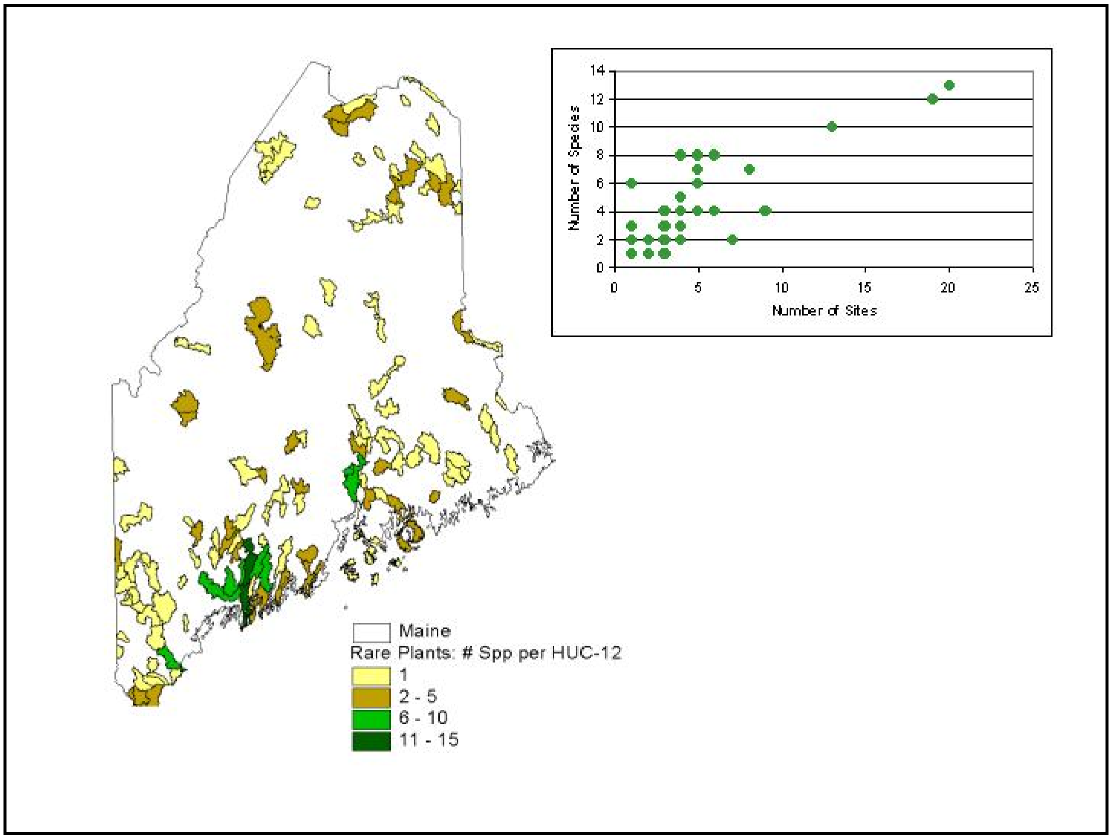


Figure 3.6: Number of rare aquatic plant species recorded by small watershed (HUC-12). Data include lake, stream and some wetland records. Inset graph shows relationship between one measure of sampling effort in a watershed and the total number of species rare species recorded in that watershed. Sampling effort is the number of sites visited per HUC-12 – a site being defined as a unique pair of coordinates. This effort measure probably does not provide a fully accurate indicator of the actual amount of sampling effort expended – rather it simply indicates the number of sites visited (and which yielded data). Source data are from Natural Heritage database (supplied by D. Cameron, MNAP 2004).

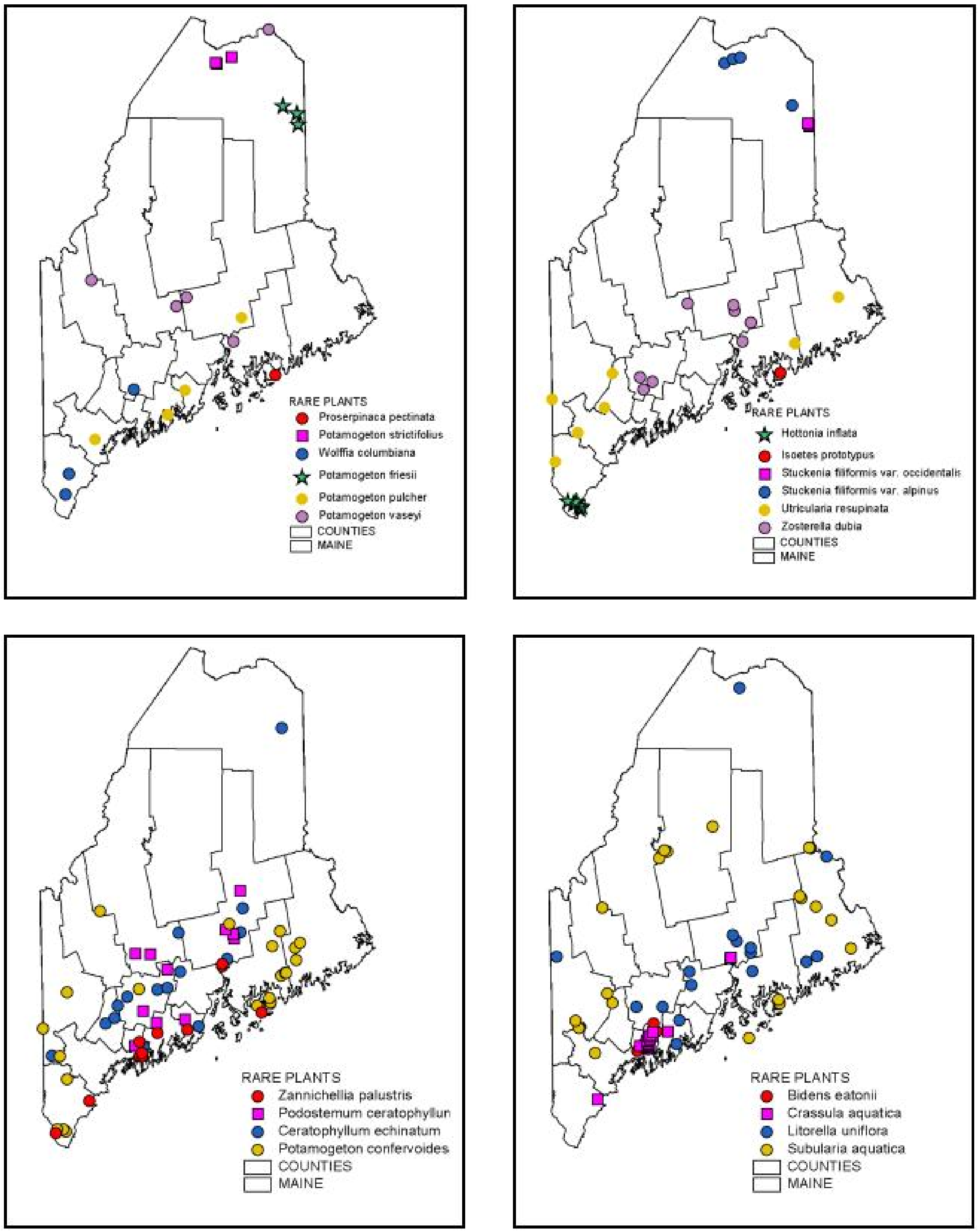


Figure 3.7: Distributions of selected rare aquatic plant species in Maine. Data source: MNAP 2004.

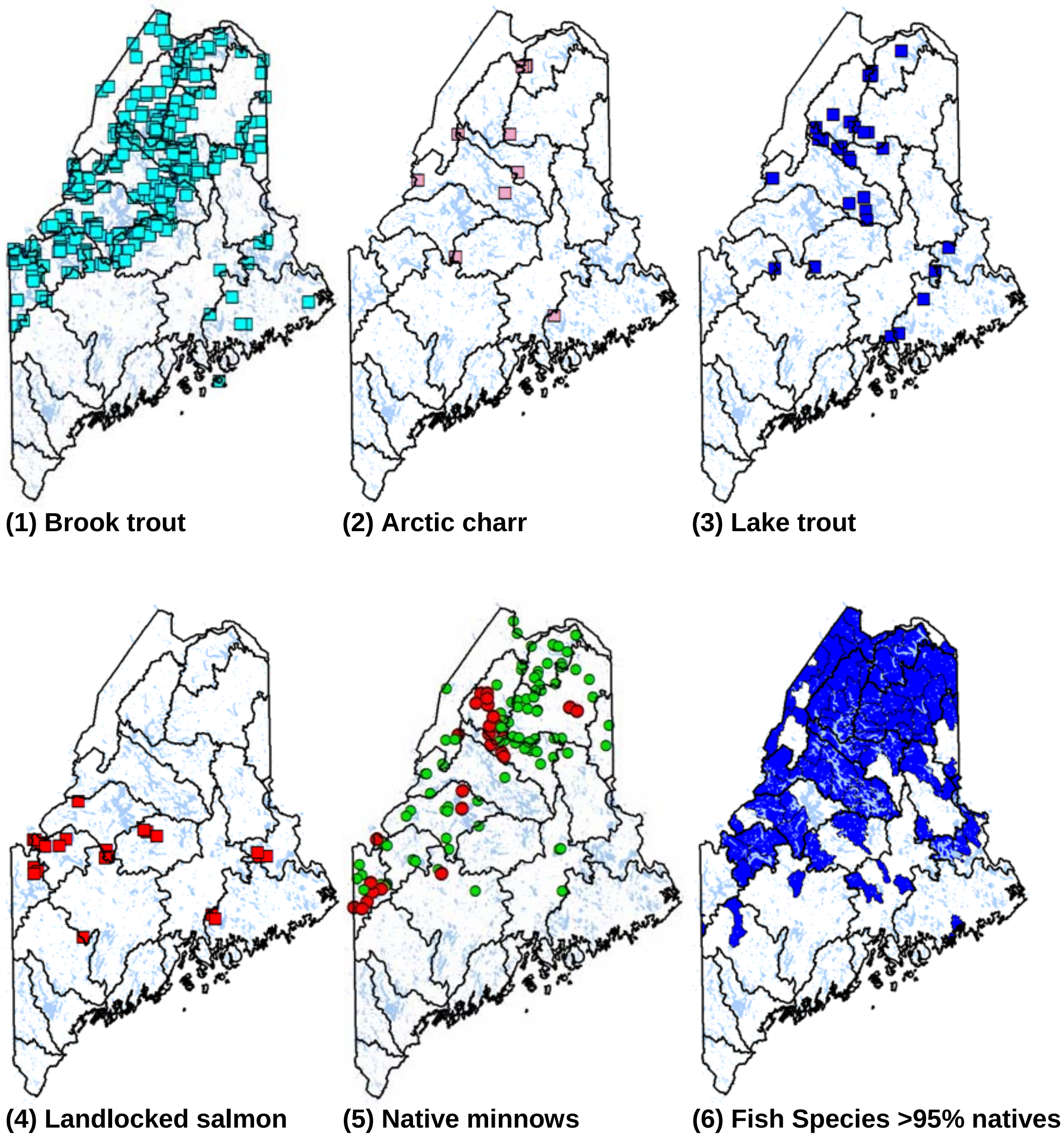


Figure 3.8: Six aspects of Maine's native fish fauna. Lakes with wild populations of: (1) Brook trout, (2) Arctic charr, (3) Lake trout, and (4) Landlocked salmon. (5) Lakes with high numbers of native minnow species: green = 6-7 species, red = 8-10 species. (6) Watersheds with >95% native fish species (species aggregated within each watershed). Golden shiner was excluded from minnow species totals. Data source: MDIFW.

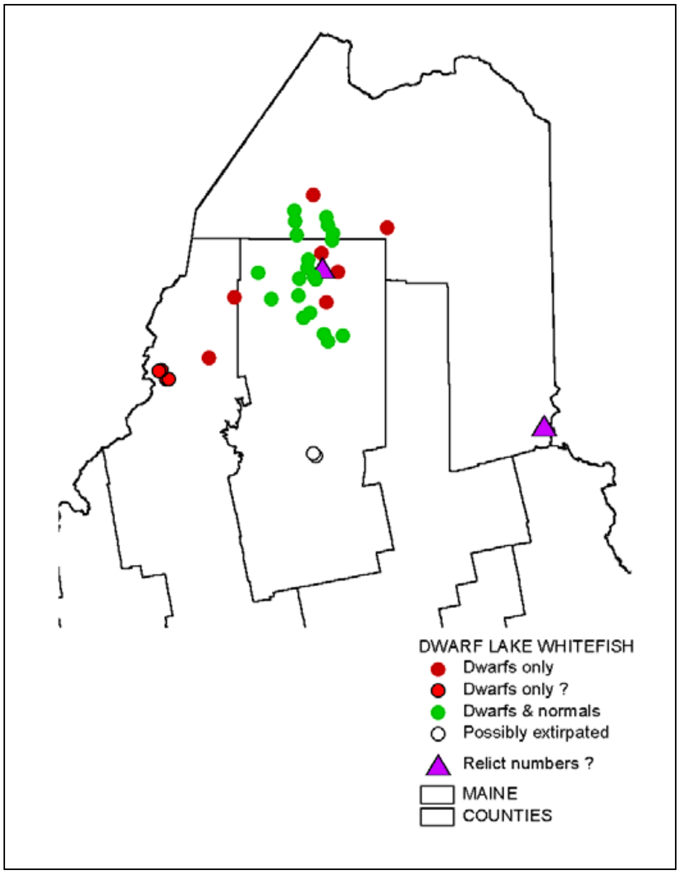


Figure 3.9: Location and status of dwarf lake whitefish populations in Maine.
Data sources: D. Basley and M. Smith, MDIFW, pers. comm.

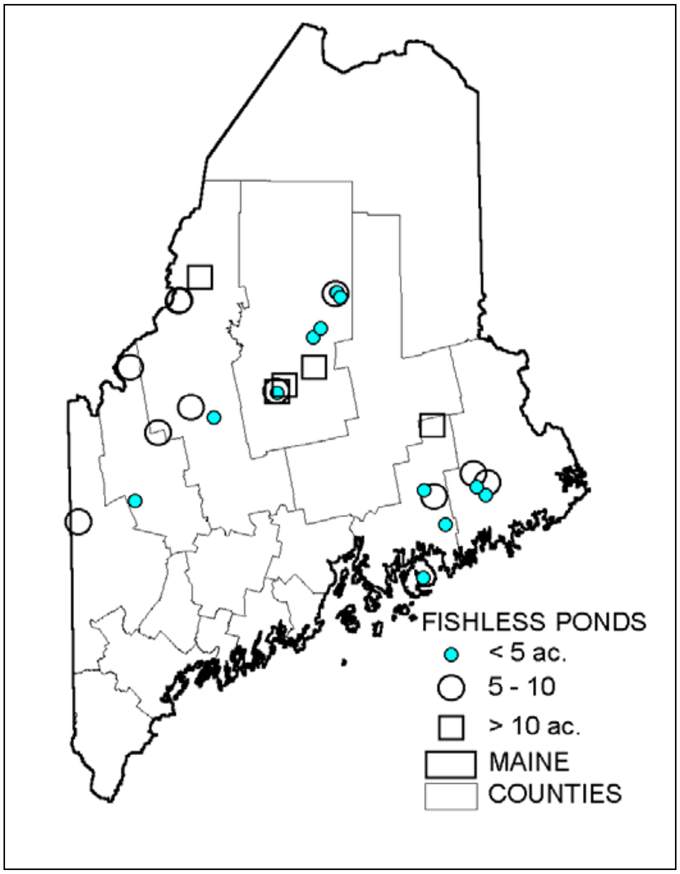
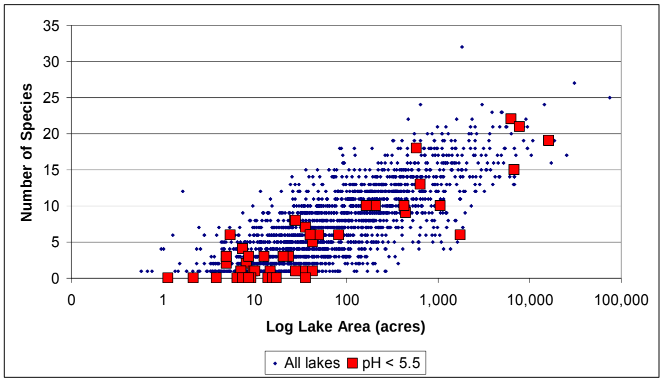
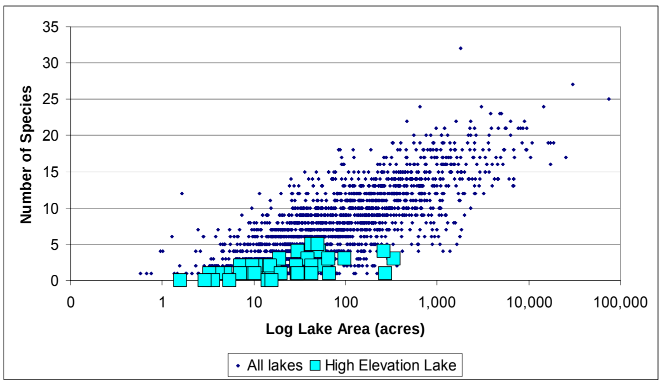


Figure 3.10: Lakes documented as apparently fishless, by size class.
Data sources: MDIFW and E. Schilling, pers. comm.

(A)



(B)



(C)

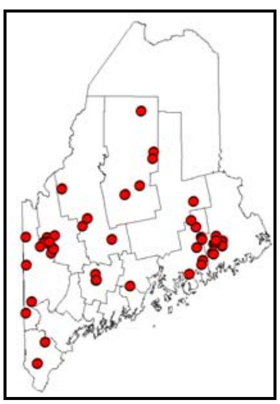


Figure 3.11: Fish species richness in (A) low pH lakes, and (B) high elevation lakes. (B) Location of low pH lakes (pH < 5.5).

In (A) and (B), fish species numbers are shown separately for all lakes and for low pH / high elevation lakes. In (C), all low pH lakes are shown, regardless of whether or not they have been sampled for fish.

Data sources: Fish: MDIFW; pH: University of Maine and MDEP.