6. FRESHWATER FLORA AND FAUNA: SPECIES DIVERSITY, COMMUNITY STRUCTURE AND ECOLOGY

6.1 INTRODUCTION

This chapter provides an in-depth focus on patterns of freshwater biodiversity in Maine (for an overview of aquatic taxa and ecosystems, see Chapter 3). The level of detail with which each taxonomic group is addressed reflects the amount of information available to MABP. Some groups, such as fish, odonates and mussels have been well-surveyed in Maine (Chapter 5) and the resulting data have resulted in a rich series of information analyses. Conversely, survey effort for other groups has been either patchy (e.g. caddisflies) or very limited (e.g. freshwater snails). In these cases, it is clear that there is much that we do not know about patterns of aquatic biodiversity in Maine – indeed it is likely that current species lists are significantly incomplete. Many of the findings presented here result from MABP-derived analyses using the composite MABP database; other information has been gleaned from various literature sources.

6.2 VASCULAR PLANTS

Defining a list of “aquatic” plant species is problematic, particularly in the case of emergent plants. Species that grow entirely or largely below the water surface (e.g. many of the pondweeds [*Potamogeton* spp.], or the hornworts [*Ceratophyllum* spp.]) or float on the water surface (water lilies, duckweeds) are clearly obligate aquatic taxa. However, many emergent species straddle the often diffuse boundary between lakes (and streams) and palustrine wetlands. Others inhabit lake or river shores, where the habitat which may change over time from shallow water to being fully exposed. For the purposes of MABP, the decision to label a species as aquatic was based on habitat descriptions presented in Haines and Vining (1998) and Magee and Ahles (1999), supplemented by information provided by D. Cameron (MNAP, pers. comm.). Examples of transitional groups where the aquatic designation for some species was not clear-cut, and thus unavoidably rather subjective, include the spikerushes (*Eleocharis* spp.) and the bur-reeds (*Sparganium* spp.).

Information Sources: Seven sources provided the majority of aquatic plant data for the MABP database. (i) University of Maine herbarium data (provided to MABP by C. Campbell in 2002) include township-level resolution for species records [11]. Approximately 67% (345/515) of townships represented in the herbarium database have records for one or more aquatic plant species (records from the remaining townships comprise only terrestrial species). (ii) The Maine Natural Areas Program (MNAP) maintains a database of rare, threatened and endangered species (i.e. “tracked” species). Data are derived from both community-level plant surveys as well as targeted ‘searches’ for high-interest species. The most recent delivery of data for aquatic species was provided to MABP in 2004. (iii) MNAP has conducted “rapid bioassessments” of lake plant communities as part of an effort to detect invasive plant species. These community-level data were made available to MABP by D. Cameron (MNAP). (iv-vi) The studies of Greene et al. (1997) Cameron (2000) and Dieffenbacher-Krall (1988) provide community-level data from a number of Maine lakes (Figure 6.2.1). It is likely that the extent and type of sampling effort differed among these three studies. (vii) Records of invasive plant species (see Chapter 4) were provided by MDEP.

Two other information sources were accessed by MABP. Extensive plant data, currently unpublished, from Highland Lake (Windham/Falmouth) were provided by Dr. Keith Williams, who

[11] Data from about 45,000 taxon records are available on-line at www.umesci.maine.edu/biology/herbarium/plant-database.

has been studying that lake for over 10 years. Data provided to MABP are from the 2001 survey. County-level plant species records are provided in the checklist of Campbell et al. (1995) and also in Magee and Ahles (1999). These were reviewed for correspondence with the finer-resolution records from the sources listed above. For a few of the rarer plant species, the county-level records of Campbell et al. (1995) suggest that MABP's finer-resolution records under-estimate some taxon ranges – examples are provided below.

Additional plant data exist for Maine but were not included in the MABP database. For example, information from some of the samples collected by B. Hellquist and others exist in various herbaria (B. Hellquist, pers. comm.) whose databases were not readily accessible by MABP. The most recent data collected by D. Cameron and others in MNAP were not available prior to MABP's data cut-off.

Species Diversity: Of the 3,573 species of vascular plants (<u>all</u> taxa: terrestrial, wetland and aquatic) known from New England and New York east of Lake Champlain (Magee and Ahles 1999), 2,096 have been recorded from Maine (Haines and Vining 1998; Table 6.2.1)[12]. Of these Maine species, and using the habitat descriptions of Haines and Vining (1998), we consider 438 species as being primarily wetland taxa, whereas 130 are considered to be fully aquatic. This total of 568 Maine wetland/aquatic species represents approximately 50% of the wetland species included in Crow and Hellquist's (2000) treatise on wetland species from northeastern North America (Table 6.2.1). Analyses in this report focus on the pool of 130 aquatic species in Maine.

The USFWS (Tiner et al. 1995) lists a total of 1,436 wetland species for Maine (location records are not provided). This total includes facultative and obligate wetland species as well as fully aquatic taxa (Table 6.2.1). Obligate wetland species in this list number 562 and, of these, 242 are considered as submerged, floating or emergent aquatic species (Tiner et al. 1995). The USFWS total of 562 obligate wetland species agrees closely with the combined total of 568 (438+130) wetland and aquatic species developed by MABP from the Haines and Vining habitat descriptions.

Thirty five plant families have aquatic representatives in Maine. Sixteen of these families are primarily aquatic, i.e. >80% of their species are aquatic – note several families contain very few species (Figure 6.2.1; see also Appendix 11.4). The family of pondweeds (Potamogetonaceae) is the most species-rich in Maine, in terms of aquatic taxa. Within this family, Maine has about 70% of all species recorded from the northeastern North America (Crow and Hellquist 2002; Appendix 11.2).

No aquatic vascular plant species is endemic to Maine – in fact, among all Maine plant species, there are only two confirmed endemics (Gawler et al. 1996). Of the 27 aquatic species that are rare in Maine and tracked by MNAP, two are considered rare throughout their global range (the quillworts *Isoetes prototypus* and *I. acadiensis*). Just under 50% of these 27 rare species are listed as being threatened, endangered or potentially endangered in Maine; the remaining species are of special concern status (Table 3.4). From the species distribution maps produced from MABP-compiled data (Appendix 11.5.1), nine species (excluding invasives) appear rare in Maine but are not tracked by MNAP. For most species in this group, there is a significant discrepancy between MABP and the county records of Magee and Ahles (1999), suggesting that MABP is under-reporting their distributions. However, a few species, such as branching bur-reed (*Sparganium androcladum*), soft-stem bulrush (*Schoenoplectus tabernaemontani*), and watercress (*Rorippa nasturtium-aquaticum*) also appear rare from the county-level distribution maps (Magee and Ahles 1999).

Since the type and amount of sampling effort underlying the species distribution maps in Appendix 11.5.1 is so variable, it is difficult to adequately characterize the extent of occurrence

[12] Note that these totals tend to vary over time, primarily reflecting taxonomic revisions, but also, to a much lesser extent, new state records (Gawler et al. 1996)

for many species – in terms of either spatial distribution or frequency of occurrence (commonness/rarity). Nevertheless, approximately one third of Maine's aquatic species appear to be common and another third appear relatively rare. Twenty four percent of aquatic species appear to be distributed statewide and another 34% are found primarily in the southern and central (lowland) parts of the state. Five species are primarily coastal and eight species appear to be restricted to the northern parts of the state. For the remaining species, the data are too few to permit adequate characterization of their geographic ranges.

Gawler et al. (1996) noted that about 20% of all rare plant species in Maine (both terrestrial and wetland/aquatic taxa) exhibit a southern distribution (c.f. 34% of aquatic species noted above). According to Gawler et al. (1996), two factors probably contribute to this pattern. First, southern Maine is a transitional zone between Appalachian and boreal regions and thus contains representatives of both southern and northern species. Second, there has been more botanical surveying in the southern part of the state, in part because more people live there. The map of data-collection sites shown in Appendix 11.5.1 clearly shows this pattern of higher survey effort in the south. On the other hand, and in the context of rare plants, Cameron (2000) suggests that there is "no particular evidence suggesting that any area of the state has been less thoroughly surveyed than any other part".

Community Structure and Ecology: Plant assemblage data are available from relatively few lakes (and even fewer large rivers) in Maine. Perhaps the most complete study of lake plant communities in Maine is that of Cameron (2000), who surveyed 30 lakes and ponds that were relatively undisturbed by human-associated development. The number of sampling transects varied among lakes and were not located randomly, but rather targeted different habitats. Using ordination (detrended correspondence analysis), Cameron distinguished four plant community types:

- Pipewort – water lobelia aquatic bed: found consistently on mineral soils in relatively shallow water (<1.0 m). The composition of this community, dominated by pipewort (*Eriocaulon aquaticum*), was relatively consistent, even though it occurred in a variety of landscape settings, ranging from exposed shores to sheltered coves.
- Water-lily – macrophyte bed: found on organic soils in depths of 0.5 – 1.5 m. The dominant species is typically the white water lily (*Nymphaea odorata*), with co-dominants including purple bladderwort (*Utricularia purpurea*), yellow water-lily (*Nuphar variegata*) and Robbin's spike-rush (*Eleocharis robbinsii*).
- Pickerelweed- macrophyte bed: found on organic soils, usually in shallow water. The dominant species is generally pickelweed (*Pontedaria cordata*), but many other species contribute to this community.
- Circumneutral-alkaline waters macrophyte suite: found in higher conductivity waters and possibly consisting of a number of species associations. Future survey effort in higher pH lakes may better define these associations. This community type includes species such as tapegrass (*Vallisneria americana*), Canada (=common) waterweed (*Elodea canadensis*), water stargrass (*Zosterella dubia*), white water crowfoot (*Ranunculus aquatilis*), and several pondweed species – including perfoliate pondweed (*Potamogeton perfoliatus*), fern (=Robbin's) pondweed (*P. robbinsii*), alpine (=red) pondweed (*P. alpinus*), Vasey's pondweed (*P. vaseyi*) and straight-leaved (*P. strictifolius*) pondweed. Cameron (2000) noted that some of these species are not exclusively found in higher conductivity water and thus may be represented in other community types (see below for discussion of alkalinity relationships).
- In addition to the above four community types, Cameron (2000) suggested that there may be another type occurring on organic soils, dominated by water shield (*Brasenia schreberi*) but containing few white water-lily.

Langdon et al. (1998) studied the macrophyte communities of 229 Vermont lakes and, using ordination analyses, identified three species groups corresponding to (i) high elevation, acidic lakes, (ii) oligotrophic lakes, and (iii) mesotrophic-eutrophic lakes. A fourth community type, corresponding to dystrophic (humic water) lakes was also suggested by the data. These relatively distinct species groups did not represent the full complement of species found in Vermont lakes. Instead, they were "super-imposed" on a group of other species that were much more widely distributed across lake types. Indeed, a clustering analysis (TWINSPAN) of all the species data had limited success in defining clear species groupings. Langdon et al. (1998) noted that one limitation of their data was that they lacked information on the relative abundance of the various species (i.e. analyses were based only on presence-absence). In contrast, Cameron (2000) did incorporate relative abundance into his analysis of plant communities in Maine lakes.

The number of species per sample (transect or plot) in Cameron's study ranged from 2 to 17. Aggregating species by lake (i.e. combining all transects/plots at a lake), the species richness (per lake) ranged from 3 to 26. Figure 6.2.3 shows the relationships between plant species number and (A) lake area and (B) alkalinity. We used simple linear regression and forward stepwise multiple regression (p-value to enter or remove variables was set at .15) to investigate the influence of lake area, alkalinity[13] and elevation on plant species richness in these data sets. Data from each study were analyzed separately because of differences in plant sampling technique and effort. Lake area was log-transformed to homogenize variance. Alkalinity data are from MDEP and represent grand means. While Cameron measured alkalinity at most of the lakes he surveyed for plants, we elected to use the MDEP data to enhance data consistency across the different plant surveys. Species richness was not significantly ($p>0.05$) associated with lake area, alkalinity or elevation in Cameron's data set. For the MNAP rapid bioassessment lakes and Greene's lakes on Mount Desert Island, species richness was significantly ($p<.05$) associated with lake area; however neither alkalinity nor elevation entered into the stepwise regressions. Lake area accounted for 11% and 57% of plant species richness in the MNAP and Greene data sets, respectively. The regression equations are:

MNAP rapid bioassessment lakes: $S = 6.6.4 + 2.639 \log A$ ($R^2 = .11$)
Greene MDI lakes: $S = 11.12 + 3.43 \log A$ ($R^2 = .57$)

Two factors may contribute to the observation that lake area was a better predictor of species richness in the Greene lakes vs. the MNAP lakes. First, Greene's lakes are all located in the same region of the state (Mount Desert Island). Consequently, their plant communities draw from the same regional species pool. Second, the Greene lakes span a wider range of logarithmic surface area than do those of MNAP. The R^2 value for the Greene lakes is very similar to that obtained when regressing fish species richness against lake area (see Chapter 6.4).

Alkalinity data were available from only a few of Dieffenbacher-Krall's (1998) lakes and thus were not used in the regression analysis. Species richness was not significantly associated with lake area or elevation ($p>.05$; see Figure 6.2.3 A).

While alkalinity and elevation were not significant predictors of the total number of plant species in Maine lakes, these factors do appear to influence the geographic distributions of some taxa. Figure 6.2.4 shows the distribution of selected species across alkalinity and elevation gradients in Maine lakes. Within the genus *Potamogeton*, the alga-like pondweed (*P. confervoides*), and Oakes's pondweed alpine (*P. oakesianus*) tend to be found in lower alkalinity systems, whereas the alpine (=red) pondweed (*P. alpinus*), whitestem pondweed (*P. praelongus*) and straight-leaved pondweed (*P. strictifolius*) are found in higher alkalinity lakes (Figure 6.2.4 B-C). The latter two species, also appear to be separated across an elevation gradient. Among the *Sagittaria* species, the common arrowhead (*S. latifolia*) is generally found at elevations below 600 ft., whereas the grass-leaved arrowhead (*S. graminea*) occupies a broader range of elevations (Figure 6.2.4 A). Some water-lilies (e.g. the white water-lily, *Nymphaea odorata*) are found in a broad range of lake types, whereas others (e.g. the pygmy water lily, *N. leibergii*) occupy

---

[13] Conductivity and pH are other water quality parameters that may influence plant diversity in lakes. We focus on alkalinity here because this is the parameter for which most information is available for Maine lakes.

predominantly lower alkalinity waters (Figure 6.2.4 D). Inspection of elevation – alkalinity plots for 56 vascular plant species (Appendix 11.6) suggests that 9% (5 species) are “restricted” by elevation, 21% (12 species) by alkalinity, and 12% (7 species) by both elevation and alkalinity (note that these associations are correlative, not necessarily causative). The remaining species tend to be found over broad elevation and alkalinity ranges (or are too rare to permit reliable analysis). The broad distribution of many aquatic plant species in Maine underscores the observation by Langdon et al. (1998) that relatively few species appear to be useful for distinguishing lake types in Vermont; most species being widely distributed.

Clearly many factors – in addition to the possible influences of alkalinity and elevation – determine the presence and relative abundance of a species in any particular lake. Littoral zone features potentially impacting aquatic plant species include gradient, exposure, water transparency, substrate and water level fluctuations. Aside from Cameron’s (2000) study, however, little information is available from Maine lakes to quantify these relationships.

Data collected at Highland (Duck) Lake by Dr. Keith Williams represent one of the most detailed plant data sets available for any lake in Maine (Table 6.2.2). Highland Lake (MIDAS=3734) is a large (634 acres) low elevation (190 ft) lake in southern Maine, that is fairly shallow (mean depth = 19 ft) and moderately productive (average Secchi depth = 5.7 meters, average chlorophyll concentration = 3.5 ppb). Over the past 14 years, littoral plant communities around the lake have been surveyed each year (more recently, ever other year) by Williams (pers. comm.). In 2001, a total of 85 plots around the lake were sampled, producing a list of 80 plant species (note that this list includes some taxa that are better classified as wetland and/or lake-shore species, rather than fully aquatic forms). Despite routine intensive sampling in previous years, approximately 28% of this species list was observed for the first time in 2001. Eleven species recorded in previous surveys were not recorded in 2001. The Highland Lake data well illustrate the “patchiness” of plant assemblages in lakes. In 2001, the number of species per plot ranged from 2 to 36 (mean = 12.7). Eleven of the 85 plots yielded < 5 species, while 20 plots yielded ≥ 20 species. This patchiness also illustrates the extent to which the amount of sampling effort can influence documented species richness (see also Chapter 5). A species-effort analysis[14] of these data shows that approximately 30 plots would be required to document 80% of the 2001 species list in this lake; for 90% of the species pool, approximately 55 plots are required (Figure 6.2.5).

[14] Analysis conducted using PC-ORD (McCune and Medford 1999)

Table 6.2.1: Vascular plant diversity in Maine and New England.

Grouping	# Families	# Genera	# Species	Source
All plants: New England & adjacent New York	190	1048	3573 (+ 560 sub-species or named hybrids)	Magee and Ahles (1999)
Wetland plants: Northeastern U.S. and Canada (1)	109	295	1139	Crow and Hellquist (2000)
All plants: Maine	139	699	2096	Haines and Vining (1998)
Wetland & aquatic plants: Maine	35		568 (438 wetland, 130 aquatic)	Developed from habitat descriptions in Haines and Vining (1998)
Wetland plants: Maine (USFWS list) (2)			Total=1436 FACW and OBL=923 OBL only= 562	Tiner et al. (1995)
"Aquatic" plants: Maine (MABP records)	32	51	130	MABP database

(1) Newfoundland west to southeastern Manitoba and Minnesota, south to Virginia and Missouri.
(2) USFWS lists wetland plants by habitat class. The total number of species in the Maine list (1436) includes all wetland-affiliated species, whether or not they are primarily wetland taxa. FACW taxa are facultative wetland species, but occurring most often in wetland habitats. OBL taxa are obligate wetland species. Some species are listed under both FACW and OBL classes, hence the inclusion of the OBL-only, total.

Table 6.2.2: Plants of Highland Lake (Windham/Falmouth), with frequency of occurrence. A total of 85 littoral plots were sampled in 2001. Species in this list include taxa that are recorded as being absent from the 2001 plots but had been recorded during earlier surveys. (Unpublished data provided by Dr. K. Williams, 9/2004.)

Species	*% Plots*	*Species*	*% Plots*
Alnus incana ssp. rugosa *	1.2	Myrica gale *	3.5
Bidens frondosa	0.0	Myriophyllum tenellum	21.2
Brasenia schreberi	30.6	Najas flexilis	2.4
Calamagrostis canadensis *	2.4	Nitella	20.0
Carex comosa *	2.4	Nuphar variegate	12.9
Carex lasiocarpa *	7.1	Nymphaea odorata	47.1
Carex limosa *	3.5	Nymphoides cordata	55.3
Carex utriculata	10.6	Phalaris arundinacea *	1.2
Cephalanthus occidentalis *	10.6	Pontederia cordata	81.2
Cenchrus longispinus	0.0	Potamogeton amplifolium	4.7
Cicuta bulbifera	1.2	Potamogeton epihydrus	10.6
Cladium mariscoides	7.1	Potamogeton natans	5.9
Drosera intermedia *	3.5	Potamogeton perfoliatus	0.0
Dulichium arundinaceum	24.7	Potamogeton praelongus	0.0
Echinochloa crus-galli	0.0	Potamogeton pulcher	21.2
Elatine minima	23.5	Potamogeton pusillus	0.0
Elecoharis acicularis	58.8	Potamogeton robbinsii	0.0
Eleocharis obtusa	3.5	Potamogeton spirillus	9.4
Eleocharis palustris	41.2	Proserpinaca palustris	1.2
Eleocharis robbinsii	8.2	Sagittaria graminea	25.9
Elodea nuttallii	24.7	Sagittaria latifolia	32.9
Equisetum fluviatile	10.6	Salix nigra *	2.4
Eriocaulon aquaticum	76.5	Schoenoplectus acutus	3.5
Eupatorium perfoliatum *	7.1	Schoenoplectus pungens	16.5
Galium trifidum *	5.9	Schoenoplectus subterminalis	7.1
Glyceria borealis	7.1	Schoenoplectus tabernaemontanii	29.4
Glyceria grandis *	4.7	Schoenoplectus torreyi	2.4
Gratiola aurea	7.1	Scirpus atrocinctus *	1.2
Hypericum boreale	27.1	Scirpus cyperinus	12.9
Isoetes lacustris	0.0	Scirpus expansus *	1.2
Isoetes tuckermanii *	12.9	Sium suave	9.4
Juncus canadensis	12.9	Sparganium americanum	12.9
Juncus effusus *	1.2	Sparganium angustifolium	28.2
Juncus gerardii	0.0	Sparganium emersum	27.1
Juncus militaris	63.5	Sparganium fluctuans	9.4
Juncus pelocarpus	8.2	Sphagnum	5.9
Leersia oxyoides	78.8	Stuckenia pectinata	0.0
Lemna minor	2.4	Subularia aquatica *	1.2
Lobelia dortmanna	23.5	Triadenum virginicum	25.9
Ludwigia palustris	0.0	Typha latifolia	16.5
Lycopus americanus *	2.4	Typha xglauca *	3.5
Lysimachia terrestris	44.7	Utricularia cornuta *	2.4
Megalodonta beckii	8.2	Utricularia intermedia	2.4

Species	*% Plots*	*Species*	*% Plots*
Mimulus ringens *	1.2	Utricularia macrorhiza	4.7
Myosotis scorpioides	4.7	Utricularia purpurea	7.1
		Veronica scutellata *	1.2

* Species first recorded in 2001.

(Table 6.2.2, continued)

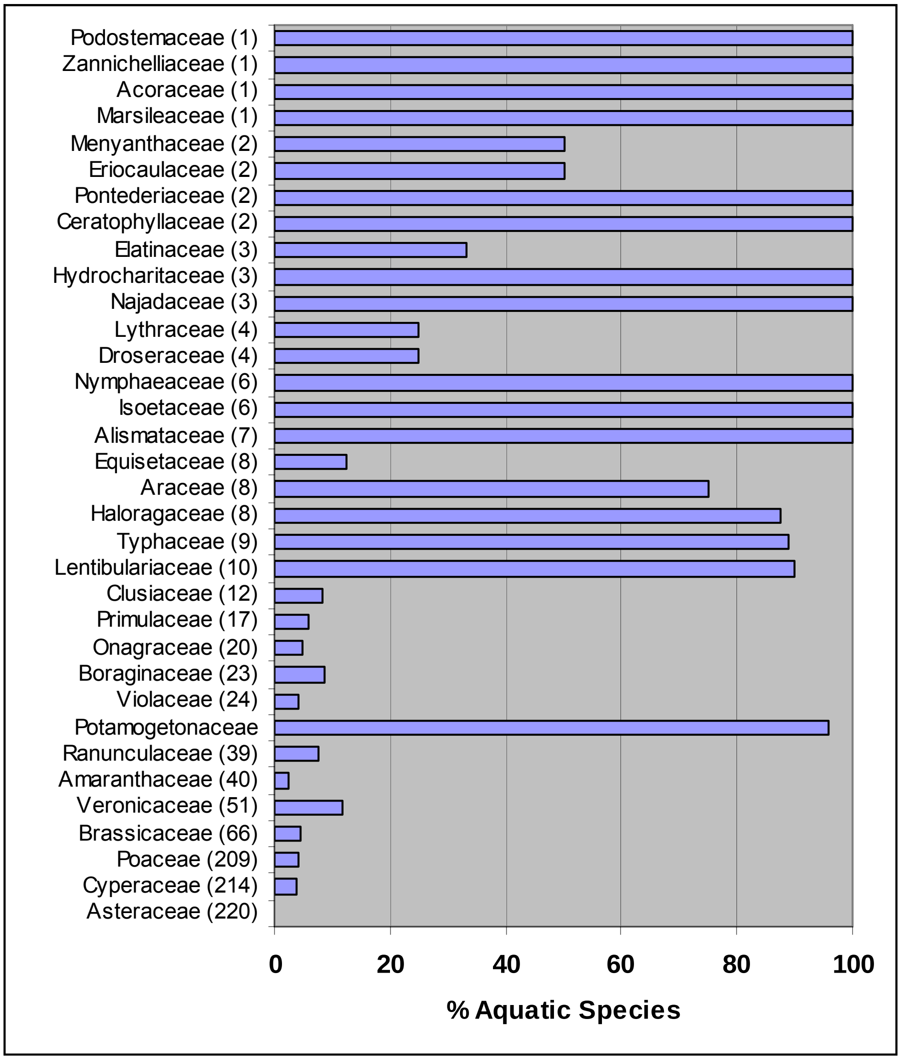


Figure 6.2.1: Aquatic vascular plants of Maine.
Figure shows number of freshwater aquatic species expressed as % of total number of species occurring in Maine, by family. Total number of Maine species are indicated in parentheses after family name. Aquatic species were designated from habitat decriptions in Haines and Vining (1998), and include submergent, floating and some emergent species. Only those families with aquatic representatives are shown in this figure. Note that Haines and Vining (1998) include the duckweeds (elsewhere classified within the family Lemnaceae) within the family Araceae.

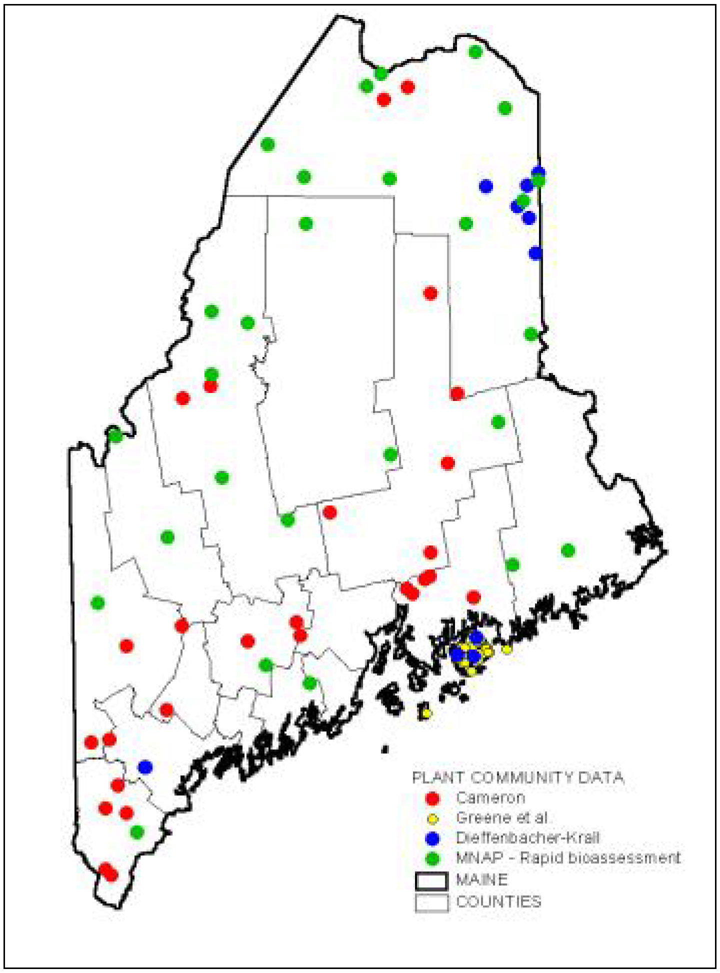


Figure 6.2.2: Lakes with community-level vascular plant data.
Not shown is Highland Lake in Windham / Falmouth for which extensive aquatic plant data have been collected by Keith Williams (see text).

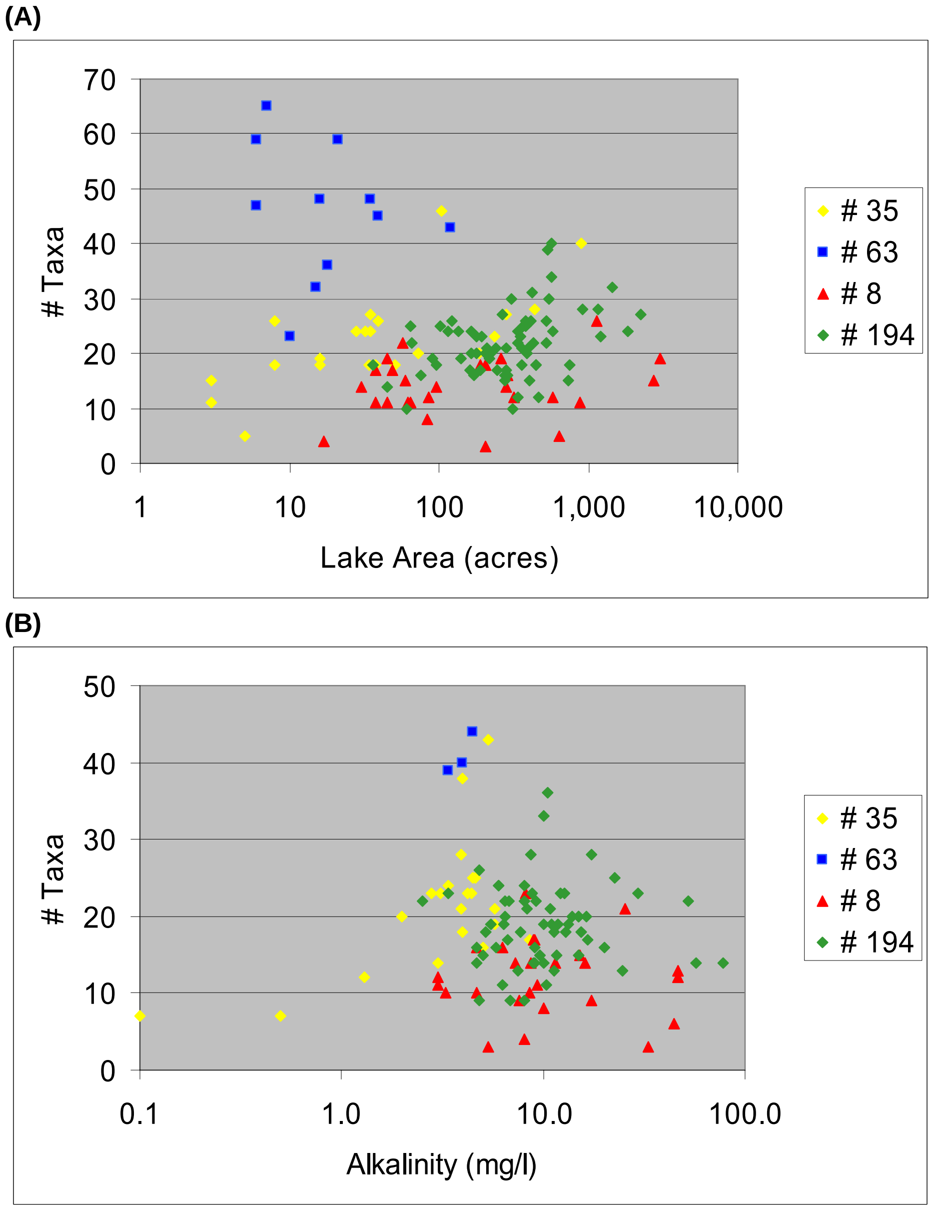
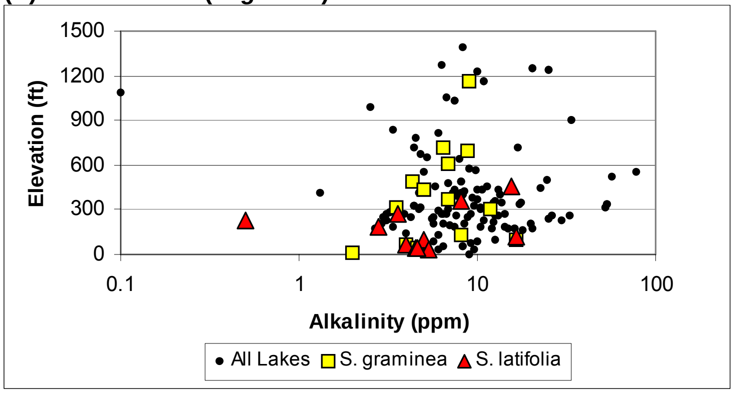
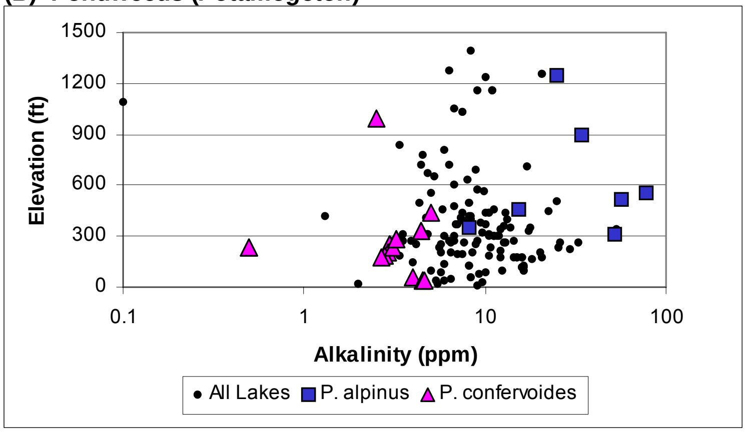


Figure 6.2.3: Relationship between number of macrophyte species (per lake) and (A) lake area, (B) alkalinity.
Data from the four contributing studies are shown separately because sampling type and effort was not consistent among studies. Studies are: #35 = Greene et al. (1997); #63 = Dieffenbacher-Krall (1998); #8 = Cameron (2000); #194 = MNAP rapid bioassessment surveys (unpublished data, courtesy of D. Cameron). See Figure 6.2.2 for map showing areas surveyed.

(A) Arrow-heads (*Sagittaria*)



(B) Pondweeds (*Potamogeton*)



(C) Pondweeds (*Potamogeton*)

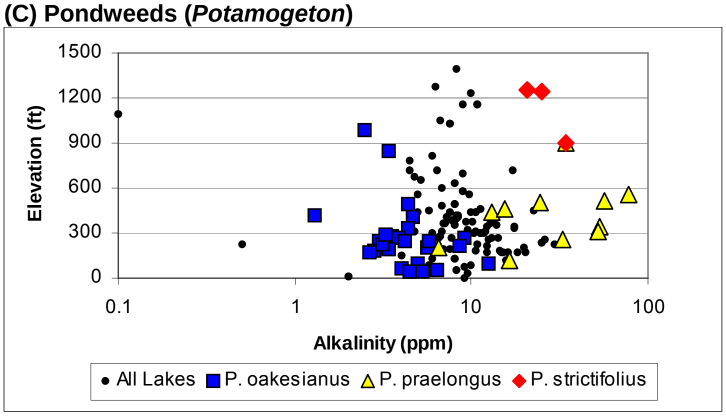


Figure 6.2.4: Distribution of nine plant species across elevation and alkalinity gradients in Maine lakes.
Small black dots indicate other lakes included in this composite data set and thus define the alkalinity – elevation range of sampled lakes. See Appendix 11.6 for similar plots for 56 plant species. Data sources: Cameron (2000), MNAP (unpublished data, provided by D. Cameron, MNAP), Greene et al. (1997), Dieffenbacher-Krall (1998), as compiled in MABP database. Alkalinity data from MDEP.

(D) Water lilies (*Nymphaea*)

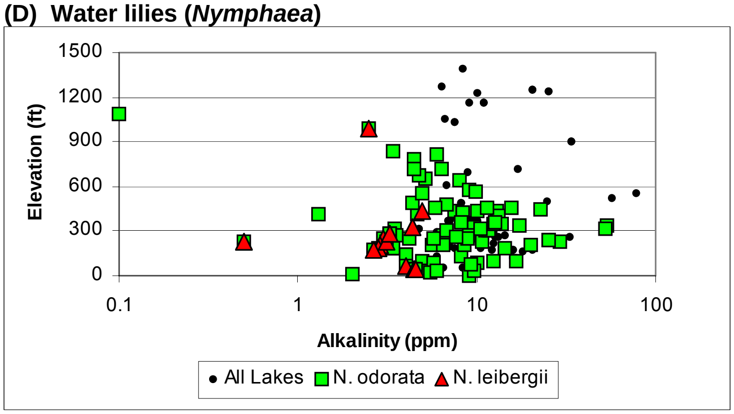


Figure 6.2.4 (continued)

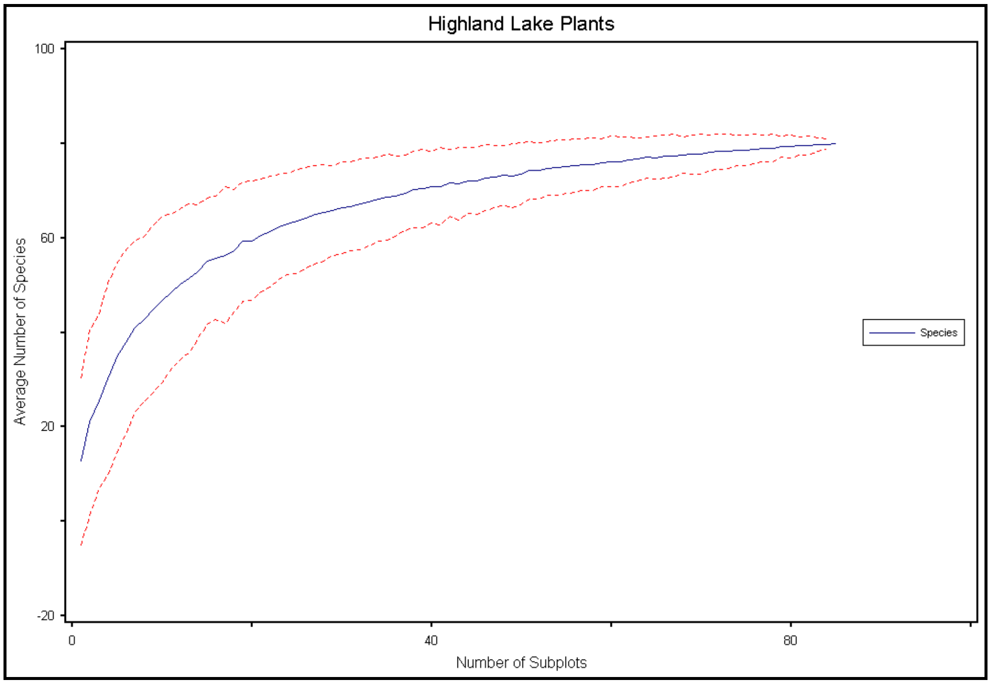


Figure 6.2.5: Species – effort plot for Highland Lake plant survey data.
The "Species" curve shows the average number of species obtained as the number of sampling units (plots) is increased (red lines indicate plus and minus one standard deviation of mean species estimate). Plant survey data were provided by K. Williams. Species accumulation curves were generated using PC-ORD software (McCune and Mefford 1999).

6.3 AMPHIBIANS & REPTILES

Maine's amphibians and turtles include species that are exclusively aquatic, others that are primarily terrestrial, as well as forms that are intermediate in habitat requirements. The primary habitat of many species varies with life history stage and/or season. Many species frequent wetlands and vernal pools, habitats that are peripheral to MABP's primary focus on stream and lake systems (see Chapter 1). Because of the difficulty of assigning an "aquatic" label to some species, we elected to include all amphibians and turtles (excluding marine forms) in the MABP database and in this report. Snakes have been largely excluded from MABP analyses, even though one form, the northern water snake (*Nerodia sipedon*), is often, but not exclusively, found in aquatic and semi-aquatic habitats.

In view of the excellent – and readily available – treatment of Maine's amphibians and reptiles provided by Hunter et al. (1999), we provide here only a review of key biodiversity data, together with a summary of information published subsequent to 1999.

Information Sources: The primary source of information is the Maine Amphibian and Reptile Assessment Project (MARAP). Completed in 1992, MARAP was a five-year effort undertaken by volunteers working with five state and non-governmental organizations. The MARAP database has been augmented with more recent data collected by MDIFW, as well as other contemporary and historical studies accessed by MABP[15]. Since 1997, anuran (frog and toad) monitoring in Maine has been carried out by the Maine Amphibian Monitoring Project (MAMP), coordinated by Maine Audubon, MDIFW and the University of Maine. This project is part of the North American Monitoring Program (NAAMP); data are compiled by the USGS and are available on-line (www.pwrc.usgs.gov/naamp). Data from 2003-2004 were accessed by MABP (although they have not been integrated into the MABP database). The MAMP uses frog and toad calls to document the presence of species along a series of pre-defined routes. While 61 routes are available for data collection in Maine, only 52 of these were monitored during 2003-2004. Just over 30% of the routes monitored during these two years are in southern Maine (MAMP's Zone 1), while 48% and 12% are in the central (Zone 2) and northern (Zone 3) regions of the state, respectively. Data are collected by volunteers during early spring, late spring and summer "runs".

Species Diversity & Distribution: There are forty species and sub-species of amphibians and reptiles in Maine. Nine of these are salamanders, nine are frogs / toads, eleven are turtles (including three marine forms), and eleven are snakes (Tables 6.3.1 and 6.3.2). No species are thought to have been extirpated from Maine (Gawler et al. 1996). The only amphibian species known to be non-native to Maine is the mudpuppy (*Necturus maculosus*), which also is the state's largest amphibian. The mudpuppy populations in Maine probably derive from escapees from Colby College in the late 1930s or early 1940s. By the 1950s, this species was established in one of the Belgrade Lakes (Great Pond). Today, the mudpuppy still appears to be restricted to this region, although there is the possibility that it is spreading downstream toward the Kennebec (Hunter et al. 1999).

The mudpuppy is an obligate aquatic species. While it typically inhabits lakes and streams, it is also found in marshes and other wetlands. Other salamander species are both aquatic and terrestrial, depending on life stage and season (Table 6.3.1). The Eastern newt (*Notophthalmus viridescens*) is the most aquatic of the Maine-native species. It is also unusual in having three stages in its life cycle: larvae and adults are aquatic, but the juvenile stage (efts) are terrestrial. Some newt populations are neotonous, i.e. they do not pass through the juvenile stage, instead

[15] In the electronically available version of the MARAP database used by MABP, species records are referenced only to township (finer resolution locational information is available for some records, but only in hardcopy form). Consequently, townships are the units used in this report to summarize amphibian and reptile distributions. Furthermore, even when it is available, more precise spatial information for sensitive tracked species, such as the spotted turtle, has been deliberately removed from the MABP database at the request of MDIFW.

becoming sexually mature while retaining larval characteristics. The spring salamander (*Gyrinophilus porphyriticus*) is another primarily aquatic species, typically inhabiting cold stream and seeps. At the other end of the habitat spectrum is the northern redback salamander (*Plethodon cinereus*) which is exclusively terrestrial (Hunter et al. 1999). While frog and toad species are all aquatic as tadpoles, adults vary in the extent of their dependence on freshwater habitats. The bullfrog (*Rana catesbeiana*) is entirely aquatic and the mink frog (*R. septentrionalis*) is almost so, being found on land only after heavy rain. The green frog (*R. clamitans*) and pickerel frog (*R. palustris*) are typically found close to water, in riparian and wetland habitats. The two species in the family Hylidae – gray treefrog (*Hyla versicolor*) and spring peeper (*Pseudacris crucifer*) – frequent wooded habitats, but are generally found close to water. Adult northern leopard frogs (*R. pipiens*) are terrestrial except during hibernation when they inhabit permanent waterbodies. The American toad (*Bufo americanus*) inhabits a broad range of habitats, while the wood frog (*R. sylvatica*) is entirely terrestrial (except during the breeding season).

Four of Maine's non-marine turtle species are primarily or exclusively aquatic: the snapping turtle (*Chelydra serpentia*), musk turtle (*Sternotherus odoratus*), painted turtle (*Chrysemys picta*) and Blanding's turtle (*Emydoidea blandingii*). Two species – the spotted turtle (*Clemmys guttata*) and the wood turtle (*C. insculpta*) – inhabit both wetlands and upland areas, while the eastern box turtle (*Terrapene carolina*) is almost exclusively terrestrial (Table 6.3.2). Maine has two sub-species of painted turtle (four are recognized in the U.S.): the eastern and midland painted turtles. Distributions of these sub-species overlap and intergrades are common (Hunter et al. 1999). Interestingly, painted turtle populations on Mount Desert Island show intermediate characteristics between the two sub-species, suggesting that they may derive from early post-glacial immigration of midland turtles (Rhodin and Butler [1997] cited in Hunter et al. [1999]). Of Maine's nine species of snakes, only one, the northern water snake (*Nerodia sipedon sipedon*) is dependent on aquatic and semi-aquatic habitats. It is not exclusively found in the water, however (Hunter et al. 1999).

Two turtles are listed as endangered species in Maine (Blanding's turtle and the eastern box turtle) and one (spotted turtle) is considered threatened (Table 3.4). Two other turtle species, as well as three amphibians are listed as being of Special Concern.

Figure 6.3.1 illustrates the documented distributions of Maine's amphibian and turtle species. Six salamander species are broadly distributed through the state, although the northern red-backed salamander is apparently absent from northwestern Maine (but note that fewer collections have been made from this part of the state). Four of these broadly distributed salamanders (blue-spotted, spotted, northern dusky and northern red-backed salamanders) have either not been recorded from Downeast Maine or appear to be much less common in this region. Five frog/toad species (American toad, spring peeper, bullfrog, green frog and wood frog) are found statewide, although records tend to be sparser in the upper elevation parts of the state. Three species (gray treefrog, pickerel frog and northern leopard frog) appear to be largely absent from western and northwestern Maine, although limited sampling may contribute to this pattern – particularly in the case of the latter two species (c.f. Hunter et al. 1999). The mink frog is the only Maine amphibian species that has a southern range limit within the state (Figure 6.3.1; Hunter et al. 1999).

In contrast to the amphibians, only one turtle species (the wood turtle) is found statewide (Figure 6.3.1). The snapping turtle is also broadly distributed within Maine, but appears to be absent from the northwestern corner of the state. The remaining five turtles are generally restricted to south (Blanding's turtle) or south and central Maine (musk, eastern painted, spotted and eastern box turtles). Blanding's turtle is primarily a mid-western species and its presence in Maine apparently represents part of a disjunct population inhabiting eastern New England (McCoy 1973, cited in Hunter et al. 1999). Although the MARAP survey documented the musk turtle only as far north as the Penobscot basin, Mairs (1962, cited by Hunter et al. 1999) recorded an individual in the Narraguagus River of Washington County.

Three information sources can be used to quantify the frequency of occurrence (spatially, but not necessarily in terms of density at any specific location) of Maine's amphibian and turtle species (Table 6.3.3). Based on the percent of towns in which each species has been recorded (c.f. Figure 6.3.1), the five most common taxa are the wood frog, spring peeper, green frog, American toad and bullfrog. Excluding the non-native mudpuppy, the rarest taxa include two salamanders and the four turtle species restricted to southern Maine (Table 6.3.3). For frogs and toads, similar patterns in frequency of occurrence are seen when using the amphibian call data from MAMP – with the spring peeper and wood frog being the most commonly recorded species and the northern leopard and the mink frogs being the least common. A final quantitative estimate of spatial distributions comes from the Maine GAP project (Krohn et al. 1998). This study used a combination of habitat models and GIS-based landscape characterization to predict species occurrences in Maine. Using the GAP data, we calculated how much of the state is predicted to represent suitable habitat for each amphibian and reptile species (Table 6.3.3). Comparing the empirical (% town records) and predicted (GAP) distribution extents shown in Table 6.3.3, three major patterns are evident:

(1) Some species are rare by both measures, e.g. northern dusky salamander, spring salamander, four-toed salamander, musk turtle, spotted turtle and Blanding's turtle.
(2) Some of the more frequently recorded species are also predicted to occupy greater portions of the state, e.g. American toad, spring peeper, green frog, wood frog and wood turtle.
(3) For other species, however, the two frequency measures lead to different conclusions. For example, about 73% of the state's area is estimated to represent suitable habitat for the blue-spotted salamander, whereas it was recorded from only 8% of towns. Similar disparities are seen for the northern red-backed salamander and the pickerel frog. Conversely, the bullfrog was commonly observed at the township level, while only about 10% of the state was considered to provide suitable habitat. The reasons for these disparities are not known, but lower levels sampling effort in some parts of the state, particularly the northwest and Downeast, may play a role. Another contributing factor may be differences in the ease with which different species are observable in the field (c.f. Hunter et al. 1999). It seems improbable that artifacts resulting from the GAP methodology would explain the disparities noted above. Accuracy assessments ("ground-truthing") conducted as part of the GAP study suggested that predicted occurrences were highly accurate for amphibians (ca. 100%) and somewhat less so (ca. 90%) for reptiles (Krohn et al. 1998).

Patterns of documented species richness by county are shown in Figure 6.3.2. While using counties to summarize richness is clearly an imperfect approach – because of the area effect – it is the only realistic way of collapsing the town-based data from the MARAP survey. Documented amphibian richness exhibits no obvious latitudinal effect, whereas documented turtle richness is clearly lowest in northern and Downeast regions of the state (Figure 6.3.2). Maps of predicted species richness produced by the GAP project (Krohn et al. 1998) partially support the patterns shown in Figure 6.3.2. Latitudinal gradients in predicted amphibian richness are not pronounced, whereas they are for reptiles (Figure 8 in Krohn et al. 1998), with predicted richness increasing from north to south (note that snakes are included in the reptile totals from the GAP project). However, the lower documented richness of reptiles in the Downeast region, depicted in Figure 6.3.2, is not matched by the pattern of predicted richness from the GAP project; the latter suggests that reptile richness is similar across a broad west - east sweep of central Maine. Certainly Downeast Maine is one region which would benefit from more intensive sampling of both amphibians and, especially, reptiles.

Status & Trends: Habitat loss and impairment is probably the most serious threat to Maine's amphibians and turtles (Hunter et al. 1999). Of particular importance are the destruction of vernal pools and other wetlands, along with some forest management practices that lead to habitat reduction and fragmentation (DeMaynadier and Hunter 1995, 1998, 2000; Guerry and Hunter 2002; see also Chapter 4). Conversely, beaver activity has increased the number of palustrine wetlands in some parts of the state in recent years (Lisle 1994, McCall et al. 1996), in turn producing a likely positive impact on amphibian populations (e.g. Cunningham 2003). For some species, harvest by humans and predators is another significant threat. There have been a few reports of amphibian die-offs in some regions of Maine (including Acadia National Park), at least some of which are associated with a chytrid fungus and a ranavirus implicated in die-offs in other parts of the world (P. deMaynadier, pers. comm.). While all these effects are well accepted, there appear to be few quantitative data documenting trends in the population densities and ranges of Maine's amphibian and reptile species. The North American Amphibian Monitoring Project, of which MAMP is a part, is a response to this need for long-term data on amphibian populations; data currently being collected in Maine will contribute to our understanding of population status and trends. There is evidence that two amphibian species historically collected on Mount Desert Island, the gray treefrog and the northern leopard frog, may no longer occur there (Manville 1939, Davis 1958, Cunningham 2003).

Table 6.3.1: Amphibian species in Maine.
Distribution and habitat notes are derived primarily from Hunter et al. 1999. Distributions refer only distributions within Maine, not the entire range of the species. See also Table 6.3.3. Distribution maps are shown in Figure 6.3.1.

Scientific Name	Common Name	Comments
CAUDATA	**SALAMANDERS**	
Proteidae		
Necturus maculosus	Mudpuppy	Aquatic throughout life cycle. Only non-native amphibian or reptile in Maine. Introduced to Belgrade lakes region in 1939.
Ambystomatidae		
Ambystoma laterale	Blue-spotted salamander	Statewide, but uncommon. Many individuals are triploid hybrids.
Ambystoma maculatum	Spotted salamander	Statewide.
Salamandridae		
Notophthalmus viridescens	Eastern newt	Statewide. Most aquatic of Maine's native salamanders--larvae and adults are aquatic, juveniles are terrestrial.
Plethodontidae		
Desmognathus fuscus	Northern dusky salamander	Statewide.
Eurycea bislineata	Two-line salamander	Abundant, statewide.
Gyrinophilus porphyriticus porphyriticus	Northern spring salamander	Apparently absent from northern and downeast Maine. Associated with cool, well-oxygenated habitat.
Hemidactylium scutatum	Four-toed salamander	Rare; apparently restricted to southern and central Maine. Adults are terrestrial.
Plethodon cinereus	Redback salamander	Statewide; most abundant amphibian (and probably most abundant vertebrate) in Maine. Terrestrial for entire life-cycle.
SALIENTA (ANURA)	**FROGS & TOADS**	
Bufonidae		
Bufo americanus	American toad	Statewide. Diversity of color forms, but sub-species status of two major forms is now questionable.
Hylidae		
Hyla versicolor	Gray treefrog	Common, but primarily restricted to southern, central and downeast Maine. Tetraploid.
Pseudacris crucifer	Spring peeper	Common, statewide.
Ranidae		
Rana catesbeiana	Bullfrog	Statewide, although much less common in extreme western and north-western Maine. Most wholly aquatic and most carnivorous of Maine's frogs.
Rana clamitans	Green frog	Statewide, common. Usually found close to water.
Rana palustris	Pickerel frog	Statewide, although much less common in extreme western and north-western Maine. Usually found close to water.
Rana pipiens	Northern leopard frog	Apparently absent from northwestern part of Maine. Generally less common than pickerel frog. Semi-terrestrial, but hibernate in water.
Rana septentrionalis	Mink frog	Generally absent from south and downeast Maine. Fully aquatic, venturing occasionally onto wetted land.
Rana sylvatica	Wood frog	3 forms that were considered as sub-species are now not generally recognized as valid sub-species. Entirely terrestrial, except during breeding season.

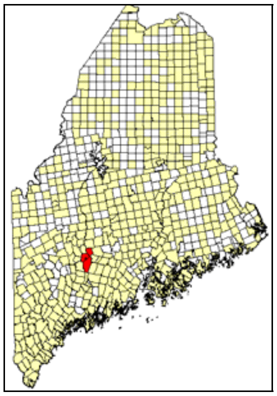
Table 6.3.2: Reptile species in Maine.
All of Maine's reptile species are included in this table, although only two snakes are generally associated with freshwater habitats. Distribution and habitat notes are derived primarily from Hunter et al. 1999. Distributions refer only distributions within Maine, not the entire range of the species. See also Table 6.3.3. Distribution maps for turtles are shown in Figure 6.3.1.

Scientific Name	Common Name	Comments
TESTUDINES (CHELONIA)	**TURTLES**	
Chelydridae		
Chelydra serpentina serpentina	Snapping turtle	Apparently absent from northwestern Maine. Exclusively aquatic.
Kinosternidae		
Sternotherus odoratus	Common musk turtle	Restricted to southern and central Maine (northern limit of species). Exclusively aquatic.
Emydidae		
Chrysemys picta picta	Eastern painted turtle	Largely restricted to southern and central Maine. Two sub-species overlap somewhat in their distributions. Primarily aquatic, but also sometimes found on land.
Chrysemys picta marginata	Midland painted turtle	
Clemmys guttata	Spotted turtle	Rare, restricted to southern and central Maine. Primarily aquatic, but also found on land.
Clemmys insculpta	Wood turtle	Statewide. Preferred habitat is riparian areas, but often found far from water – one of the most terrestrial of N. American turtles.
Emydoidea blandingii	Blanding's turtle	Restricted to the extreme southern part of Maine. Primarily aquatic, but terrestrial nesting.
Terrapene Carolina	Eastern box turtle	Uncommon, restricted to southern and central parts of Maine (although more northern records may represent escapees); probably Maine's rarest reptile. Primarily terrestrial.
Cheloniidae		
Caretta caretta	Loggerhead	Marine
Lepidochelys kempii	Atlantic ridley	Marine
Dermochelyidae		
Dermochelys coriacea	Leatherback	Marine
SERPENTES	**SNAKES**	
Colubridae		
Coluber constrictor	Racer	Terrestrial
Diadophis punctatus	Ringneck snake	Terrestrial
Lampropeltis triangulum	Milk snake	Terrestrial
Nerodia sipedon	Northern water snake	Largely restricted to southern part of Maine. Dependent on aquatic and semi-aquatic habitats, but rarely use open water.
Opheodrys vernalis	Smooth green snake	Terrestrial
Storeria dekayi	Brown snake	Terrestrial, although also found in wetlands.
Storeria occipitomaculata	Redbelly snake	Terrestrial, although also found in riparian areas and wetlands.
Thamnophis sauritus sauritus	Eastern ribbon snake	Restricted to southern Maine (state is a northern extent of range). Primarily a wetland species.
Thamnophis sauritus septentrionalis	Northern ribbon snake	
Thamnophis sirtalis sirtalis	Eastern garter snake	Terrestrial
Thamnophis sirtalis pallidulus	Maritime garter snake	

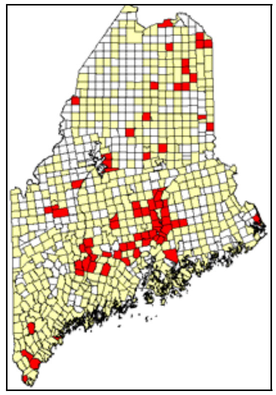
Table 6.3.3: Distribution and frequency of occurrence of Maine's amphibians and turtles. See Tables 6.3.1 and 6.3.2 for scientific names.

CommonName [1]	**% Towns (MABP)** [2]	**% State (GAP)** [3]	**% MAMP Routes-Dates** [4]	**% MAMP Routes** [4]
Common mudpuppy	0.3	--	n/a [5]	n/a
Blue-spotted salamander	8.0	72.8	n/a	n/a
Spotted salamander	16.5	76.3	n/a	n/a
Eastern newt	11.9	30.1	n/a	n/a
Northern dusky salamander	5.9	5.7	n/a	n/a
Northern two-lined salamander	14.4	28.2	n/a	n/a
Spring salamander	2.9	2.8	n/a	n/a
Four-toed salamander	2.1	7.0	n/a	n/a
Northern red-backed salamander	12.3	75.4	n/a	n/a
American toad	25.0	86.0	44	81
Gray treefrog	15.3	43.0	43	73
Spring peeper	29.4	83.9	87	100
Bullfrog	20.3	10.9	24	64
Green frog	27.6	73.1	44	92
Pickerel frog	13.5	90.4	14	40
Northern leopard frog	8.6	46.1	7	19
Mink frog	7.9	9.0	6	21
Wood frog	29.8	79.7	38	96
Snapping turtle	15.4	10.8	n/a	n/a
Musk turtle	3.7	0.4	n/a	n/a
Eastern painted turtle	16.4	11.4	n/a	n/a
Spotted turtle	4.1	0.2	n/a	n/a
Blanding's turtle	2.7	1.7	n/a	n/a
Wood turtle	15.3	47.1	n/a	n/a
Eastern box turtle	2.0	0.4	n/a	n/a

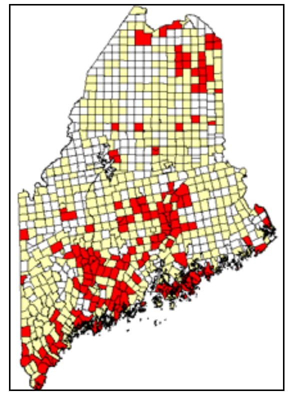
1) Species in bold type are 'tracked' by MDIFW in the Natural Heritage database.
2) % Towns: number of townships in which species has been recorded (based on composite data in MABP database, which do not include the MAMP data), expressed as a percentage of total number of Maine townships with any amphibian/reptile data (N=317). Data are presence/absence, with no measure of relative abundance within a township.
3) % State: Percent of total Maine area in which species is predicted to occur, based on habitat models and landscape analyses. Data are from Krohn et al. 1998.
4) Data are from the Maine Amphibian Monitoring Project (MAMP), part of the North American Amphibian Monitoring Project (NAAMP). MAMP data are based on records of frog and toad calls along specific routes across Maine. Data in this table refer to 2003 and 2004 records and are based on source data accessed from NAAMP's website (www.pwrc.usgs.gov/naamp). Routes-Dates refers to route – date combinations (N=223); Routes refers to routes, with data aggregated across dates (N=52). See text for additional information.
5) n/a = not applicable. MAMP data are only collected for frogs and toads.



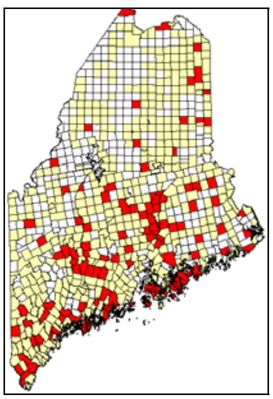
Common mudpuppy



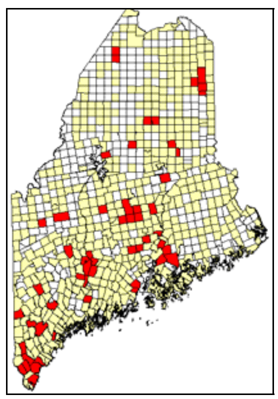
Blue-spotted salamander



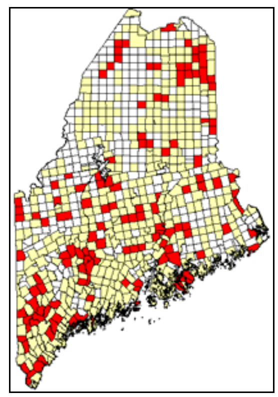
Spotted salamander



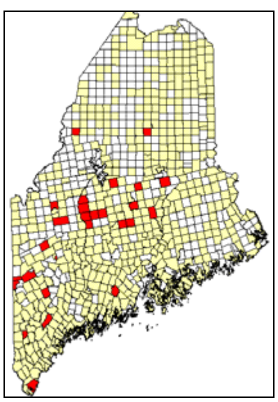
Eastern newt



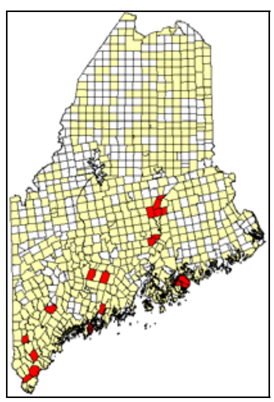
N. Dusky salamander



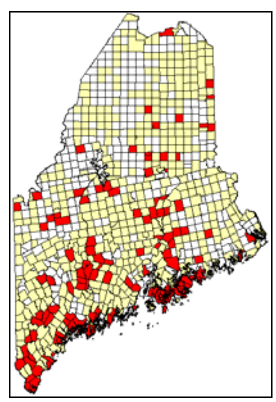
N. Two-lined salamander



Spring salamander



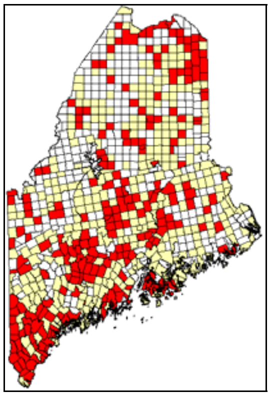
Four-toed salamander



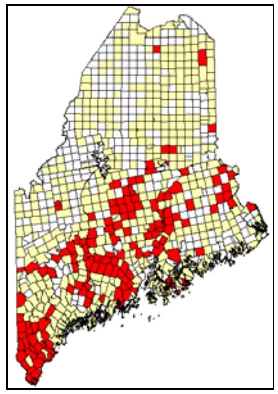
N. red-backed salamander

Figure 6.3.1: Distribution maps for amphibian and turtles.
Species records from towns are indicated by red-shading. Yellow-shaded polygons are other towns from which amphibian/reptile data are available (i.e. other species). Data sources: MDIFW, Maine Amphibian and Reptile Atlas Project (MARAP), and other records in MABP database. Distributions are summarized by township because records in the MARAP electronic database are georeferenced only at the township level.

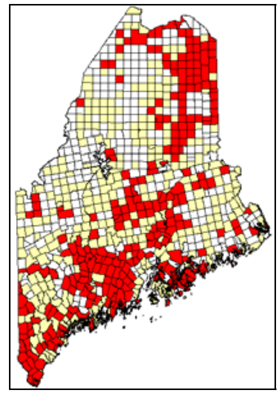
These distribution maps, together with range maps generated by the Maine GAP project, are also available on-line at:
http://www.pearl.maine.edu/windows/biodiversity/amphibians_distribution.htm



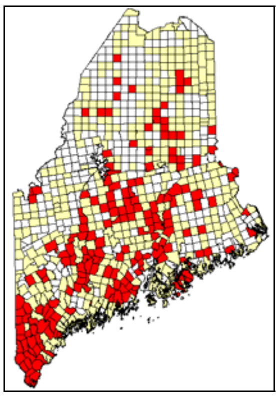
American toad



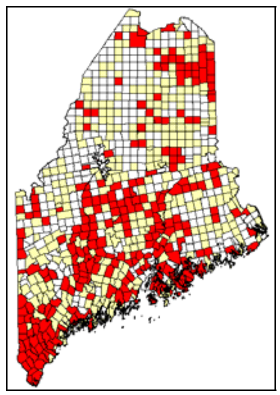
Gray treefrog



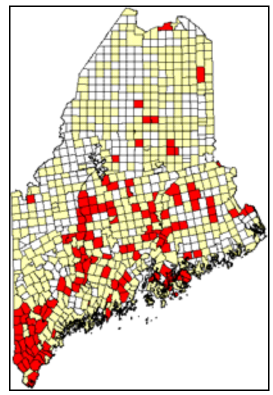
Spring peeper



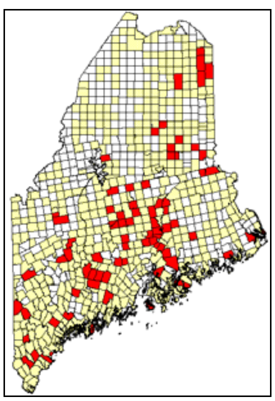
Bullfrog



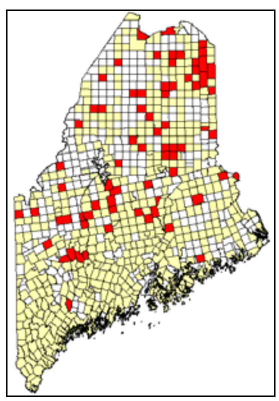
Green frog



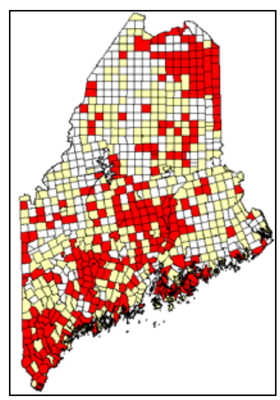
Pickerel frog



Northern leopard frog

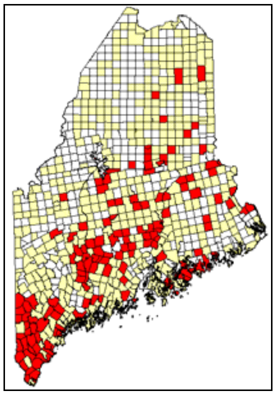


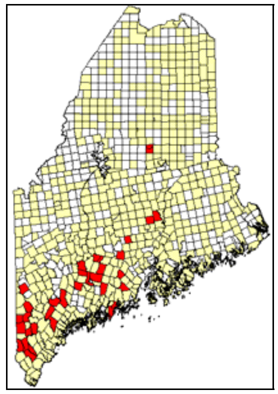
Mink frog

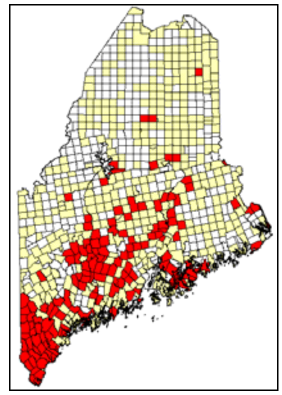


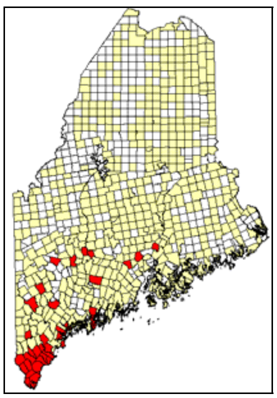
Wood frog

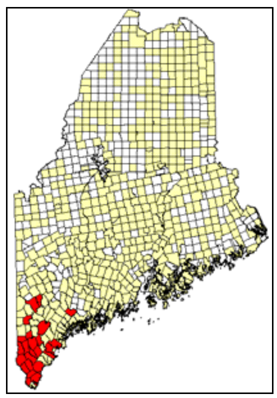
Figure 6.3.1 (continued)

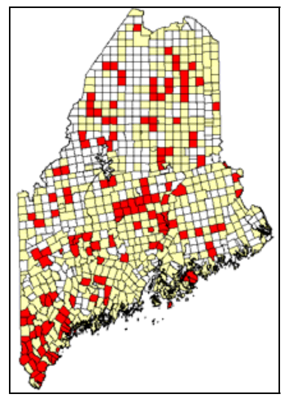

Snapping turtle


Musk turtle


Eastern painted turtle


Spotted turtle


Blandings turtle


Wood turtle

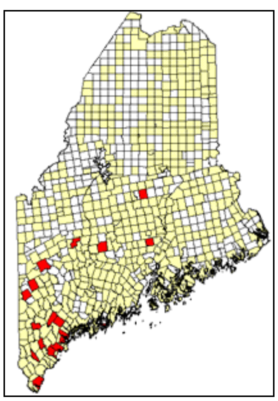

Eastern box turtle

Figure 6.3.1 (continued)

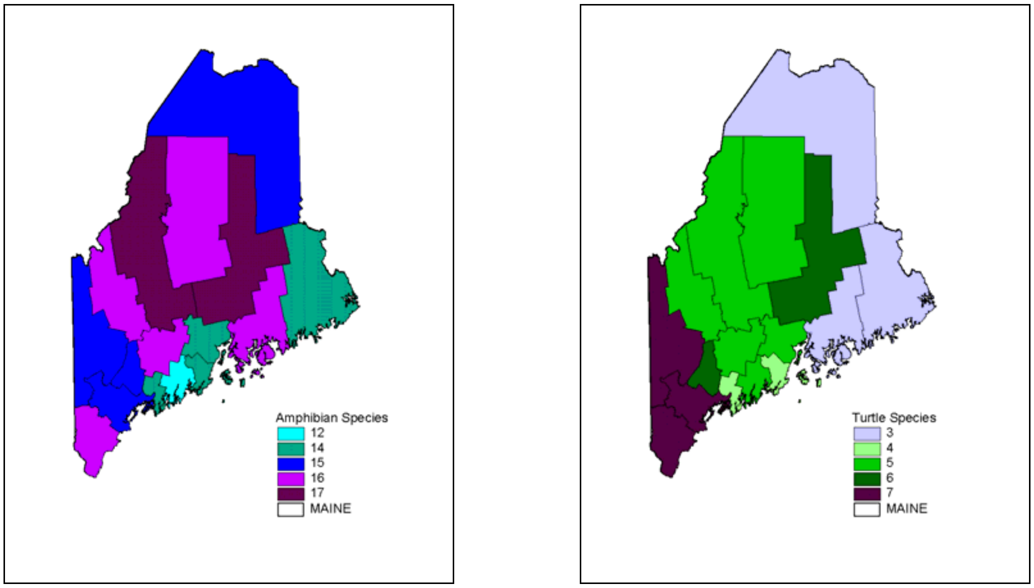


Figure 6.3.2: Number of amphibian (left panel) and turtle (right panel) species by county. Data sources: multiple, as compiled in MABP database (major source is MARAP).

6.4 FISH

The contemporary composition and distribution of Maine's freshwater fish fauna largely reflect two sets of processes:

(1) Colonization by fish species of the region following retreat of the Wisconsinian glacier, starting approximately 13,000 years ago. Colonization occurred from refugia in the Mississippi basin, Atlantic slope and the Acadian region (Hocutt and Wiley 1986, Bernatchez and Wilson 1998). Patterns of colonization have been influenced in part by changes in drainage patterns following rebound of the land surface as the ice retreated. This process of "natural" colonization continues today.
(2) Human-associated dispersals of fish species. These movements include both introductions of taxa from other parts of North American and Eurasia, as well as translocations of regionally-native species to watersheds and waterbodies in which they were not originally present. Translocation of fish species probably started in pre-colonial times and was certainly being practiced in the early 1800s (Williamson 1832). Fish introductions and translocations, however, did not become commonplace until the late 19th century. Today, they continue as both gamefish and baitfish species are introduced illegally into lake and stream systems. As a result, Maine's freshwater fish fauna is becoming increasing homogenized.

Information Sources: The primary data sources accessed during MABP are the MDIFW lake and streams surveys, and the EMAP probabilistic survey. Valuable historical information comes from the Cooper and Fuller surveys of lakes conducted during the 1930s and 1940s. Chapter 5.2 includes a detailed discussion of these information sources. Other data sources accessed during MABP include regional surveys, student dissertations and theses, and environmental impact studies (see Appendix 11.1).

Species Diversity and Distribution: In Maine there are currently 71 fish species that spend at least part of their life cycle in freshwaters[16]. They belong to 45 genera and 18 families (Table 6.4.1). These species and genus totals represent approximately one half of those for the northeastern U.S. (Table 3.1). The most species-rich family in Maine is the Cyprinidae (carps-minnows) with 21 species. Next are the Salmonidae (salmon-trouts: 8 species), Centrarchidae (black basses and sunfishes: 8 species), and Clupeidae (herrings: 5 species). Five families are each represented by just one species in Maine, while seven families have two or three species.

Approximately 70% (49/71) of Maine's fish species are native to the state. However, as mentioned above and in Chapter 4.5, Maine-native status does not necessarily mean that a species was historically found throughout its current distribution within the state. Introductions of non-Maine native fish species include both north American and European / Asian taxa (Table 4.5). At least five species appear to be relatively recent introductions to the state: white catfish (*Ameiurus catus*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), rock bass (*Ambloplites rupestris*), and central mudminnow (*Umbra limi*; Schilling, in press (Table 6.4.1).

Fourteen species are obligate or facultative diadromous taxa, i.e. they move between fresh and salt water (Table 6.4.1 and Figure 6.4.1). There is a broad range of diadromy among these taxa. At one end of the spectrum is the American eel (*Anguilla rostrata*), a catadromous species that breeds in the ocean but undergoes most of its growth in freshwaters. The eel is the only catadromous species in Maine. At the other end of the diadromy spectrum are obligate anadromous species that enter freshwaters to breed. Examples are the sea lamprey

[16] Some species are found only in large rivers and/or estuaries, for example the striped bass (*Morone saxatilis*), Atlantic tomcod (*Microgadus tomcod*) and the sturgeons (*Acipenser spp.*). These taxa were largely excluded from coverage in MABP.

(*Petromyzon marinus*) and several alosids, including the blueback herring (*Alosa aestivalis*) and American shad (*A. sapidissima*). Some anadromous species exhibit both sea-run and landlocked populations. For example, the alewife is primarily anadromous, but has a few landlocked populations in Maine (Table 6.4.1). Sea-run and landlocked populations are also characteristic of the rainbow smelt (*Osmerus mordax*). Brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*), although primarily freshwater species, also have some sea-run populations.

Historically, there were thriving populations of sea-run Atlantic salmon (*Salmo salar*) in most Maine rivers with unobstructed coastal access (Baum 1997). Today, anadromous populations are restricted to the Penobscot River and eight smaller watersheds that are home to the federally designated Distinct Population Segment of this species (see Chapter 3 and Figure 3.5). Most salmon in Maine today are of the landlocked variety. Landlocked salmon apparently originated in four river basins: St. Croix (West Grand Lake), Union (Green Lake), Penobscot (Sebec Lake) and Presumpscot (Sebago Lake) (Warner and Havey 1985). Beginning in the late 1860s, landlocked salmon were distributed throughout much of Maine and today are found in over 300 lakes (Table 6.4.1).

Most anadromous species will, in the absence of barriers, ascend to reach smaller streams and lakes. In contrast, the Shortnose sturgeon (*Acipenser brevirostrum*) is an anadromous species that, in freshwater, is restricted to large rivers (and apparently only in the Kennebec system in Maine). Other large-river diadromous species are amphidromous, i.e. they move between salt and fresh water for purposes other than spawning (Moyle and Cech 2000). Examples include the Atlantic sturgeon (*Acipenser oxyrhynchus*), striped bass (*Morone saxatilis*) and the Atlantic tomcod (*Microgadus tomcod*). The white perch (*Morone americana*) is originally a coastal species whose range has been expanded substantially in Maine via sportfish and illegal introductions (Tables 4.5).

The following paragraphs present brief synopses of the distribution and status of members of the major freshwater and diadromous fish families in Maine. Species distribution maps are presented in Appendix 11.5.2. They can also be viewed on-line at:
http://www.pearl.maine.edu/windows/biodiversity/fish_checklist.htm

Petromyzontidae: The only lamprey known from Maine is the sea lamprey (*Petromyzon marinus*), a parasitic species that occurs in the mid-coast and Downeast regions of the state. Lampreys spawn in stream riffles and runs, although the species is rarely collected in stream electrofishing surveys. Adults feed in lakes and in the ocean. The species has been recorded from lakes larger than about 500 acres (Appendix 11.5.2). Another lamprey species, the non-parasitic American brook lamprey (*Lampetra appendix*), occurs along the Atlantic slope to just south of Maine. To date, however, it has not been recorded from the state.

Anguillidae: The American eel (*Anguilla rostrata*) is the only catadromous fish species in North America. While the eel is a transient species in freshwaters (Halliwell et al. 1999), much of its long life cycle occurs in inland waters. It has been recorded from 32% of Maine's surveyed lakes (Table 6.4.1); most of these lakes are under 1000 ft elevation (Table 6.4.2). Although undoubtedly present in many streams, only one third of eel samples in the MABP database derive from stream sites. Historically, the American eel is estimated to have comprised 25% of total fish biomass in coastal streams of the eastern U.S (ASMGC 2000). Eel population densities declined from these high values, but remained relatively stable until the 1980s. Based on harvest and limited assessment data, populations have apparently been in significant decline in recent years (ASMGC 2000). Factors responsible for declining populations include over-harvest, barriers to migration (both upstream and downstream) and habitat degradation. The economically important yellow/silver eel fishery in Maine has been subject to recent comprehensive review and modernization of regulations (ASMGC 2000).

Clupeidae: Of the three alosid species that reproduce in Maine waters, only the alewife spawns in lacustrine and slow-moving stream habitats – the other two species are river spawners. Sea-run alewife populations have been recorded from 104 lakes, with landlocked populations occurring in another 31 (Table 6.4.1). Year-class abundance of anadromous alewife populations appears to be established before juveniles migrate out of nursery areas in lakes (Havey 1973, Walton 1983, 1987). Alosids are a primary focus of current efforts aimed at restoring anadromous fish runs to Maine rivers. For example, a major restoration program for American shad and alewife began in the Kennebec River in 1986, employing trap and truck stocking and, more recently, improvements to fish passage at dams. Concerns have been raised that restored alewife populations might compete with species such as smelt (e.g. Gately 1978), and salmonid and other sportfishes (Kircheis et al. 2002). It has also been suggested that alewives may have significant impacts on lake water quality. For example, alewives emigrating from a lake may result in significant nutrient export from the system and thus potentially lower productivity within the lake ecosystem (e.g. Mower 1978). Conversely, the planktivorous alewives may decrease populations of larger zooplankton species, in turn reducing grazing pressure on phytoplankton, potentially resulting in higher algal biomass. In general, there appears to be little conclusive evidence documenting the impacts of alewives on other components of freshwater ecosystems in Maine. A recent multi-year study designed to investigate the effects of alewife stocking in Lake George (Canaan-Skowhegan) failed to demonstrate negative impacts on any of the nine major and minor sport fish species investigated (Kircheis et al. 2002). Smelt actually grew faster during the years that alewives were present, although smelt population size was lower. Water transparency and chlorophyll concentrations were unaffected by alewife presence, although total phosphorus concentrations did decrease in the presence of alewives.

Salmonidae: Brook trout is the most widely distributed fish species in Maine, occurring in 69% of surveyed lakes (Table 6.4.1) and an estimated 22,250 miles of streams (Bonney 2005)[17]. Maine possesses the most significant brook trout resource in the northeastern U.S. and this species is one of the state's most sought-after game fish. Brook trout occurs statewide and in lakes of all size classes and elevations (Appendix 11.5.2 and Table 6.4.2). However, its natural distribution is limited by temperature and thus, in warmer water lakes, populations are often maintained by stocking (see below). Wild populations (i.e. never stocked) were thought to exist in about 350 lakes in Maine (Figure 3.8), although an ongoing review by MDIFW will likely result in this number being revised downward (T. Obrey, MDIFW, pers. comm..). While brook trout is a symbol of clean, cold waters and pristine habitat (Bonney 2005), Whittier and Hughes (1998) classify this species as moderately intolerant of environmental stressors. Habitat degradation has resulted in declining brook trout populations in Maine and elsewhere in the northeastern U.S. (Bonney 2005, Halliwell et al. 2001).

In addition to brook trout, there are two other charr (*Salvelinus*) species in Maine: the lake trout (*S. namaycush*) and the Artic charr (*S. alpinus*). Lake trout (togue) occurs statewide, but predominantly in western and northern regions. It is present in about one tenth of the number of lakes inhabited by brook trout (Table 6.4.1). Lake trout are characteristic of larger, deep, oligotrophic lakes – most togue lakes are >100 acres surface area. Wild populations are thought to occur in approximately 20 lakes (Figure 3.8). Splake, a stocked hybrid between brook and lake trout, is present in 4% of surveyed lakes. Within the lower 49 states, Maine is the only state with native

[17] Ideally, the range and frequency of occurrence of each species would be best summarized by the number of watersheds occupied by the species. However, geographic variation in the extent to which streams have been sampled, and data made available in a computerized format, mean that a watershed-based assessment would be biased at the present time. Consequently, we use the proportion of lakes inhabited by each species as a measure of frequency of occurrence. A watershed-by-watershed (HUC-12) assessment of brook trout status was being undertaken in Maine and the eastern U.S. during early 2005 (M. Gallagher, MDIFW, pers. comm.)

populations of Arctic charr. It is one of two freshwater species listed as of Special Concern by MDIFW. The charr was extirpated from the Rangeley Lakes in the early 1900s following introduction of landlocked salmon and smelt (Kendall 1918). Although found in relatively few lakes today (20, approximately half of which have been stocked), most of these populations appear to be relatively stable (F. Bonney, MDIFW, pers. comm.).

Landlocked salmon are distributed statewide, generally in lakes >100 acres surface area (Appendix 11.5.2) and in about 600 miles of rivers (MDIFW, unpublished information). As mentioned above, although this salmon is a Maine-native species, virtually all landlocked salmon populations in Maine are the result of past and/or present stocking. Some of these historically stocked populations are now considered naturalized (i.e. the populations are self-sustaining). In contrast to the landlocked salmon, Maine's other *Salmo* species, the brown trout, is exotic (it is native to Europe), although it has been in Maine for about 100 years. It is found principally in lower elevation areas in the southern and Downeast regions of the state, where it provides an alternate gamefish species in waters that tend to be too warm for brook trout.

Two other salmonids native to Maine are the lake whitefish (*Coregonus clupeaformis*) and round whitefish (*Prosopium cylindraceum*). Both are relatively uncommon, primarily northern, species that tend to frequent large, deeper oligotrophic lakes. According to MDIFW biologists, lake whitefish populations are declining in many lakes, likely as a result of multiple factors, including competition from smelt and other introduced species, over-harvest, and habitat degradation. As previously discussed in Chapter 3, some lakes exhibit dwarf lake whitefish populations (Fenderson 1964) – the number of these populations has probably decreased substantially over the last several decades, probably in large part as a result of competition by smelt.

Although historically there have been attempts to introduce to Maine several Pacific salmon species, the rainbow trout (*Oncorhynchus mykiss*) is the only one that is here today. It is present in 10 lakes and also stocked in a number of rivers (see below).

<u>*Osmeridae:*</u> The only species in this family, the rainbow smelt (*Osmerus mordax*), is native to coastal drainages (Halliwell et al. 2001). Its current statewide distribution largely reflects stocking as forage for landlocked salmon. Smelt occur in all elevation zones and are uncommon in ponds <10 acres (Table 6.4.2). There are some concerns that smelt may negatively impact some native fish species (Halliwell et al. 2001), but conclusive data from Maine are sparse. Conversely, illegal species introductions are likely impacting smelt populations in some lakes. Smelt are harvested commercially, likely at unsustainably high rates in some river systems. Historically, commercial landings from anadromous populations have fluctuated drastically (Flagg 1972). Similarly, lacustrine population densities are typically highly variable (McCullough 1978, Warner and Havey 1985). In addition to anadromous and land-locked populations of normal smelt, dwarf populations are also known from a number of locations in Maine (see Chapter 3).

<u>*Cyprinidae:*</u> About 60% of Maine's minnow species are likely native to the state (Table 6.4.1). Most of the species occurring in Maine are considered both lake and stream dwellers (Halliwell et al. 1999). Six species are relatively common and broadly distributed in Maine: the golden shiner (*Notemigonus crysoleucas*), creek chub (*Semotilus atromaculatus*), common shiner (*Luxilus cornutus*), fallfish (*S. atromaculatus*), northern redbelly dace (*Phoxinus eos*) and blacknose dace (*Rhinichthys atratulus*). Eight species are rare, all but one of which are non-natives (Table 6.4.1). The remaining five minnow species exhibit predominantly northern and western distributions in the state. Geographical patterns in native minnow species richness are further discussed below. The common carp (*Cypinus carpio*) is currently restricted to the Kennebec River system. Its distribution extended upstream in this river following removal of the Edwards dam in

the late 1990s; it is likely that future dam removals will result in further expansion in the range of this species in Maine.

Fundulidae: The banded killifish (*Fundulus diaphanus*) is the only primarily freshwater killifish in the northeastern U.S. (Page and Burr 1991). It is common in Maine, recorded from 365 lakes, generally at elevations <1000 ft (Table 6.4.2). The mummichog (*Fundulus heteroclitus*) is a euryhaline species and not adequately represented in the sampling base captured by MABP.

Cottidae: The slimy sculpin (*Cottus cognatus*) is the only member of this family in Maine. While characteristic of riffle areas in cold streams, it also inhabits lakes – it has been recorded from about 5% of surveyed lakes in all elevation zones, tending to favor larger systems (Table 6.4.2) with rocky substrates.

Catostomidae: The white sucker (*Catostomus commersoni*) is the second most common fish species in Maine lakes (Table 6.4.1), being relatively more common at lower elevations and in larger systems (Table 6.4.2). Its sister species, the longnose sucker (*C. catostomus*) is much less common in Maine, although this species is considered to be the most widespread of the North American suckers (Page and Burr 1991). This species is resticted largely to western and northern Maine and thus is rarely found at elevations <300 ft. It is not commonly found in smaller lakes and then only at higher elevations (Appendix 11.5.2). The third member of this family, the creek chubsucker (*Erimyzon oblongus*) is primarily a stream species, although it is poorly represented in stream collections in the MABP database. Maine is the northern range limit for this species (Page and Burr 1991); it has been recorded from 19 lakes in the extreme southern and western regions of the state.

Ictaluridae: While this is the largest family of freshwater fishes endemic to North America (Page and Burr 1991), only one species is native to Maine – the brown bullhead (*Ameiurus nebulosus*). This bullhead is one of the most common species in Maine lakes (Table 6.4.1), particularly larger systems at lower elevations (Table 6.4.2). Although the brown bullhead is tolerant of degraded conditions (Whittier and Hughes 1998), it also frequently occurs in lakes with good water quality. The other ictalurid species present in Maine is the non-native white catfish (*A. catus*). First recorded from Maine in the early 1980s (Halliwell 2005), it has been recently collected from the Androscoggin, Cathance and Kennebec Rivers (Table 6.4.4).

Centrarchidae: Most Maine representatives of this family are not native to the state. The two species that are native, the pumpkinseed (*Lepomis gibbosus*) and redbreast sunfish (*L. auritus*), typically occur south of a diagonal extending from the Umbagog Lake region, in the south, to Madawaska, in the north. They are infrequently seen in the western-most regions of the state, or in lakes above 1200 ft. elevation. Redbreast sunfish is generally not present in smaller lakes (<50 acres), whereas the pumpkinseed is found in lakes of all size classes (Table 6.4.2 and Appendix 11.5.2). Halliwell et al. (1999) consider the pumpkinseed to be the most widespread lake-dwelling fish species in the northeastern U.S.; it is the seventh most frequently recorded species in Maine lakes (Table 6.4.1). The other two sunfish species, the green sunfish and bluegill, are recent introductions to Maine (via the Sebasticook River drainage; Table 4.5) and not widespread at the current time. Maine has two black bass species: the smallmouth (*Micropterus dolomieu*) largemouth bass (*M. salmoides*), the former occurring in about 30% more lakes than the latter. Bass are among the earliest introductions to the state – 1868 in the case of the smallmouth. Today, their ranges continue to increase in Maine as a result of illegal introductions to both lake and stream/river systems. Expansion of bass into the Rapid River / Richarson Lakes area is today a major concern (see Chapter 4). Pond in the River (just west of Lower Richardson Lake), for example, has one of the highest, if not the highest, diversities of native minnows in the state – this large number of species is unlikely to persist in the event of the area being colonized by bass. Bass provide a good example of a significant dilemma in fisheries management – both species are valuable gamefish and are actively managed as such in many lakes and streams (see below). However, their continued spread threatens other gamefish species, in addition to non-game species. The black crappie (*Pomoxis nigromaculatus*) is much less common than bass, but its distribution parallels that of largemouth bass in Maine. It was originally introduced in 1925, in Stoneham, Oxford County (MDIFW 2002). The newest centrachid to be found in Maine is the rock bass (*Ambloplites rupestris*), recorded in 2002 from the Androscoggin River.

<u>Percidae:</u> Two of the three species in this family are native to Maine, one (yellow perch, *Perca flavescens*) being very common and often very abundant, the other being very rare (swamp darter, *Etheostoma fusiforme*). Although native to the state, yellow perch has been introduced to many lakes (see Chapter 4, and below). It is found in lakes of all sizes, but appears to be rarely present in small higher-elevation ponds (Appendix 11.5.2). The swamp darter is the only representative in Maine of the darter group of fishes, a group that is species-rich in other regions of the U.S. Maine is at the extreme northern edge of this species' range; it is one of two species listed as of Special Concern by MDIFW. The third percid in Maine is the walleye (*Sander vitreus,* formerly *Stizostedion vietreum*). Introduced illegally in the Belgrade lakes region in the early 1900s (Cooper 1941), it has not spread appreciably and its current status is unclear.

<u>Esocidae:</u> There are four pike/pickerel species in Maine, two of which are relatively recent introductions. The muskellunge (*Esox masquinongy*) is an "accidental" migrant to Maine waters (Table 4.5), following its introduction to the St. John river basin by Canadian biologists in the 1970s. First confirmed reproduction in Maine waters occurred in 1981 (Kircheis 1994) and the species is now well-established in the watershed. The northern pike (*E. lucius*) was first observed in Maine in 1981 and is now well established in parts of the Androscoggin and, especially, Kennebec, drainages. Most recently, it has been recorded from Pushaw Lake in the Penobscot basin. There are concerns that proposed future dam removals on the Penobscot will contribute to the spread of this species throughout much of this watershed. Northern pike is known to hybridize with chain pickerel in the Belgrade lakes (Herke 1988), and likely also competes with this and other gamefish species. The chain pickerel (*E. niger*) is probably native only to the southwestern part of the state, but "may have been the first northeast species to experience extensive anthropogenic translocation", with reports that it was introduced into the Penobscot basin in the early 1800s (Whittier et al. 1999). Today, the chain pickerel is the sixth most common species, in terms of number of lakes inhabited (Table 6.4.1). It is found in lakes of all sizes, but rarely occurs at elevations >1000 ft. (Table 6.4.2). The redfin pickerel (*E. americanus americanus*) is rare in Maine, restricted to a few sites in the lower mid-coast region of the state. Previous reports of the grass pickerel (*E. americanus vermiculatus*) from the Kennebec drainage (e.g. Kircheis 1994) appear to have incorrectly identified the specimens – they were likely the redfin or chain pickerel (Gallagher 1998).

<u>Umbridae:</u> The central mudminnow (*Umbra limi*) – not a true minnow – was first recorded in Maine in 1999 from the Orono – Old Town area. Multiple year classes were observed in subsequent year. It probably represents a release from a local bait dealer (Schilling, in press). The EMAP survey recorded this species from only one location in New England, in Vermont (Whittier et al. 2001).

<u>Moronidae:</u> The white perch (*Morone americana*) is native in Maine only to coastal regions and low gradient river segments with direct coastal access (Whittier et al. 1999). The fact that this species now occurs in one quarter of all surveyed lakes, in all regions of the state except for northern Aroostook county and the western-most mountains (Appendix 11.5.2), is testimony to the human-associated translocation of fish species.

White perch can stunt in lakes when there is over-production (e.g. Hines 1981). There is speculation that white perch may be associated with excessive phytoplankton production in some lakes, perhaps via cropping by fish of filter-feeding zooplankton populations (D. Halliwell, MDEP, pers. comm.). An ongoing study is attempting to evaluate this hypothesis (K. Webster, University of Maine, pers. comm.). The other Maine representative of this family is the striped bass (*Morone saxatilis*) which here is a euryhaline coastal, estuarine and large-river species. Gulf of Maine populations are today much smaller than they were historically, when strong spawning runs occurred in virtually all rivers along the New England coast (Little 1995). Today, New England's only spawing population of this species is in the Kennebec River.

Gasterosteidae: All four North American sticklebacks (Page and Burr 1991) are present in Maine. Two species occur statewide and are relatively common: the threespine (*Gasterosteus aculeatus*) and ninespine (*Pungitius pungitius*) sticklebacks, whereas the fourspine stickleback (*Apeltes quadracus*) and brook stickleback (*Culaea inconstans*) are much rarer.

Gadidae: The cusk (= burbot; *Lota lota*) is the only truly freshwater representative of this predominantly marine family (the cods). Although widespread in Maine, it is not common, occurring in about 8% of surveyed lakes. Most of these lakes are >100 acres. The cusk is also found in many of the larger rivers. Apparently, this species is particularly uncommon in the Downeast and northeast regions of the state (Appendix 11.5.2).

Acipenseridae: The shortnose sturgeon (*Acipenser brevirostrum*), a federally endangered species, is a large-river and coastal taxon that occasionally enters open sea (Page and Burr 1991). The primary population in Maine is in the Kennebec basin (NMFS 1998). Although not listed as endangered, the Atlantic sturgeon (*A. oxyrhynchus*) has, like the shortnose sturgeon, become significantly depleted throughout much of its range. In the Kennebec estuary, the Atlantic sturgeon is less common than the shortnose sturgeon.

Table 6.4.1: Freshwater and diadromous fish species in Maine, with frequency of occurrence in lakes sampled by MDIFW.
MDIFW has sampled 2,154 lakes as of 2004. Species list includes both lake and stream records. Appendix 11.5.2 contains distribution maps for these species. Maps can also be viewed on-line at: http://www.pearl.maine.edu/windows/biodiversity/fish_checklist.htm

Family	Scientific Name	Common Name	Maine Native?	Diad-romous?	# Lakes	Comments
Petromyzontidae	Petromyzon marinus	Sea lamprey	Yes	Yes	13	
Anguillidae	Anguilla rostrata	American eel	Yes	Yes	684	
Clupeidae	Alosa aestivalis	Blueback herring	Yes	Yes	0	
Clupeidae	Alosa mediocris	Hickory shad	Yes	Yes	0	Do not reproduce in New England
Clupeidae	Alosa pseudoharengus	Alewife	Yes	Yes / No	31 (LL) 104 (SR)	Primarily an anadromous species, but with a small number of land-locked populations
Clupeidae	Alosa sapidissima	American shad	Yes	Yes	0	
Clupeidae	Dorosoma cepidianum	Gizzard shad	No	No	0	Range extension into Maine waters?
Salmonidae	Coregonus clupeaformis	Lake whitefish	Yes	No	76	
Salmonidae	Oncorhynchus mykiss	Rainbow trout	No	No	10	
Salmonidae	Prosopium cylindraceum	Round whitefish	Yes	No	59	
Salmonidae	Salmo salar	Atlantic salmon	Yes	Yes	0	
Salmonidae	Salmo salar sebago	Landlocked Atlantic salmon	Yes	No	304	
Salmonidae	Salmo trutta	Brown trout	No	No *	213	
Salmonidae	Salvelinus alpinus	Arctic char	Yes	No	20	
Salmonidae	Salvelinus fontinalis	Brook trout	Yes	No *	1482	
Salmonidae	Salvelinus hybrid1	Splake	Yes +	No	88	
Salmonidae	Salvelinus namaycush	Lake trout	Yes	No	160	
Osmeridae	Osmerus mordax	Rainbow smelt	Yes	Yes / No	564	Sea-run and landlocked populations (normal and dwarf).
Cyprinidae	Carausius auratus	Goldfish	No	No	3	
Cyprinidae	Couesius plumbeus	Lake chub	Yes	No	292	
Cyprinidae	Cyprinus carpio	Common carp	No	No	0	
Cyprinidae	Hybognathus regius	Eastern silvery minnow	No	No	0	
Cyprinidae	Luxilus cornutus	Common shiner	Yes	No	463	
Cyprinidae	Margariscus margarita	Pearl dace	Yes	No	165	
Cyprinidae	Notemigonus crysoleucas	Golden shiner	Yes	No	861	
Cyprinidae	Notropis atherinoides	Emerald shiner	No	No	3	
Cyprinidae	Notropis bifrenatus	Bridled shiner	Yes	No	7	
Cyprinidae	Notropis heterodon	Blackchin shiner	No	No	0	
Cyprinidae	Notropis heterolepis	Blacknose shiner	Yes	No	84	
Cyprinidae	Notropis hudsonius	Spottail shiner	No	No	0	

Cyprinidae	Notropis rubellus	Rosyface shiner	No	No	0	
Cyprinidae	Pimephales promelas	Fathead minnow	Yes	No	97	
Cyprinidae	Phoxinus eos	Northern redbelly dace	Yes	No	439	
Cyprinidae	Phoxinus neogaeus	Finescale dace	Yes	No	256	
Cyprinidae	Scardinius erythrophthalmus	Rudd	No	No	1	
Cyprinidae	Semotilus atromaculatus	Creek chub	Yes	No	569	
Cyprinidae	Semotilus corporalis	Fallfish	Yes	No	459	
Cyprinidae	Rhinichthys atratulus	Blacknose dace	Yes	No	435	
Cyprinidae	Rhinichthys cataractae	Longnose dace	Yes	No	3	
Fundulidae	Fundulus diaphanus	Banded killifish	Yes	No	365	
Fundulidae	Fundulus heteroclitus	Mummichog	Yes	No	1	Euryhaline, with some freshwater populations
Cottidae	Cottus cognatus	Slimy sculpin	Yes	No	124	
Catostomidae	Catostomus catostomus	Longnose sucker	Yes	No	130	
Catostomidae	Catostomus commersoni	White sucker	Yes	No	1207	
Catostomidae	Erimyzon oblongus	Creek chubsucker	Yes	No	19	
Ictaluridae	Ameiurus nebulosus	Brown bullhead	Yes	No	851	
Ictaluridae	Ameiurus catus	White catfish	No	No	0	Recent records from large rivers
Centrarchidae	Lepomis auritus	Redbreast sunfish	Yes	No	223	
Centrarchidae	Lepomis cyanellus	Green sunfish	No	No	1	Recent introduction
Centrarchidae	Lepomis gibbosus	Pumpkinseed	Yes	No	788	
Centrarchidae	Lepomis macrochirus	Bluegill	No	No	1	Recent introduction
Centrarchidae	Micropterus dolomieu	Smallmouth bass	No	No	471	
Centrarchidae	Micropterus salmoides	Largemouth bass	No	No	374	
Centrarchidae	Pomoxis nigromaculatus	Black crappie	No	No	60	
Centrarchidae	Ambloplites rupestris	Rock bass	No	No	0	Recent record from Androscoggin River
Percidae	Etheostoma fusiforme	Swamp darter	Yes	No	3	
Percidae	Perca flavescens	Yellow perch	Yes	No	855	
Percidae	Sander vitreus	Walleye	No	No	1	
Esocidae	Esox americanus americanus	Redfin pickerel	Yes	No	0	
Esocidae	Esox lucius	Northern pike	No	No	19	
Esocidae	Esox masquinongy	Muskellunge	No	No	4	
Esocidae	Esox niger	Chain pickerel	Yes	No	809	
Umbridae	Umbra limi	Central mudminnow	No	No	0	Recent first record
Moronidae	Morone americana	White perch	Yes	No	520	
Moronidae	Morone saxatilis	Striped bass	Yes	No	0	Marine and large rivers
Gasterostidae	Apeltes quadracus	Fourspine stickleback	Yes	No	7	
Gasterostidae	Culaea inconstans	Brook stickleback	Yes	No	12	
Gasterostidae	Gasterosteus aculeatus	Threespine stickleback	Yes	No	153	

Gasterostidae	Pungitius pungitius	Ninespine stickleback	Yes	No	116	
Gadidae	Lota lota	Cusk	Yes	No	158	
Gadidae	Microgadus tomcod	Atlantic tomcod	Yes	Yes	0	Estuaries and rivers
Acipenseridae	Acipenser brevirostrum	Shortnose sturgeon	Yes	Yes	0	Primarily freshwater, but also coastal
Acipenseridae	Acipenser oxyrhynchus	Atlantic sturgeon	Yes	Yes	0	

+ Hybrid between two native species, brook and lake trouts.
* Sea-run populations exist.

(Table 6.4.1, end)

Table 6.4.2: Occurrence of lake fish species by elevation and lake area classes. Data are weighted number of lakes in which a species is recorded in each elevation or area class. The weighting standardizes the number of lakes to 1000 in each elevation or area class (weighting factor = 1000 / # sampled lakes in class). See Appendix 11.5.2 for elevation-lake area plots for individual species.

SPECIES	ELEVATION CLASS (ft)					AREA CLASS (acres)			
	<500	500-999	1000-1499	1500+		<10	10-99	100-999	1000+
Sea lamprey	13	0	0	0		0	0	11	36
American eel	557	237	53	25		51	220	518	619
Alewife, landlocked	19	15	8	5		0	3	27	60
Alewife, searun	107	0	0	0		0	19	96	137
Lake whitefish	20	73	45	0		0	0	57	238
Round whitefish	7	62	41	10		0	3	43	173
Landlocked salmon	155	168	114	88		4	30	246	684
Brown trout	185	49	10	15		7	56	166	262
Arctic char	3	9	22	10		0	5	17	24
Brook trout	474	761	943	916		610	694	683	797
Splake	40	45	41	5		4	23	70	71
Lake trout	60	131	73	20		0	7	126	428
Rainbow smelt	318	264	196	142		7	119	465	815
Lake chub	26	185	251	260		11	101	190	357
Common shiner	171	359	216	98		22	122	365	565
Pearl dace	20	166	125	25		18	82	81	125
Golden shiner	530	415	255	113		241	369	480	559
Emerald shiner	2	0	2	0		0	0	2	12
Bridled shiner	6	0	2	0		0	2	5	12
Blacknose shiner	18	101	33	15		11	35	52	60
Northern redbelly dace	79	312	345	181		102	233	188	220
Finescale dace	18	155	257	167		62	152	85	119
Fathead minnow	23	80	71	10		44	50	40	36
Blacknose dace	90	344	257	279		69	173	261	387
Longnose dace	1	0	4	0		0	1	2	6
Creek chub	108	428	419	250		88	237	343	434
Fallfish	248	275	155	54		15	73	382	803
Banded killifish	258	200	41	5		44	116	250	411
Slimy sculpin	30	88	86	49		0	16	90	298
Longnose sucker	14	99	104	83		0	16	93	321
White sucker	676	604	427	250		106	436	864	952
Creek chubsucker	14	9	0	5		0	11	9	6
Brown bullhead	617	383	120	59		124	292	580	797
Redbreast sunfish	146	153	18	5		11	43	201	280
Pumpkinseed	645	277	61	5		110	280	551	631
Smallmouth bass	412	135	12	0		18	105	403	571
Largemouth bass	340	88	4	0		55	136	265	262
Black crappie	55	15	0	0		4	16	47	71
Yellow perch	624	350	137	74		73	279	619	845

Walleye	1	0	0	0		0	0	0	6
	ELEVATION CLASS (ft)					AREA CLASS (acres)			
SPECIES	<500	500-999	1000-1499	1500+		<10	10-99	100-999	1000+
Northern pike	19	0	2	0		0	4	11	48
Muskellunge	0	4	4	0		0	0	5	6
Chain pickerel	685	269	31	10		106	304	551	613
White perch	460	131	20	5		11	106	468	631
Fourspine stickleback	7	0	0	0		0	2	2	24
Brook stickleback	3	11	4	10		0	6	3	24
Threespine stickleback	45	159	67	5		7	33	107	280
Ninespine stickleback	77	77	10	0		29	41	58	161
Cusk	54	118	98	5		0	15	112	422

(Table 6.4.2, continued)

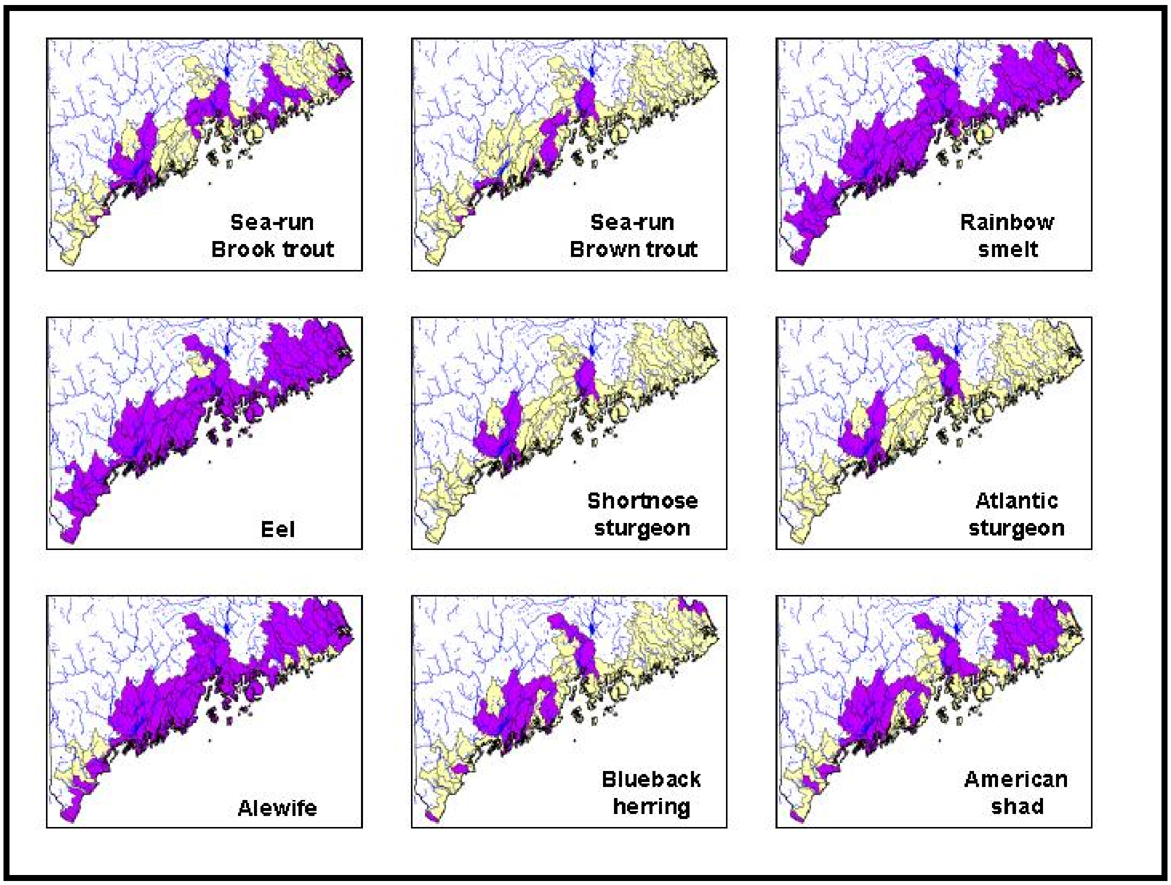


Figure 6.4.1: Distribution of diadromous fish species runs, by coastal watershed.

Dark-shaded regions are coastal watersheds (HUC-10) for which species runs were documented as occurring in the 1980s. Light-shaded regions are other coastal watersheds. Maps do not show inland watersheds in which runs occur (i.e. maps give no indication of upstream extent of fish runs). See text for additional information. Data sources: CMRI (1984), ECCM (1980), Eipper et al. (1982), as compiled in MEGIS file (ACFISH2) and further documented by S. Barker (DMR, pers. comm. to P. Vaux).

Patterns of Species Richness: There is north-south gradient of fish species richness in Maine, with approximately one third more species present in the southern half of the state than in the north. One way of depicting this trend is by summing the total number of species known to occur in each watershed, e.g. HUC-8 (Figure 6.4.2A). Lowest total species richness occurs in the Upper St. John and Allagash watersheds; highest species numbers are seen in the lower Kennebec and Penobscot watersheds. The higher species richness of southern Maine reflects the addition of a group of non-native, generally warmer-water, species to the pool of native species. Watersheds in southern Maine have about 20% of their fish fauna composed of non-Maine natives (Figure 6.4.2B), whereas this group represents <5% of the species pool in northern watersheds.

As with any summary of cumulative species richness by watershed, it is important to evaluate the species-area effect, i.e. smaller watersheds would, a priori, be expected to hold fewer species than larger watersheds. As Figure 6.4.2C shows, this species-area effect is evident for southern Maine watersheds, but appears to be absent for watersheds in the northern half of the state[18].

Environmental correlates of fish species richness were examined for a set of 1936 Maine lakes with environmental data, using stepwise multiple linear regression (forward selection procedure; SYSTAT 11). As expected, fish species richness in lakes is primarily a function of lake size (logarithmic surface area). Larger lakes tend to have more species (Figure 6.4.3A), with lake area accounting for 59% of variance in species richness (Table 6.4.3). Elevation is the next most important factor, responsible for additional 5% of variance in species richness – higher elevation lakes have fewer species (holding area constant). The third most important factor is maximum depth, which is positively (albeit slightly) associated with species richness. Lake location (UTM coordinates) similarly contributed only very slightly as predictors of fish species richness (Table 6.4.3). While water quality data were not available for the full set of 1936 lakes, a subset of 692 lakes did have both fish and water quality data (alkalinity, conductivity, chlorophyll). The regression analysis was repeated for this sub-set of lakes. None of the water quality parameters were significantly associated with fish species richness (beyond the effects of the morphometric and geographic parameters indicated previously).

The species-area effect just described for individual lakes parallels an effect seen at the level of watersheds. The cumulative number of lake fish species present in a medium-sized (HUC-10_ watershed is strongly associated with the total lake area in that watershed (Figure 6.4.3B) – not surprisingly, watersheds with more cumulative lake area have more fish species.

While species richness is clearly a function of lake area, there is a considerable amount of scatter around the species-area regression line (Figure 6.4.3A). We used an analysis of residuals to further investigate whether there is a regional component to this scatter, i.e. whether lakes in some parts of the state tend to have relatively more or less species than expected simply based on lake area. The fact that lake location, as quantified by UTM coordinates, played a very minor role in the stepwise regression output (Table 6.4.3), suggested a priori that the spatial effect would be slight. This was supported by the residuals analysis. Figure 6.4.4 shows box plots of species richness residuals (i.e. observed minus expected number of fish species in each lake) for six regions in the state (regions are shown in Figure 2.3). We observed no significant regional differences in species residuals (i.e. lake species richness after accounting for lake size) – either for total species (Figure 6.4.4A) or Maine-native species (Figure 6.4.4B). However there is a tendency for lakes in western Maine (Region 5) to have relatively fewer species than expected on the basis on lake size.

Geographic variation in the proportion of non-natives in lake fish assemblages is further illustrated in Figure 6.4.5 (compare with the watershed-based measures shown in Figure 6.4.2). Each point in these regional panels represents the native complement of one or more lakes (usually >1). In

[18] Figure 6.4.2C is based on lakes data, only, to avoid possible bias resulting from the fact that some streams data from northern watersheds were not available in a digitized format prior to preparation of this report.

the southern and central parts of the state, native species generally represent between 60% and 100% of each lake's total species pool. In contrast, in the north, the native species complement is generally >80%.

Numerous stream sites have been sampled for fish in Maine (Figure 5.5). Unfortunately, because of variations in sampling effort and in the consistency with which non-gamefish species were recorded, it is not possible to use all of these data for characterizing the numbers of species present at stream sites. Thus we focus here on data from the MDIFW brook trout monitoring program which employs standardized methodology and records all species captured (since the early 1990s, at least). The numbers of species recorded from 62 sites are shown in Figure 6.4.6 as a function of upstream watershed area. Watershed area was used as a surrogate for stream size and was derived in GIS using the digital elevation data and the USEPA's RF3 stream coverage. Based on this dataset, there is no significant relationship between upstream watershed area and species number. Furthermore, there appear to be no obvious regional differences in the richness of stream fish assemblages (Figure 6.4.6), an observation that parallels the finding of few regional trends in the species-area residuals for lake fish assemblages (Figure 6.4.4).

Two factors likely contribute to the absence of watershed size and regional patterns in these data. First, although the data were collected with standardized sampling, the number of years in the data record is variable among sites (Figure 5.6) and we have shown that cumulative species richness (i.e. number of species across time) depends in part on the number of years in the sampling record (Table 5.8). Second, most of the sampling sites in the brook trout monitoring study drain a relatively narrow range of watershed areas (Figure 6.4.6). Studies from other parts of North America and elsewhere have shown that stream/river fish assemblage richness is often positively correlated to watershed area, although this is not a universal pattern (see review in Matthews 1998).

Species lists derived from recent electrofishing of four large rivers in Maine (Table 6.4.4) support the consensus that species richness is indeed related to river size / watershed area when a sufficiently broad range of river sizes is included in the analysis. These rivers were sampled along a number of reaches using an electrofishing boat (Figure 5.8) as part of a study to develop a large-river Index of Biotic Integrity. A total of 43 taxa (41 if splake are excluded, and landlocked and sea-run salmon are treated as a single taxon) were collected from these four rivers – equivalent to 60% of Maine's freshwater / euryhaline ichthyofauna. Sampling in the Kennebec River yielded 38 species, while 35, 15 and 18 species were collected from the Androscoggin, Sebasticook and Cathance Rivers, respectively (Table 6.4.4).

Species richness is, of course, influenced by numerous factors, including the amount and type of in-stream habitat (e.g. Angermeier and Schlosser 1989), hydrology and position of the stream in the hydrologic network (e.g. Wiley et al. 1997, Osborne and Wiley 1992), surrounding landscape (e.g. Lammert and Allan 1999, Harding et al. 1998), and channel morphology (Matthews 1998). Using, in part, data from the brook trout monitoring program, Gaenzle (2002) showed that fish species richness in Maine streams is negatively correlated with elevation – a one-meter increase in elevation was associated with a predicted 0.2% decrease in species richness. Gaenzle (2002) further showed that native fish species richness was strongly influenced by stream type. The latter was measured using the Rosgen stream classification system that integrates a series of geomorphological variables into a hierarchical framework of stream types (Rosgen 1996). For example, steep, entrenched streams had the lowest richness (no fish present in type AA+ streams; a mean of 1.7 species present in type A streams). Highest richness (mean species number = 7.5) occurred in type C streams, which are low gradient, meandering systems typical of lower elevations. MDIFW currently integrates habitat surveys, including the Rosgen system, into the department's stream fish sampling program. Thus it is likely that future work will greatly contribute to a better understanding of the various factors responsible for structuring stream fish assemblages in Maine.

The native complement of stream fish assemblages is shown in Figure 6.4.7 and compared to the lakes data. The streams data are shown individually by site, whereas the lakes data are shown as mean per lake % richness for all lakes within each medium-sized watershed (HUC-10). . As might be expected, stream sites with lower proportions of native species are concentrated in southern Maine. This patten is not universal, however, since there are a number of sites in this region also exhibit a high native complement.

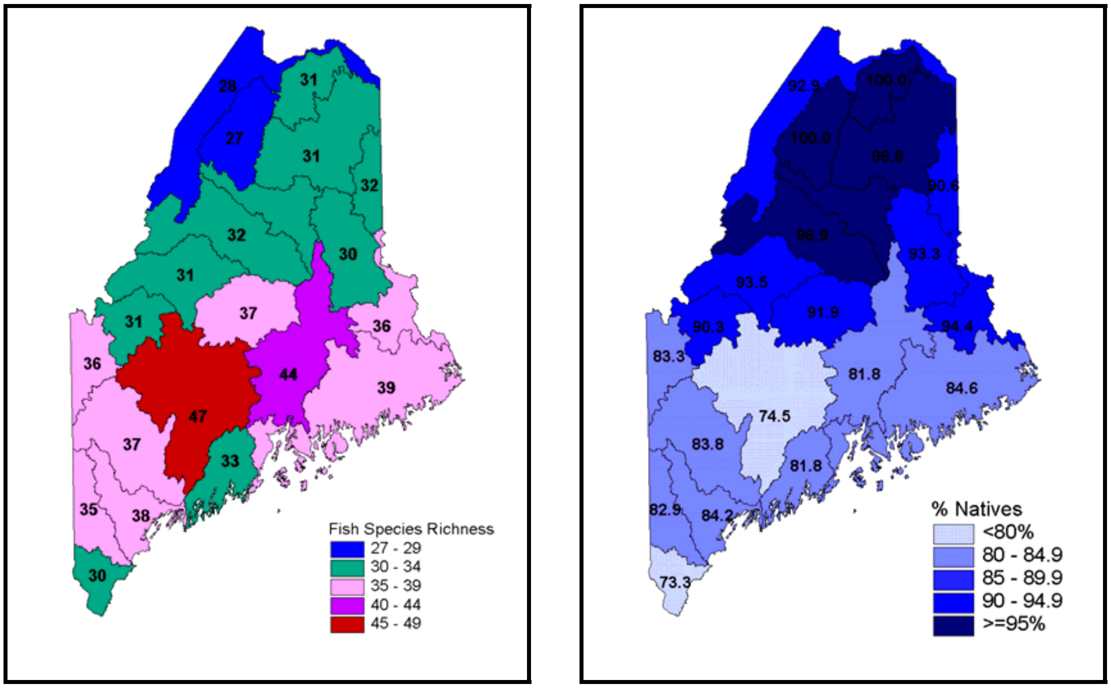
Table 6.4.3: Association between total fish species richness in Maine lakes and (i) lake morphometry and (ii) geographic location.
The table contains the output of forward-selection stepwise regression analysis. Number of lakes = 1936.

Parameter	**Constant**	**Cumulative R^2**	**p-value**
Constant	- 33.59		< .001
Log Lake Area (acres)	1.76	0.59	< .001
Elevation	- 0.003	.64	< .001
Maximum lake depth (ft)	0.029	.64	< .001
UTM-X (m)	- 0.011	.66	< .001
UTM-Y (m)	0.008	.67	< .001

Table 6.4.4: Fish assemblages in large rivers.
Data are from a recent study conducted to develop an Index of Biotic Integrity for large rivers *.

Species	Androscoggin R.	Cathance R.	Kennebec R.	Sebasticook R.
TOTAL # TAXA	**35**	**18**	**38**	**15**
Sea lamprey	X		X	
American eel	X	X	X	X
Blueback herring		X	X	
Alewife	X	X	X	X
American shad	X	X	X	
Rainbow trout	X		X	
Atlantic salmon			X	
Landlocked salmon	X		X	
Brown trout	X		X	
Splake			X	
Rainbow smelt			X	
Lake chub	X		X	
Creek chub	X	X	X	
Common carp	X	X	X	
Common shiner	X	X	X	X
Golden shiner	X	X	X	X
Spottail shiner	X	X	X	
Fallfish	X		X	X
Blacknose dace	X		X	
Longnose dace	X			
Banded killifish	X	X	X	
Mummichog		X	X	
Slimy sculpin	X			
White sucker	X	X	X	X
Longnose sucker	X			
Brown bullhead	X		X	X
White catfish	X	X	X	
Redbreast sunfish	X	X	X	X
Pumpkinseed	X	X	X	X
Smallmouth bass	X		X	X
Largemouth bass	X		X	X
Black crappie	X		X	X
Rock bass	X			
Yellow perch	X	X	X	X
Chain pickerel	X		X	X
Northern pike	X			
White perch	X	X	X	X
Striped bass	X		X	
Fourspine stickleback	X		X	
Threespine stickleback			X	
Ninespine stickleback		X		
Cusk	X		X	
Northern silverside			X	

* Data provided by B. Kulik, Kleinschmidt Associates, Pittsfield, Maine; 12/04



(A) (B)

Figure 6.4.2 (A & B): Fish species richness by large watershed (HUC-8). (A) Total species, (B) % Maine natives.
Species totals refer to the cumulative number of species (lake or stream) in each watershed *.

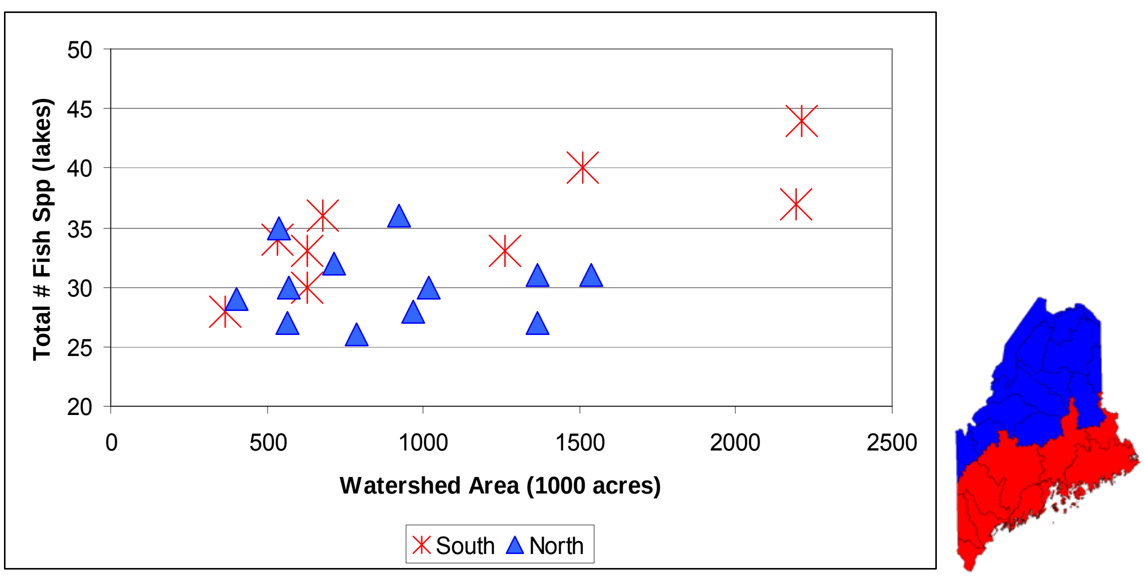


Figure 6.4.2 (C): Cumulative number of lake fish species in watersheds (HUC-8) as a function of watershed area *.
The southern and northern watersheds are indicated in the inset map. See text for additional information.Data sources: Multiple, as compiled in MABP database.

* The following species were excluded from watershed totals: mummichog, sturgeons, blueback herring, American shad, striped bass, splake, carp, white catfish, rock bass and tomcod. Sea-run and landlocked populations of alewives, smelts, salmon, brook trout, and brown trout were counted as single species.

(A)

(B)

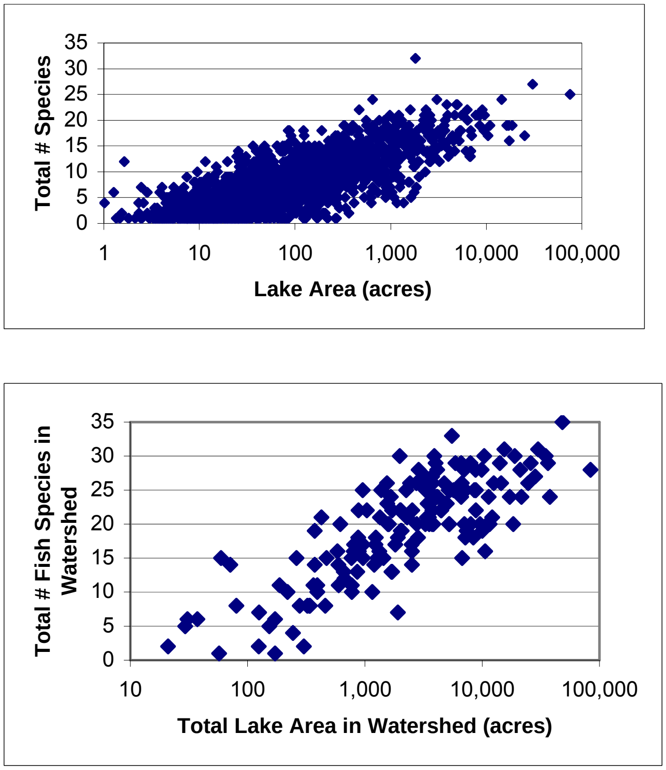


Figure 6.4.3: Associations between lake fish species richness and the extent of aquatic habitat.
(A) Species richness vs. lake area. (B) Cumulative species richness vs. cumulative lake area, by watershed (HUC-10).
Cumulative species and area refer to the total number of species and total lake area in a watershed. Cumulative lake area includes only MIDAS-numbered lakes. Data source: MDIFW.

(A) (B)

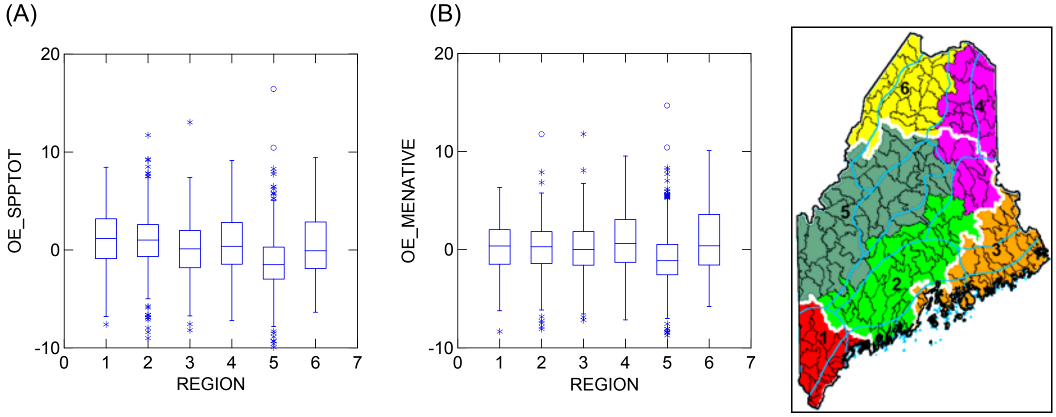


Figure 6.4.4: Geographic variation in two aspects of lake fish assemblages. (A) Residuals in plot of total species number vs. logarithmic lake area (see Figure 6.4.3). (B) Residuals in plot of number of Maine-native fish species vs. logarithmic lake area.
Panels are box and whisker plots, in which central bar represents the mean, top and base of “boxes” represent 75th and 25th percentiles, respectively, and “whiskers” represent 5th and 95th percentiles. Regions are shown in map at right. See text for more information.

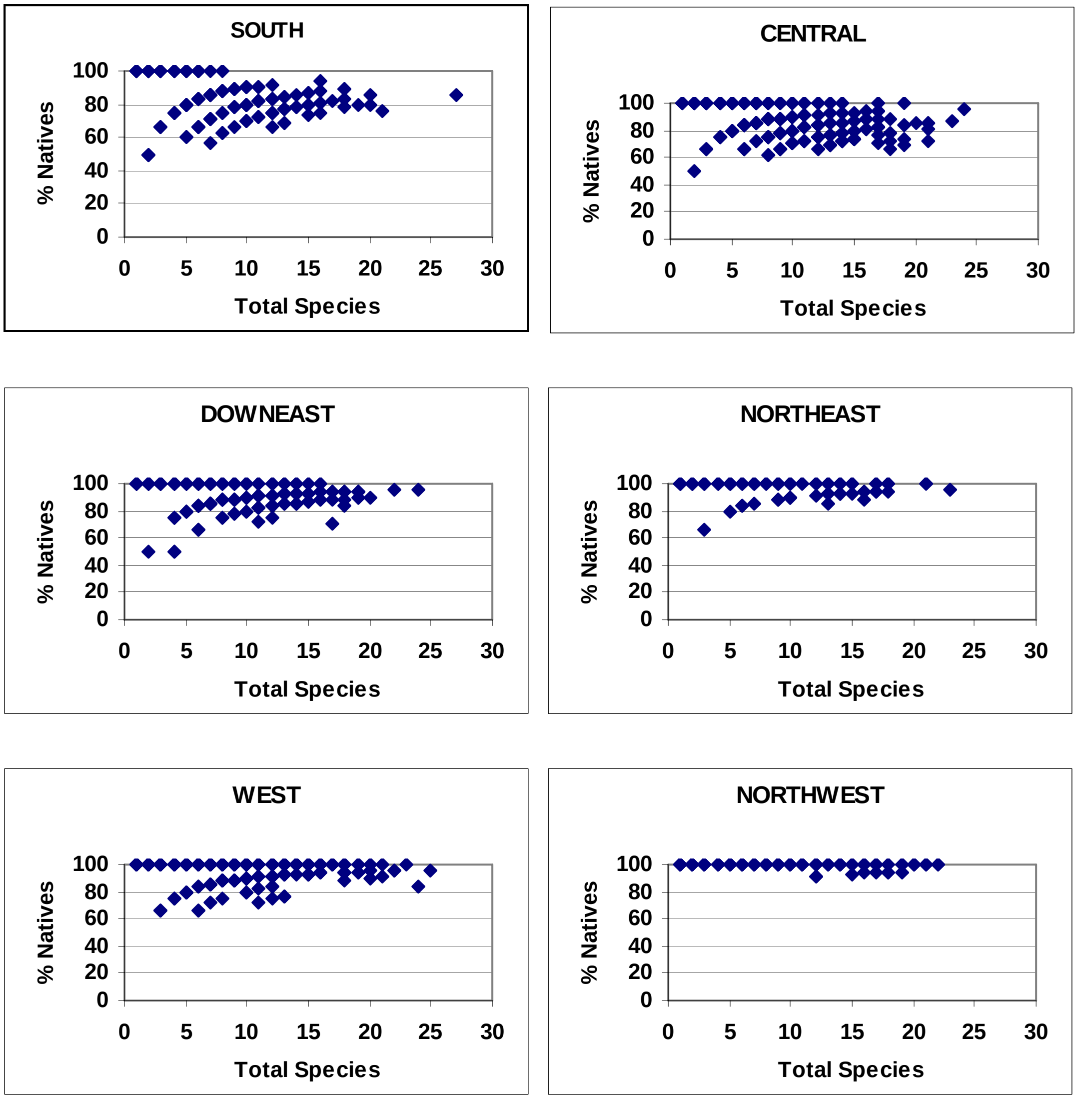


Figure 6.4.5: Percent Maine-native fish species in six regions of Maine.
Data show % natives as function of total number of fish species for individual lakes. Note that individual points may represent multiple lakes. Regions are shown in Figure 6.4.4.

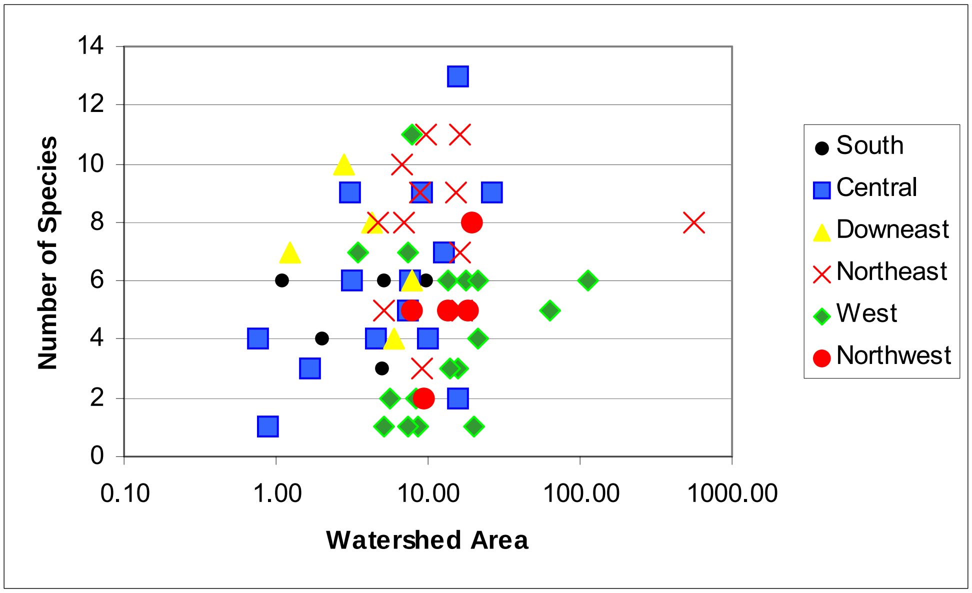


Figure 6.4.6: Species richness in stream fish assemblages, as a function of stream size (watershed area, square miles).
Data are from MDIFW Brook trout monitoring study, aggegated across years. Number of years of sampling record varies between sites. Watershed areas are those upstream of sampling site and were derived in GIS using the RF3 streams coverage. Regions are shown in Figure 2.3.

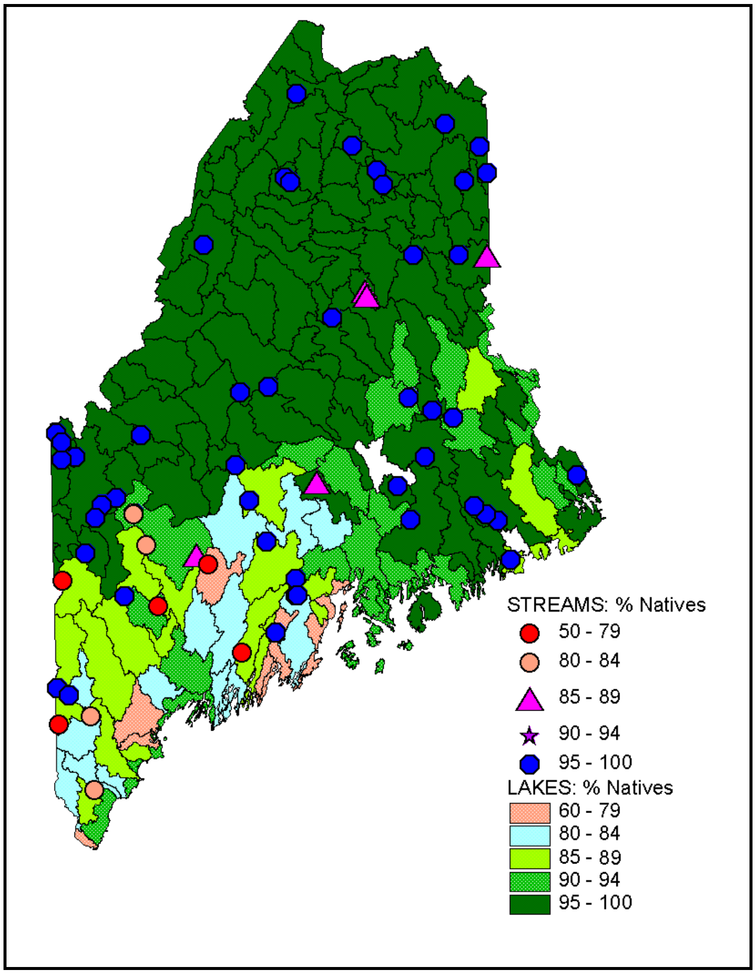


Figure 6.4.7: Geographic variation in the native species complement of lake and stream fish assemblages.
Stream data refer to % Maine-native species at indicated sampling sites. Lake fish assemblage data are summarized at the watershed level, i.e. the average % natives per lake among all lakes within a watershed. Note that this individual-lake measure is <u>not</u> the same as the cumulative native species richness within a watershed; the latter is shown in Figure 6.4.2. Lake data are from the MDIFW lake inventory (2004 update); stream data are from the MDIFW brook trout monitoring program. The few watersheds shown in white contain no lake data.

Fish Community Structure: The total number of species present in a lake or stream reach is a “coarse” descriptor of fish assemblages because it does not account for species composition. To describe geographic patterns in the composition of fish assemblages, we use five approaches: (i) minnow diversity in lakes; (ii) assemblage types derived from cluster analysis; (iii) frequency of occurrence of species in different regions of the state; (iv) occurrence frequency of pairwise species combinations (gamefish and allied species, only); and (v) patterns of relative numerical abundance of fish species in selected lakes.

Minnows: Lakes in western and northern Maine tend to contain a higher number of native minnows than lakes in other parts of the state. Lakes containing 7-11 minnow species are located almost exclusively in the west and north (Figure 6.4.8A). Lakes with 4-6 species are also concentrated in the north and west, although others occur in the Downeast region. In western and northern Maine, minnows comprise, on average, 35-50% of the species of each lake (Figure 6.4.8B). Unlike the situation for complete fish assemblages (i.e. minnows plus non-minnows), lake size appears to have little effect on minnow species richness (Figure 6.4.9; compare with Figure 6.4.3). There is nevertheless a weak relationship between lake size and number of minnow species when lakes in the northwest region of the state are analyzed separately (Figure 6.4.9). Based on EMAP data, Whittier et al. (1997) and Whittier and Kincaid (1999) have suggested that reduced minnow richness in lakes of the northeast U.S. is, in part, a result of the introduction of littoral predators such as the black basses and chain pickerel. This theory is supported with analysis of the much larger MDIFW dataset which shows the following association between the number of native minnow species and the presence of littoral predators (the basses, chain pickerel, northern pike):

# minnow spp.	*# lakes*	*% lakes with littoral predators*
0	809	61%
0-3	909	38%
4-6	270	13%
7-11	48	10%

As discussed previously, it is likely that minnow diversity in Maine lakes will continue to decline as these predators continue to expand their range.

Cluster analysis: Agglomerative cluster analysis was used to define lake fish assemblage types based on the MDIFW lake data (species presence / absence). Since the number of fish species in a lake is strongly associated with lake size, we selected two lake size classes for the clustering analysis: 10-99 acres and 100-999 acres. We used indicator species analysis (McCune and Grace 2002) to assist with defining a stopping point in the cluster analysis[19]. Indicator species analysis was also used to identify “indicator”, or diagnostic, species for each assemblage class. These diagnostic species are fish that typically (but not always) occur in lakes of a particular class. Other species commonly present were also identified via indicator species analysis. All species, whether native to Maine or introduced, were included in the cluster analysis.

Figure 6.4.10 displays the geographic pattern of fish assemblage clusters for the two size classes of lakes. For the 10-99 acres lakes, southern Maine is, as expected, clearly differentiated from the rest of the state, as are the western and northern regions. For the 100-999 acre lakes, the split is primarily elevational, separating the western and northern regions from southern, central and Downeast Maine. The clusters shown in Figure 6.4.10 are described in Table 6.4.5 which provides output from indicator species analyses. For each lake size class, there are coldwater, warmwater and mixed assemblages. Superimposed on these are species richness classes which are clearly associated with lake surface area.

[19] Analyses used PC-ORD software (McCune and Mefford 1999). Cluster analysis used Sorensen distance measure and flexible beta linkage method. Cluster level 5 was selected for output.

Frequency of species occurrence: A third approach to graphically summarizing statewide patterns in fish assemblages is depicted in Figure 6.4.11. We first attributed lakes by the major regions in which they occur (see Figure 6.4.4 for regions). We then calculated the percent of lakes in which each species occurs within each region. Data from lakes of all size classes were pooled for this analysis. Species were ordered graphically from most common to least common in southern Maine – regardless of taxonomic affiliation (top left panel in Figure 6.4.11). This species ordering was then kept constant when displaying data from all other regions. As would be expected, this graphical summary parallels the major patterns derived from cluster analysis (Figure 6.4.10). South, central and, to a lesser extent, Downeast regions are quite distinct from northern and western regions of the state.

Species pairs – frequency of occurrence: The frequency with which various pairs of species occur in Maine lakes is shown in Table 6.4.6. Numbers below the diagonal are numbers of lakes in which the species co-occur; numbers above the diagonal are percentages of the maximum possible number of co-occurrences. Thus if species A occurs in a total of 80 lakes, species B occurs in a total of 125 lakes, and they co-occur in 40 lakes, the % co-occurrence = 40/80 = 50%. Some species pairs are very rare, for example:

alewife with: round whitefish, lake whitefish, longnose sucker or cusk;
brown trout with: round whitefish, lake whitefish or longnose sucker;
round whitefish with: redbreast sunfish, or largemouth bass;
longnose sucker with largemouth bass.

Other species pairs are relatively very common, for example:

white sucker with: landlocked salmon, lake trout, round whitefish, lake whitefish or cusk;
pickerel and either of the black basses.

It seems likely that, as Maine's fish fauna becomes increasingly homogenized as a result of introductions / translocations, the frequency of high-percent co-occurrences will increase. In fact, data like those in Table 6.4.6 could provide a convenient quantitative benchmark for measuring future changes in the ichthyofauna of the state's lakes.

Relative species abundance, by lake: We used the EMAP survey data to illustrate the relative abundance of fish species in selected lakes from each of the six major regions in the state (Figure 6.4.12 A-F). Measures of absolute or relative abundance are highly dependent on the type sampling effort (i.e. gear type), as discussed in Chapter 5. Thus we show data separately for two different gear types: gill nets and trap nets. Lakes were sampled with a standardized methodology; however the number of sampling events was not completely consistent among this group of 12 lakes because some were re-sampled during one or more years. Data from these 12 lakes are intended simply to illustrate a range of fish assemblage structures in Maine lakes. As numerous studies elsewhere have demonstrated, incorporating relative abundance into descriptions of assemblage structure contributes to a whole new level of variation among lakes. For example, compare differences in the relative abundance of white perch and yellow perch in the two lakes depicted from central Maine, both typical warmwater systems (Figure 6.4.12B).

Table 6.4.5: Output from indicator species analysis of lake fish assemblage clusters *. Clusters were developed independently for two lake size classes: 10-99 acres and 100-999 acres. Geographic distributions of assemblage types are shown in Figure 6.4.10. See text for additional information.

10-99 acre lakes:

CW - *Cool water assemblage.*
Smaller lakes (A = 30 ± 24 acres), with lower species richness (2.7 ± 1.6 spp.).

Diagnostic Species: BKT
Other species commonly present: BND, FSD, GLS, NRD

CW + *Cool water assemblage.*
Larger lakes (A = 43 ± 27 acres), with higher specie richness (6.7 ± 3.2 spp.).

Diagnostic Species: BKT, CCB, CMS, LCB, NRD, WHS
Other species commonly present: SMT, BND, CMS, FSD, GLS, LCB, BUL, EEL, YLP, CSK

CW & *Cool water assemblage with some warm water species.*
Large lakes (A = 38 ± 28 acres), with moderate species richness (5.4 ± 2.6 spp.).

Diagnostic Species: BKF
Other species commonly present: BKT, BNT, BNS, FHM, FSK, NSK, TSK, SRA, WHS

WW - *Warm water assemblage.*
Smaller lakes (A = 25 ± 20 acres), with lower species richness (2.7 ± 1.4 spp.).

Diagnostic Species: PKL, BUL
Other species commonly present: BKT, GLS, PKS, WHS, YLP

WW + *Warm water assemblage.*
Larger lakes (A = 49 ± 28 acres), with higher species richness (7.4 ± 2.7 spp.).

Diagnostic Species: BUL, EEL, GLS, LMB, SMB, PKS, PKL, WHP, WHS, YLP
Other species commonly present: BKT, FLF, SLT

100 – 999 acres lakes:

CW - *Cool water assemblage.*
Smaller lakes (A = 186 ± 63 acres), with lower species richness (3.0 ± 1.6 spp.).

Diagnostic Species: BKT
Other species commonly present: BND, GLS, LCB, NRD, SLT

CW + *Cool water assemblage.*
Intermediate sized lakes (A = 224 ± 173 acres), with moderate species richness (6.4 ± 2.5 spp.).

Diagnostic Species: BKT, CCB, WHS
Other species commonly present: BND, CMS, FSD, GLS, LCB, NRD, PRD, FLF, PKS, WHS

CW ++ *Cool water assemblage.*
Larger lakes (A = 386 ± 244 acres), with higher species richness (12.4 ± 3.5 spp).

Diagnostic Species: BKT, LKT, LLS, SLT, BND, NRD, CCB, LCB, CMS, FLF, WHS
Other species commonly present: BUL, EEL, CSK, LNS, LWF, RWF, PKS, PRD, RBS, YLP

WW - *Warm water assemblage.*
Smaller lakes (A = 181 ± 103 acres), with lower species richness (2.0 ± 0.7 spp.).

Diagnostic species: PKL
Other species commonly present: BUL, LMB, YLP

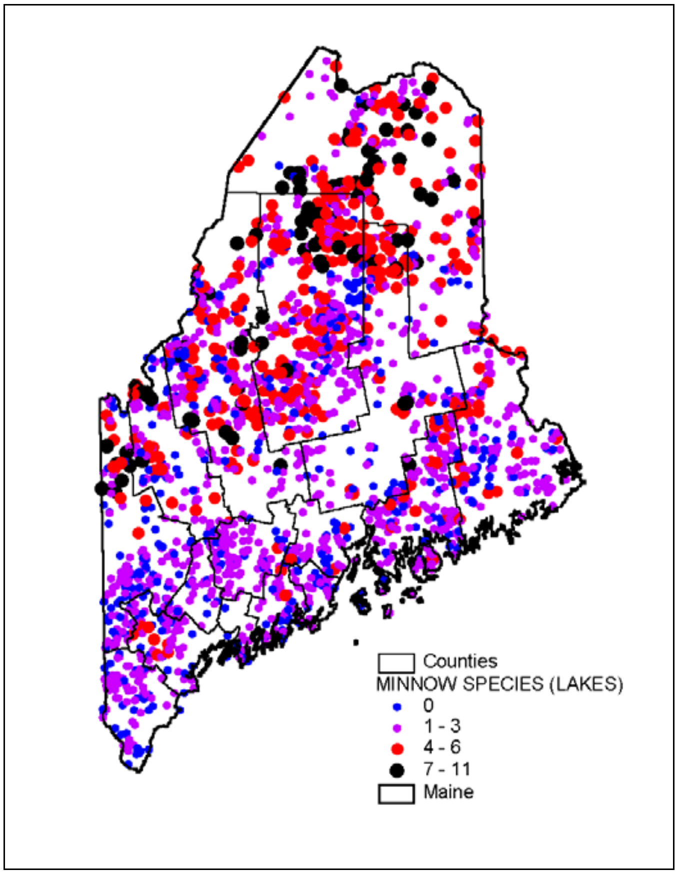
WW + *Warm water / mixed assemblage.*
Larger lakes (A = 360 ± 250 acres), with higher species richness (10.8 ± 3.0 spp.).

Diagnostic species: BUL, EEL, PKL, PKS, LMB, SMB, WHS, YLP
Other species commonly present: BKT, LLS, SLT, BNT, CMS, FLF, GLS, RBS

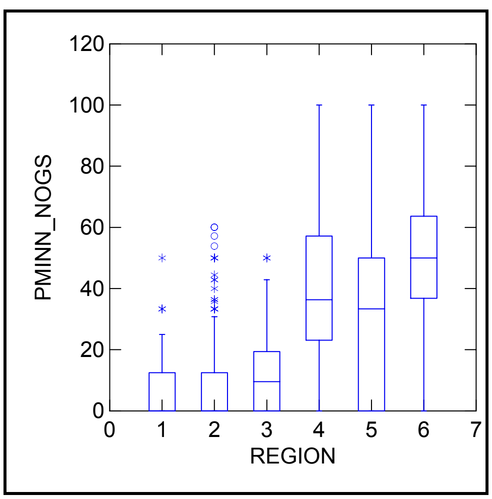
* Species codes: BKT=brook trout; BND=black nose dace; BNS=black nose shiner; BNT=brown trout; BUL=brown bullhead; CCB=creek chub; CHR=Arctic charr; CMS=common shiner; CSK=cusk; EEL=American eel; FLF=fallfish; FHM=fathead minnow; FSD=finescale dace; GLS=golden shiner; LCB=lake chub; LKT=lake trout; LLS=landlocked salmon; LMB=largemouth bass; LND=longnose dace; LWF=lake whitefish; NRD=northern redbelly dace; NSK=nine-spine stickleback; PKL=pickerel; PKS=pumpkinseed; PRD=pearl dace; RBS=redbreast sunfish; RWF=round whitefish; SLT=rainbow smelt; SMB=smallmouth bass; SRA=sea-run alewife; TSK=three-spine stickleback; WHP=white perch; WHS=white sucker; YLP=yellow perch.

(Table 6.4.5, continued)

(TABLE 6.4.6 GOES HERE)



(A)



(B)

Figure 6.4.8: Native minnows in lakes. (A) Map shows lakes designated by number of Maine-native minnow species. (B) Regional variation in the proportion of native minnows in lake fish assemblages.
Box plots show the number of native minnow species per lake expressed as percent of the each lake's total fish species. Regions are shown in Figure 6.4.4. Golden shiner was excluded from minnow species totals because, although it is native to Maine, it has been introduced to many waters throughout the state.

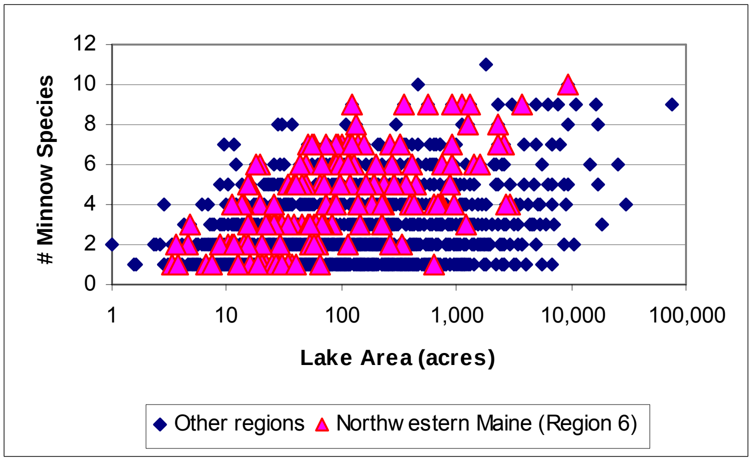


Figure 6.4.9: Species – lake area relationship for native lake minnows, with Northwest Maine (Region 6) lakes highlighted.
See Figure 6.4.4 for location of regions.

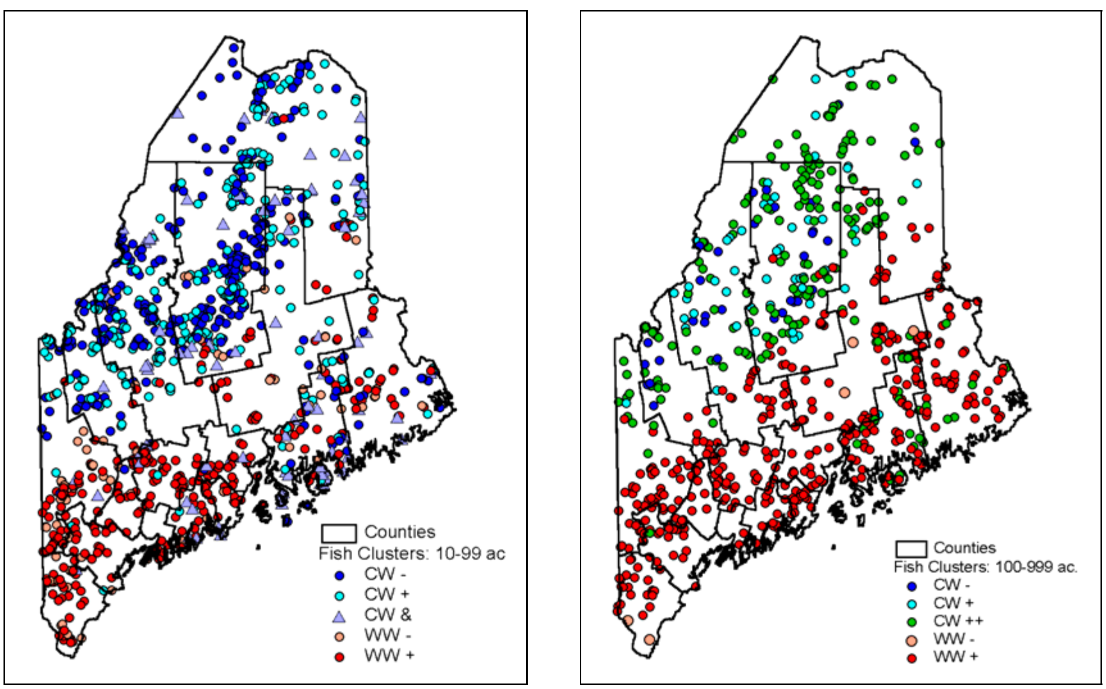


Figure 6.4.10: Spatial distribution of lake fish assemblage groups identified by agglomerative cluster analysis, for two size classes of lakes.
See text for more information about cluster derivation and composition. Fish data source: MDIFW.

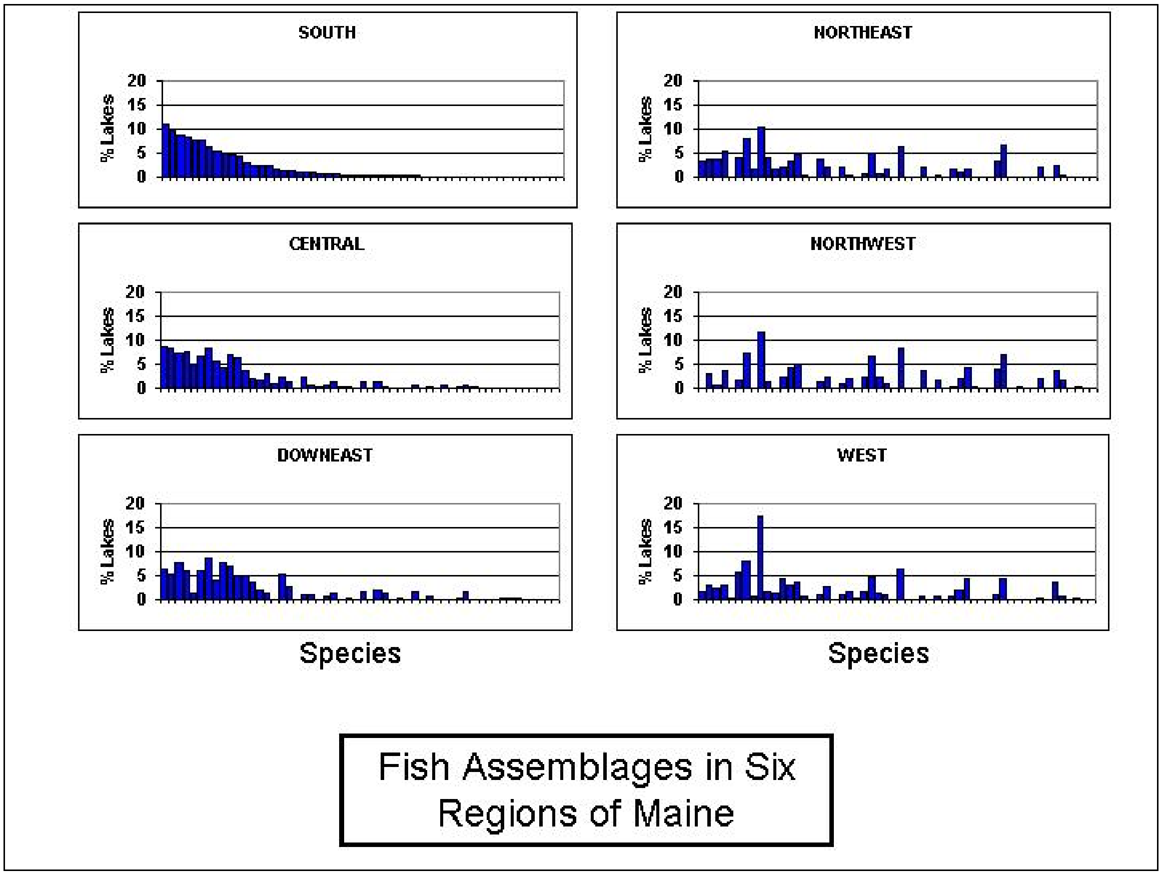
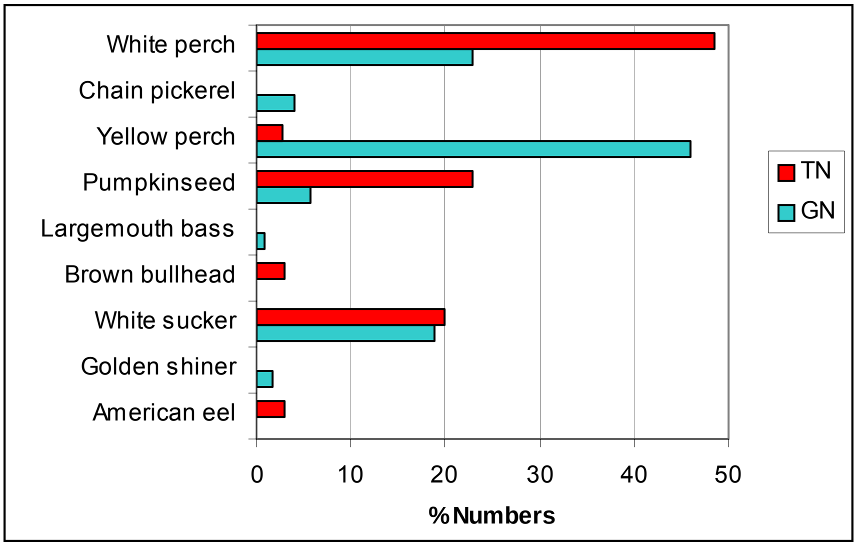
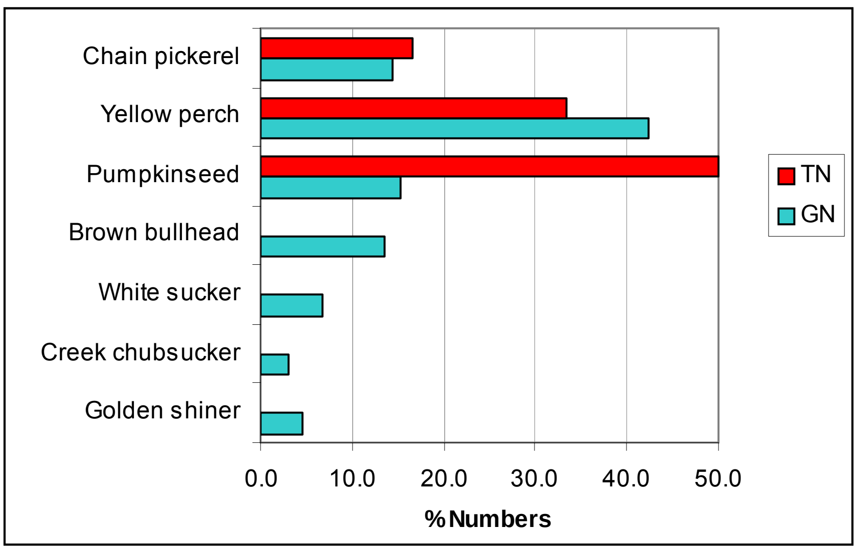


Figure 6.4.11: Overview of frequency of occurrence of lake fish species in six regions of Maine.
Frequency of occurrence is shown as the % of regional lakes in which a species is found. Each column in the graphs represents a species. Species are ordered by the frequency of occurrence in southern Maine; the order in which species are displayed remains constant in all six panels.

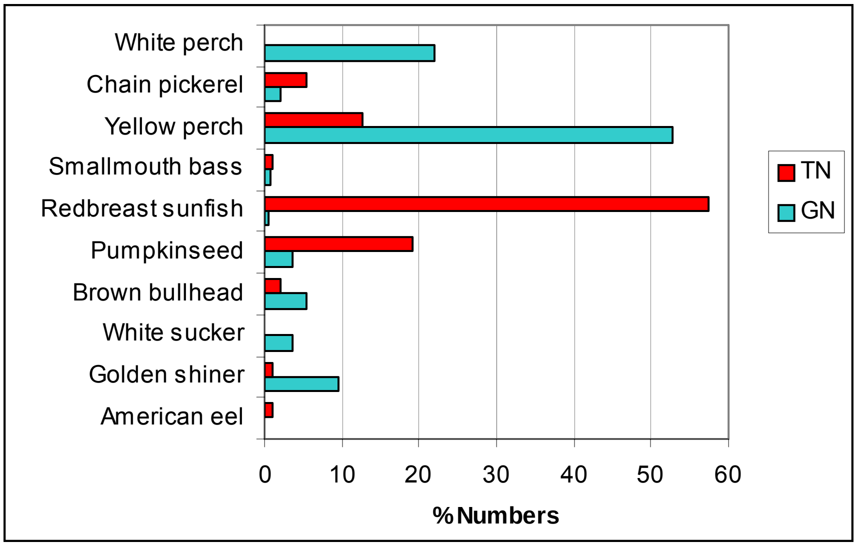


Collins Pond. Windham. 43 acres.

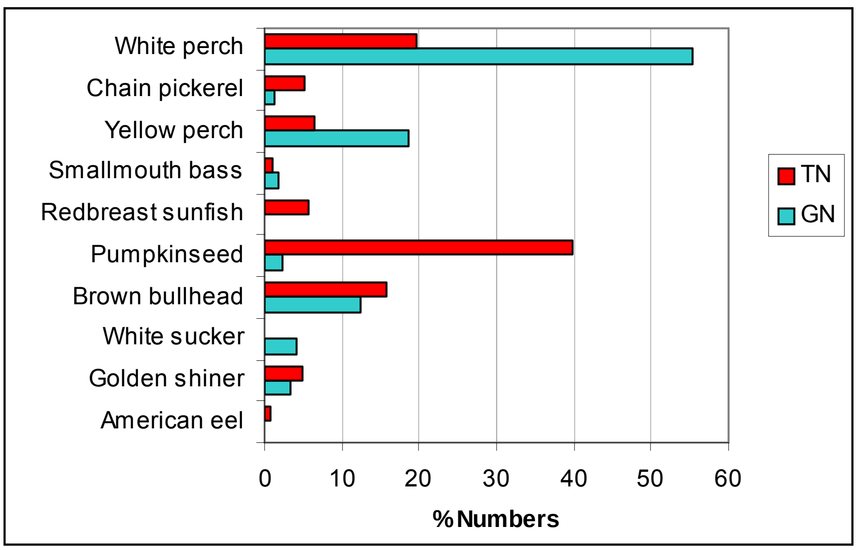


Little Papoose Pond. Albany Twp. 20 acres.

Figure 6.4.12 (A): Composition and relative abundance of fish species in two southern Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.

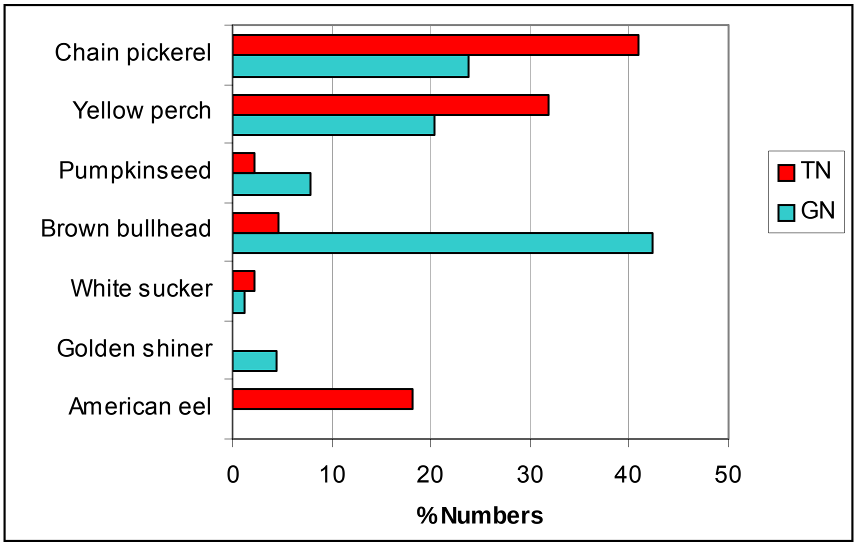


Barker Pond. Cornville. 110 acres. Central.

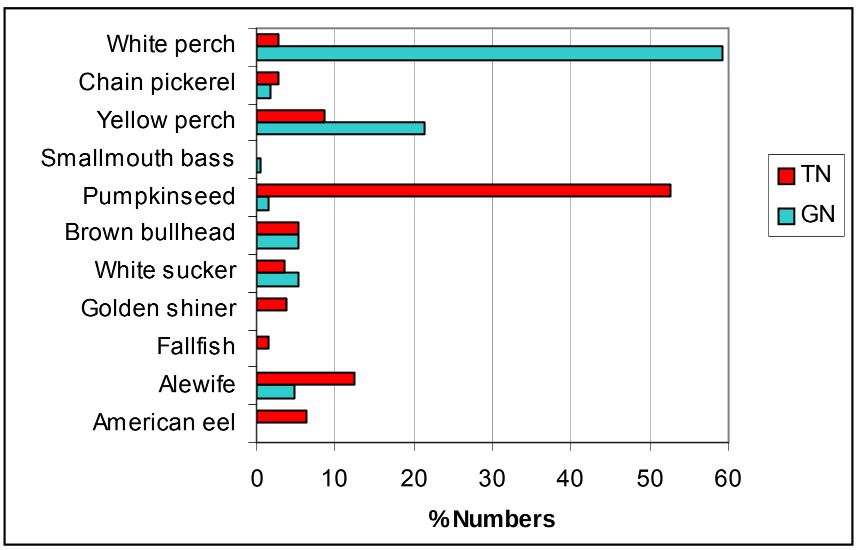


Mattanawcook Pond. Lincoln. 830 acres. Central.

Figure 6.4.12 (B): Composition and relative abundance of fish species in two central Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.

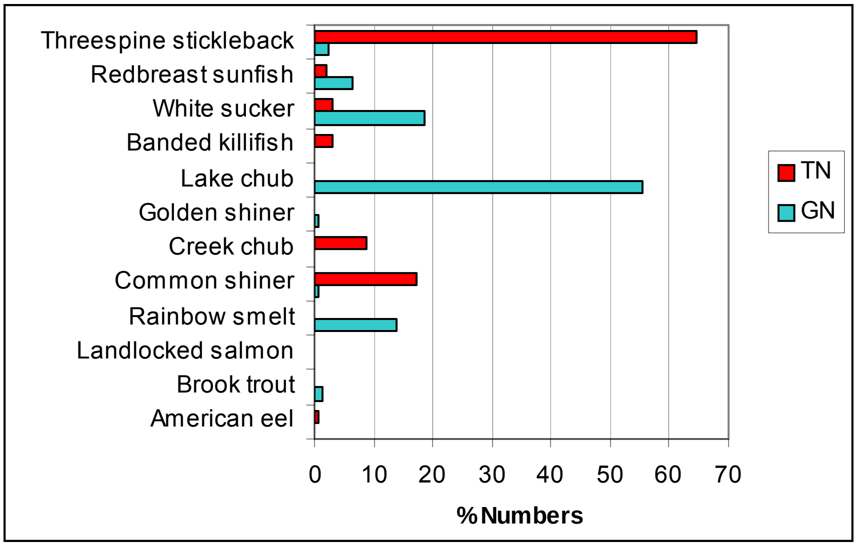


Cranberry Pond. Baring. 43 acres.

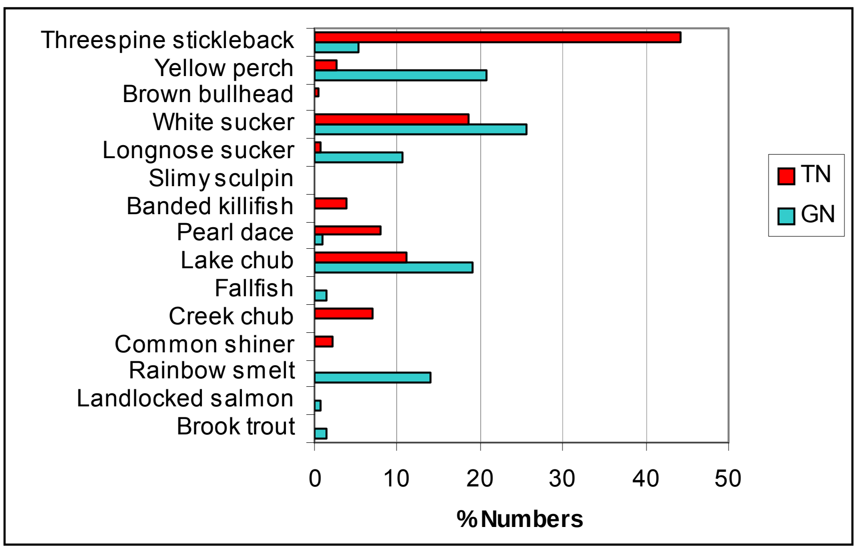


Fourth Machias Lake. T42 MD BPP. 1,913 acres.

Figure 6.4.12 (C): Composition and relative abundance of fish species in two downeast Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.

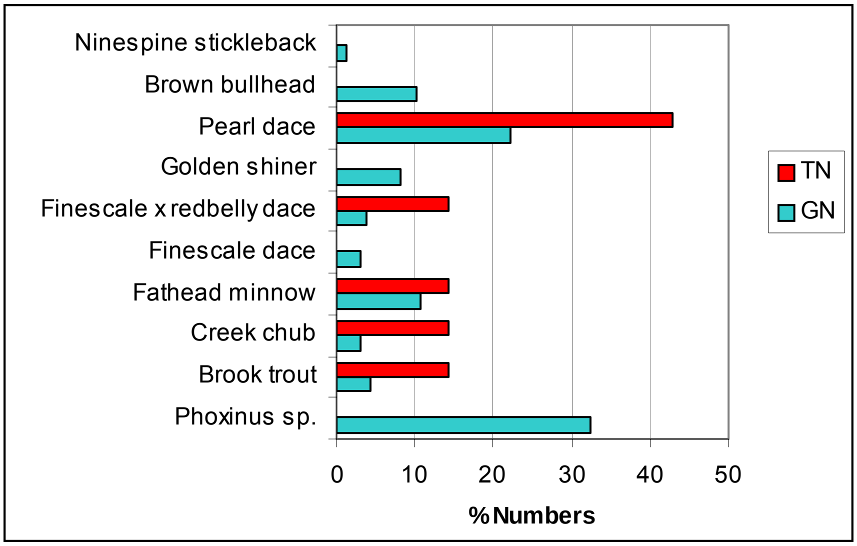


Upper Shin Pond. Mount Chase. 589 acres.

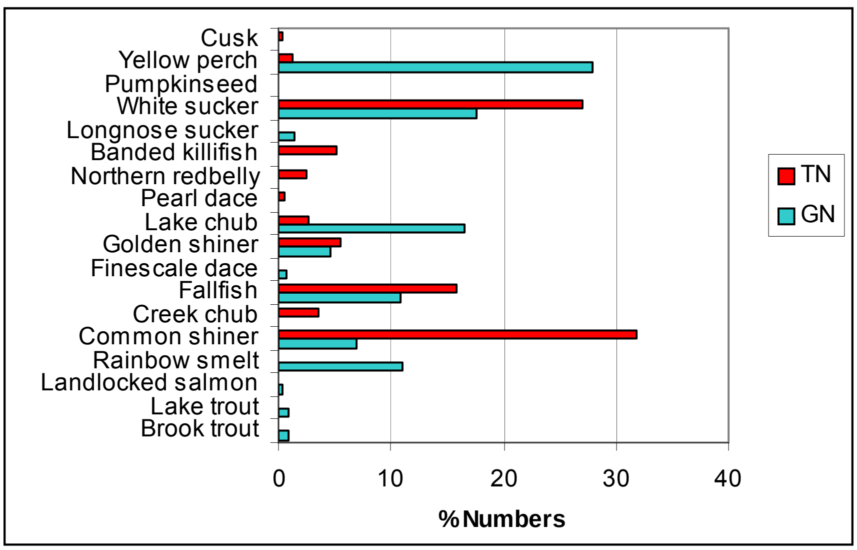


Square Lake. T16 R5. 8,090 acres.

Figure 6.4.12 (D): Composition and relative abundance of fish species in two northeastern Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.

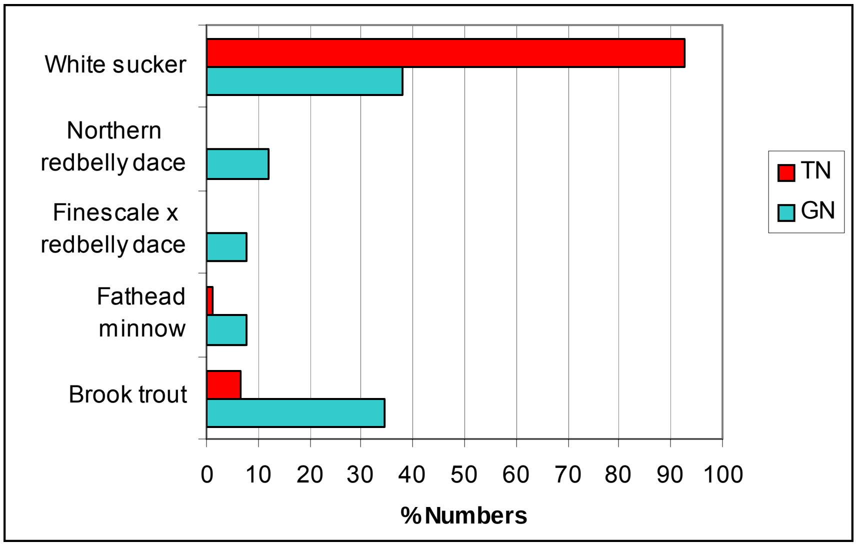


Midnight Pond. T6 R12. 77 acres.

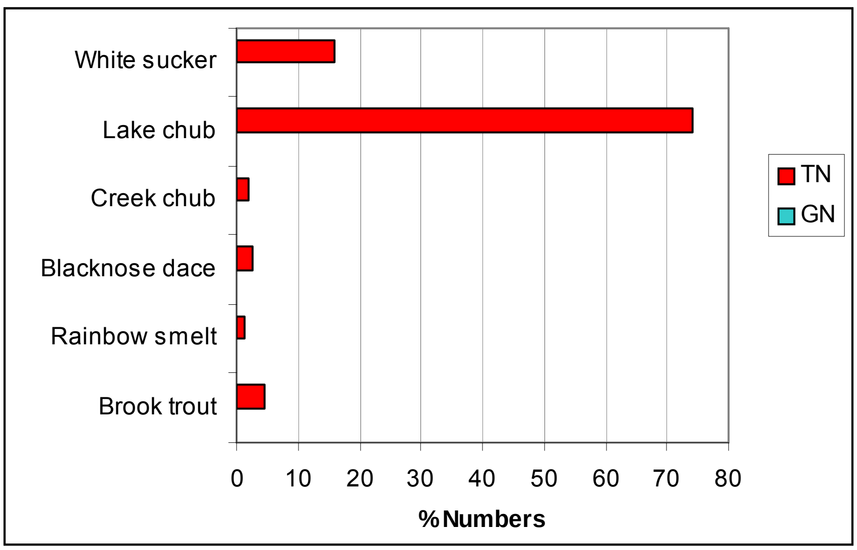


Long Pond. Dole Brook Twp. 67 acres.

Figure 6.4.12 (E): Composition and relative abundance of fish species in two western Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.



Little Reed Pond. T8 R10. 25 acres.



Big Reed Pond. T8 R10. 96 acres. (Gillnets not set at this lake)

Figure 6.4.12 (F): Composition and relative abundance of fish species in two northwestern Maine lakes sampled by EMAP.
Data are separated by gear type: TN = trap net; GN = gill net. Data are % of total individuals captured by gear type.

Fisheries Management: Much of the management-associated fisheries data available from Maine was external to the scope of MABP; for example, growth rates, length-weight data, population size estimates, etc. However, species management targets and, especially, stocking history are two issues which are relevant to MABP since they impact overall patterns of biodiversity in the state.

Principle fisheries are defined by MDIFW as those which provide a significant fishery for the lake in question. Twelve species (including the hybrid splake) provide significant fisheries in Maine. By far the most common fishery is for brook trout (Table 6.4.7). Most of the important brook trout lakes are in western Maine, although a number also occur in southern and central regions of the state. The next most common significant fisheries are for chain pickerel, white perch and smallmouth bass, all three of which are concentrated in south, central and, to a lesser extent, Downeast regions. Least common significant fisheries are for lake whitefish, cusk and black crappie.

Stocking has been a feature of fisheries in Maine for well over 100 years. Stocking data prior to the 1930s is relatively sparse. However, an excellent electronic record of authorized stocking (by MDIFW) exists for the period starting in 1937. The number of waterbodies stocked per year has progressively increased since the 1930s (Figure 6.4.13). Most stocking is of coolwater species; no authorized stocking of warmwater species has occurred since the 1970s. As previously discussed, however, illegal stocking of warmwater species continues to occur today. A majority of lakes >1000 acres have been stocked with one or more species since 1990 (Table 6.4.8). In this size class, stocking has been most common in south, central and Downeast regions, and least common in the west and northwest. Approximately one quarter to one half of lakes in the 100-999 acre size class have been stocked during this same period, with the highest rates again occurring in southern and central regions. In the 10-99 acre size class, the percent of stocked lakes ranges from a high of 23% in the south to a low of 12% in the northeast.

Stocking records can also be summarized by township (Table 6.4.9 and Figure 6.4.14). During the years 2000-2003, brook trout was lake-stocked in 15-55 towns per county and stream-stocked in up to 70 towns per county. Brown trout is the one other species for which lake stocking and stream stocking occurred in generally similar numbers of townships. Lake trout, splake, rainbow trout and salmon were all stocked primarily or exclusively in lakes (Table 6.4.9). Brown trout and rainbow trout are stocked almost exclusively in southern and central regions; brook trout stocking also tends to be concentrated in southern Maine (Figure 6.4.14). In contrast, landlocked salmon and splake are stocked across much of the state, but in many fewer townships. Table 6.4.10 summarizes the total numbers of fish stocked in lakes and streams in the period between 1995 and 2003.

One further aspect of fisheries management is directly relevant to biodiversity issues: lake reclamation. Reclamation is carried to remove unwanted species and/or cause a significant change in the targeted management species. According to MDIFW records, 138 lakes have been reclaimed once or more since 1939 (Figure 6.4.15). Reclamation was most frequently used as a management tool prior to 1970 – in recent years, <10 lakes have been reclaimed. When a lake is reclaimed it is generally stocked with one or more gamefish species; other species gradually re-colonize the lake from the surrounding watershed. When the species richness of lakes reclaimed prior to 1980 is compared to that of non-reclaimed lakes, there is no significant difference (Figure 6.4.16). For lakes reclaimed since 1980, there is some evidence that these have a lower species richness than would otherwise be expected from their size. Such a trend would be clearly expected since shortly after reclamation, species numbers by definition are reduced (although not necessarily to zero). There is very little data available on whether the species that re-colonize a lake are the same ones that were there prior to reclamation, although it is likely that this type of information exists in MDIFW hardcopy files for some lakes. Davis (1958) documented four species as being present in Echo Lake (Mount Desert Island) the year following reclamation.

Table 6.4.7: Principle fisheries in Maine lakes, by region.
Data are number of lakes in which the species has been designated by MDIFW as providing a significant fishery. Total number of lakes in this data set = 1870. Numbers in parentheses after species names represent total number of significant lake fisheries across the state.

Species	Region [1]					
	South	Central	Downeast	Northeast	West	Northwest
Brook trout (1132)	73	66	98	106	625	164
Brown trout (139	31	68	28	2	10	--
Lake trout (115)	4	12	15	2	57	25
Splake (52)	7	11	7	3	20	4
Landlocked salmon (175)	15	17	38	14	69	22
Lake whitefish (15)	1	--	3	--	6	5
Chain pickerel (656)	177	272	115	40	52	--
Smallmouth bass (410)	93	180	89	17	31	--
Largemouth bass (321)	134	151	22	--	14	--
Black crappie (34)	14	20	--	--	--	--
White perch (441)	60	206	112	18	45	--
Cusk (29)	7	6	--	3	8	5

[1] See Figure 2.3 or 6.4.4 for map showing regions. Data source: MDIFW.

Table 6.4.8: Percent of lakes that have been stocked by MDIFW during the period 1990-2003.
Stocking was with one or more species, in one or more years. Regions are shown in Figure 2.3.

Region	Area Class (acres)	Total Lakes	% Stocked		Region	Area Class (acres)	Total Lakes	% Stocked
South	< 1	70	1		Northeast	< 1	85	2
South	1-9	296	5		Northeast	1-9	266	2
South	10-99	206	23		Northeast	10-99	192	12
South	100-999	77	58		Northeast	100-999	54	31
South	1,000+	10	90		Northeast	1,000+	15	80
Central	< 1	159	0		West	< 1	330	0
Central	1-9	460	1		West	1-9	990	4
Central	10-99	341	18		West	10-99	621	20
Central	100-999	169	47		West	100-999	210	40
Central	1,000+	42	79		West	1,000+	54	56
Downeast	< 1	110	0		Northwest	< 1	67	0
Downeast	1-9	318	6		Northwest	1-9	198	1
Downeast	10-99	271	22		Northwest	10-99	176	13
Downeast	100-999	136	39		Northwest	100-999	56	27
Downeast	1,000+	39	74		Northwest	1,000+	13	62

Data source: MDIFW

Table 6.4.9: Fish stocking (2000-2003) by county, species and waterbody type.
Data are % towns in county in which stocking occurred in lakes/ponds and rivers/streams. Note that these data indicate presence/absence of stocking by town/county -- not the number of waterbodies stocked per jurisdiction.

County	Species													
	BKT		**LKT**		**SPL**		**RBT**		**LLS**		**BRN**		**LWF**	
	*L **	*S **	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*
AND	47	40	7	--	7	--	7	--	13	13	40	60	--	--
ARO	15	2	4	--	3	--	4	--	7	--	2	--	1	--
CUM	43	61	14	--	7	--	14	--	--	--	29	50	29	11
FRA	55	10	10	--	6	--	10	--	12	--	6	10	--	--
HAN	36	4	--	--	11	--	--	--	30	--	28	--	--	--
KEN	42	19	13	--	13	--	13	--	10	6	52	10	--	--
KNO	29	--	--	--	--	--	--	--	--	--	33	19	--	--
LIN	24	--	10	--	5	--	10	--	5	--	33	5	--	--
OXF	48	32	2	--	16	--	2	--	23	4	27	34	--	--
PEN	19	8	4	--	2	--	4	--	10	--	--	--	--	--
PIS	34	9	5	--	18	--	5	--	12	1	1	1	3	--
SAG	17	--	--	--	--	--	--	--	--	--	8	--	--	--
SOM	36	9	1	--	8	--	1	--	12	4	6	4	--	--
WAL	30	4	--	--	4	--	--	--	7	--	19	4	--	--
WAS	28	5	--	--	10	--	--	--	27	2	6	--	--	--
YOR	53	70	7	--	--	--	7	--	7	3	20	50	--	--

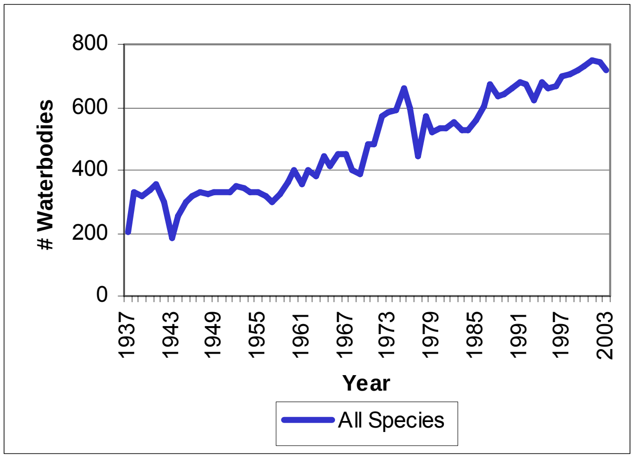
Species codes: BKT (Brook trout); LKT (Lake trout); SPL (Splake); RBT (Rainbow trout); LLS (Landlocked salmon); BRN (Brown trout); LWF (Lake whitefish).
* L = lakes/ponds S = rivers/streams. Data source: MDIFW.

Table 6.4.10: Number of fish stocked in lakes and rivers between 1995 and 2003.

Species	**# Fish Stocked (1000's)** [1]	
	Lakes	**Streams/Rivers**
Landlocked salmon	1,069	187
Brook trout	4,775	1,344
Brown trout	726	1,310
Lake trout	240	--
Splake	703	--
Rainbow trout	34	30
Lake whitefish	14	--

[1] Total numbers stocked during the 8-year period. Data source: MDIFW.

(A)



(B)

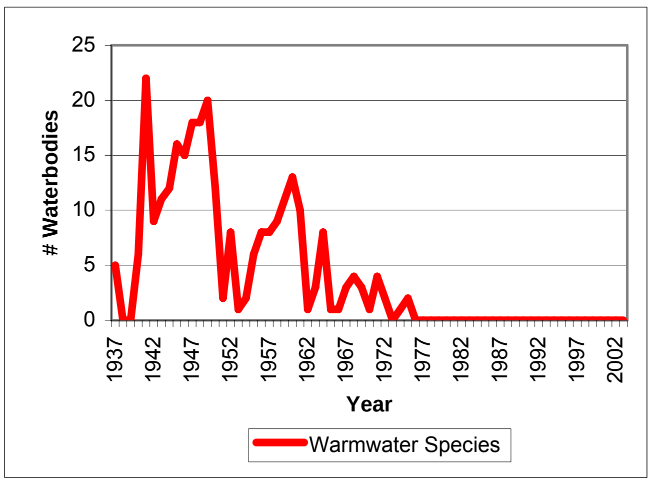


Figure 6.4.13: Number of lakes and streams stocked by MDIFW, 1937-2003: (A) all fish species, (B) smallmouth/largemouth bass.
Waterbodies were counted by MIDAS code (for both lakes and streams). Under this system, the main stem of a river is assigned one code, with each tributary having a distinct code. Thus the number of stream waterbodies includes both large river segments and shorter tributaries, with each counting once toward the total number. Note difference in y-axis scale in the two panels. See Figure 6.4.14 for summary of recent stocking records by township. Data source: MDIFW.

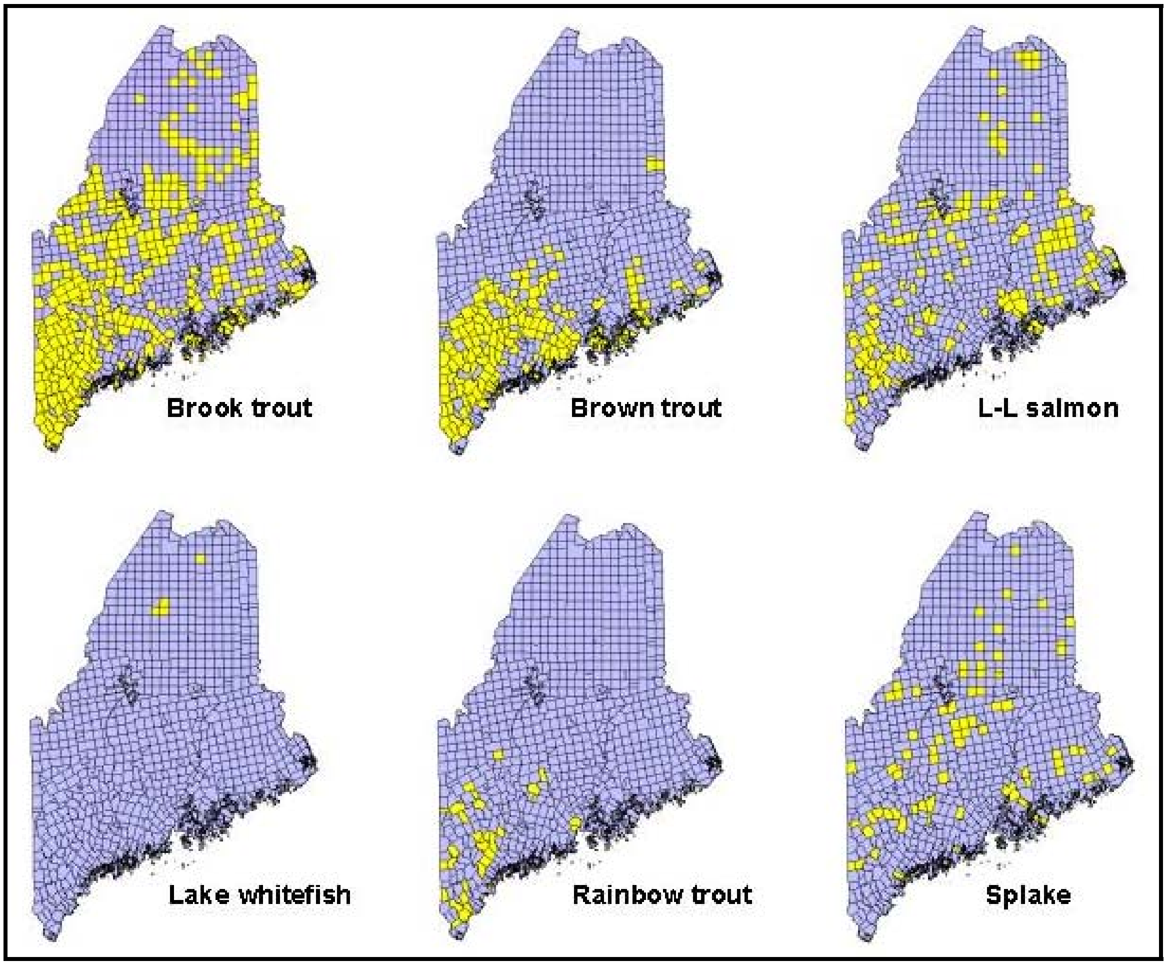


Figure 6.4.14: Townships in which six fish species were stocked between 2000 and 2003. Stocked towns are shown in yellow. Data include both lake and stream stocking, and township refers to point of stocking. Number of years in which stocking occurred varies by town and by species. Data source: MDIFW.

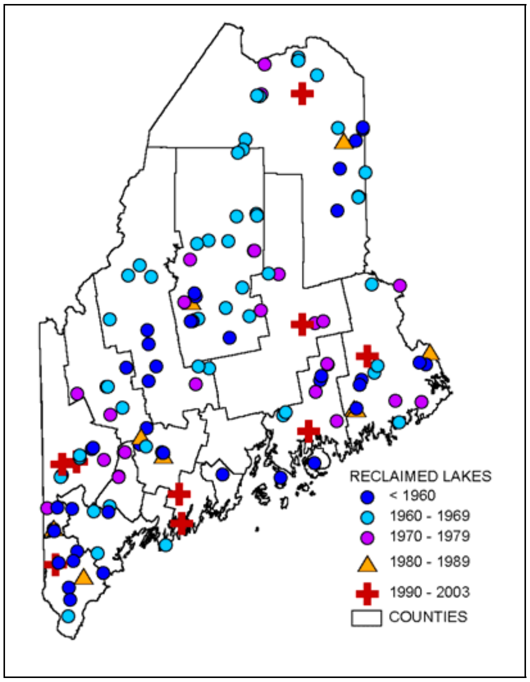


Figure 6.4.15: Location of lakes reclaimed by MDIFW (for fisheries purposes). Lakes are shown by decade of the most recent reclamation. Data source: MDIFW.

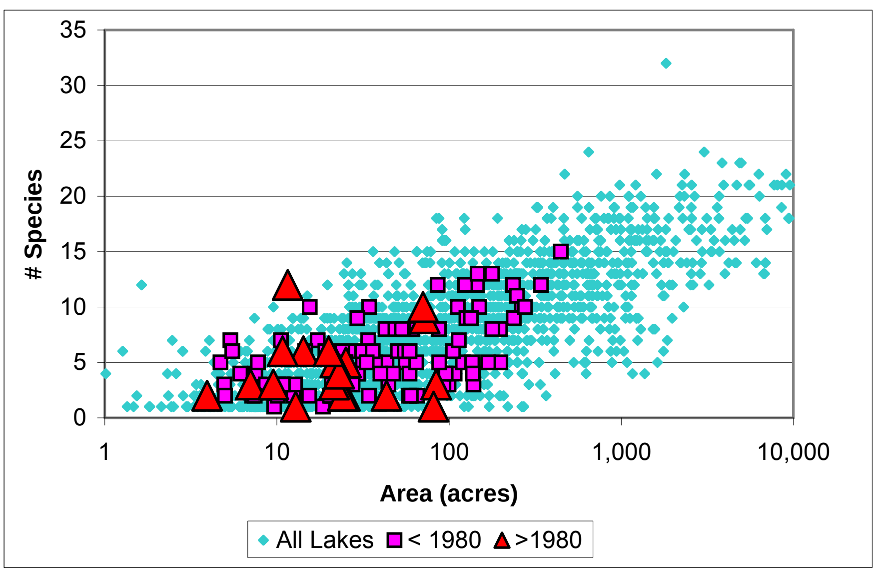


Figure 6.4.16: Fish species richness in reclaimed lakes as a function of lake area, compared to all lakes statewide.

Trends Through Time: We discuss here four sources of historical and time series data: (i) a sixty-year comparison of lake assemblages; (ii) apparent changes in the fish assemblages of Mount Desert Island; (iii) brook trout biomass in streams; and (iv) returns of sea-run Atlantic salmon to Maine rivers. Other time series data exist in MDIFW files, including population size and structure estimates for selected gamefish species (F. Bonney, MDIFW, pers. comm.) These management-focused data were not accessed by MABP[20]. A history of fish introductions to selected lakes is provided in Chapter 4.

Lake fish assemblages – a 60-year comparison: Between 1938 and 1944, Cooper and colleagues surveyed 205 lakes (Figure 5.4), most of which were in southern and central regions of the state (Cooper 1939, 1940, 1941, 1942; Cooper and Fuller 1945; Fuller and Cooper 1946). Because these surveys had a gamefish focus, it is unlikely that they succeeded in documenting the full complement of species in many of the lakes. Nevertheless, these data do provide an excellent source of information against which to compare current fish assemblages (Table 6.4.11). The greatest change over this period is in the occurrence of largemouth bass, which today is found in over six times as many lakes as was the case 60 years ago. By comparison, smallmouth bass records increased by only 30% - this presumably reflects, in part, the earlier onset of smallmouth bass introductions in Maine. Other species that appear to be substantially more widespread today include brown trout (290% increase), white sucker (91%), pumpkinseed and redbreast sunfishes (45% and 68%, respectively) and cusk (54%). While it is difficult to know if differences in minnow occurrence reflect real changes or simply inadequate sampling in Cooper surveys, it does appear that golden shiner, creek chub and fallfish are more widespread today – this would also be expected as a result of bait-bucket introductions. Yellow perch, which is known to have been introduced into a number of Maine lakes (Chapter 4), is today found in 8% more of the Cooper lakes than was the case sixty years ago. The white perch, another species known to have been widely introduced around the state, is today found in 17% more lakes than documented by Cooper et al. Apart from alewives, which Cooper et al. did not document at all, the northern pike is the most notable species recorded today that was absent in the 1930s and 1940s (Table 6.4.11).

Fishes of Mount Desert Island: Based on early and contemporary surveys, Moring et al. (2001) compiled a list of 28 species considered to be currently present on Mount Desert Island (MDI; Table 6.4.12 – note that this list includes two euryhaline species). Just under half of these species were considered by Moring et al. (2001) to be native to the island. Furthermore, half of the 28 species had not been recorded from the island in collections made prior to 1946 (Table 6.4.12). While earlier sampling may have overlooked a number of these taxa, it appears certain that there has been a significant increase in the number of species on MDI since the middle of the last century.

Brook trout biomass: The MDIFW brook trout monitoring program generates data on both fish assemblage structure and estimated brook trout biomass in unstocked, relatively pristine, streams. Temporal changes in fish species richness were described during the discussion of sampling effort issues in Chapter 5 (Table 5.8). Annual variation in estimated trout biomass is illustrated in Figure 6.4.17 for seven sites with the longest sampling history. Between 1990 and 2002, biomass varied by a factor of three at five of the seven sites, and was somewhat less variable at the remaining two sites. There is no concordance among sites in the trends through time in population size. There were also no obvious geographic patterns in the extent or pattern of temporal variation. MDIFW biologists are currently using these data to investigate possible climatic and/or hydrologic signals associated with trout population size (M. Gallagher, MDIFW, pers. comm.).

[20] In addition, earlier versions of lake inventory data (fish species lists) are available in hardcopy format in MDIFW files and would be available to track apparent changes in fish assemblages, given investment of sufficient resources – this task was not attempted during MABP.

Atlantic salmon returns: During the period 1991-2002, estimated total returns of (adult) Atlantic salmon to the eight rivers included in the Distinct Population Segment (see Figure 3.5) decreased from about 300 individuals to less than 50 (Figure 6.4.18A). Over a 30-year period in the Narraguagus River, documented returns were highest in the late 1960s and mid-1970s, but considerably lower in the other years (Figure 6.4.18B). Returns have increased in 2003 and 2004 (ASC, unpublished data).

Table 6.4.11: A sixty-year comparison of fish assemblages in selected Maine lakes. Data are number of lakes (population = 205 lakes) in which species was recorded. Population of lakes in this analysis are the 205 lakes surveyed by Cooper et al. between 1938 and 1944. Most of the lakes are in southern and central Maine. The 2004 data are from the MDIFW lake inventory. "—" indicates that the species was not recorded by Cooper et al.

Species	1939-44	2004		Species	1939-44	2004
Sea lamprey	--	5		Rudd	--	1
American eel	170	177		Creek chub	9	24
Alewife, landlocked	--	13		Fallfish	45	65
Alewife, searun	--	39		Banded killifish	57	79
Lake whitefish	4	5		Slimy sculpin	4	19
Rainbow trout	--	2		Longnose sucker	6	6
Round whitefish	1	2		White sucker	94	180
Landlocked salmon	62	70		Creek chubsucker	--	2
Brown trout	25	98		Brown bullhead	147	168
Arctic char	2	2		Redbreast sunfish	31	52
Brook trout	113	126		Pumpkinseed	110	160
Splake	--	13		Smallmouth bass	115	151
Lake trout	20	39		Largemouth bass	16	110
Rainbow smelt	105	137		Black crappie	--	14
Lake chub	7	12		Yellow perch	155	168
Common shiner	23	50		Walleye	1	1
Pearl dace	4	6		Northern pike	--	12
Golden shiner	71	130		Chain pickerel	159	167
Emerald shiner	--	3		White perch	126	147
Bridled shiner	3	4		Fourspine stickleback	1	6
Blacknose shiner	3	3		Brook stickleback	--	1
Northern redbelly dace	11	18		Threespine stickleback	7	16
Finescale dace	3	6		Ninespine stickleback	3	11
Fathead minnow	3	3		Cusk	13	20
Blacknose dace	7	18				
Rudd	--	1				

Table 11.4.12: Synopsis of native vs. current fish species on Mount Desert Island. All species listed are currently present on MDI. Native status on MDI was determined by Moring et al. (2001).

Species	**Native to MDI?**	**Recorded Prior to 1946?** [1]
American eel	Yes	Yes
Alewife	Yes	Yes
Common shiner	No	No
Golden shiner	Yes	Yes
Bridle shiner	No	No
Blacknose shiner	No	No
Northern redbelly dace	Yes	No
Creek chub	No	No
Fallfish	No	No
White sucker	Yes	Yes
Brown bullhead	No	No
Chain pickerel	No	Yes
Rainbow smelt	Yes	Yes
Landlocked salmon	No	Yes
Brown trout	No	No
Brook trout	Yes	Yes
Lake trout	No	No
Banded killifish	Yes	Yes
Mummichog [2]	Yes	Yes
Atlantic silverside [2]	Yes	No
Fourspine stickleback	Yes	No
Threespine stickleback	Yes	Yes
Ninespine stickleback	Yes	Yes
White perch	Yes	No
Redbreast sunfish	?	No
Pumpkinseed	Yes	Yes
Smallmouth bass	No	Yes
Yellow perch	No	No

[1] Recorded in one or more of the following surveys: U.S. Commission of Fish and Fisheries (1884); Batchelder (1927); Procter (1933); Fuller and Cooper (1946); Bishop and Clarke (1923).

[2] Found in lower, freshwater segments of some coastal brooks.
Data source: Moring et al. 2001.

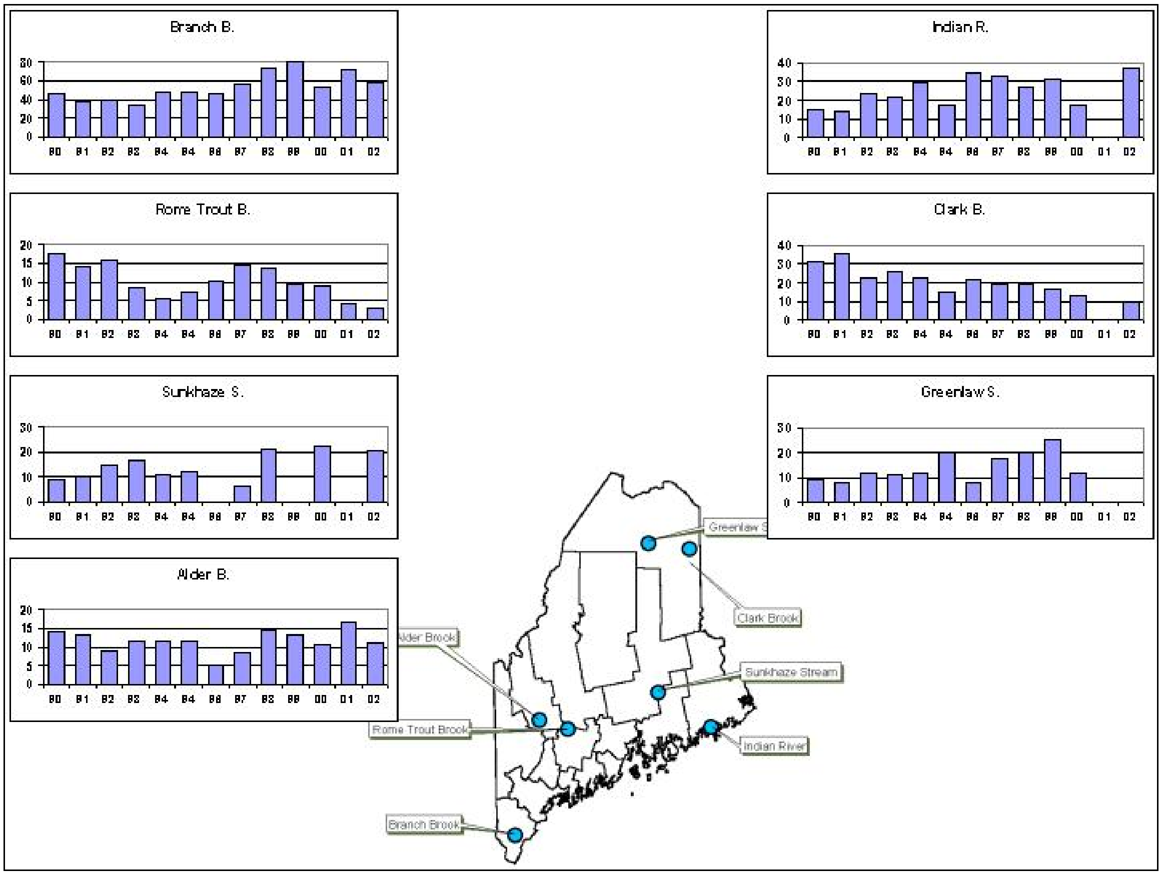
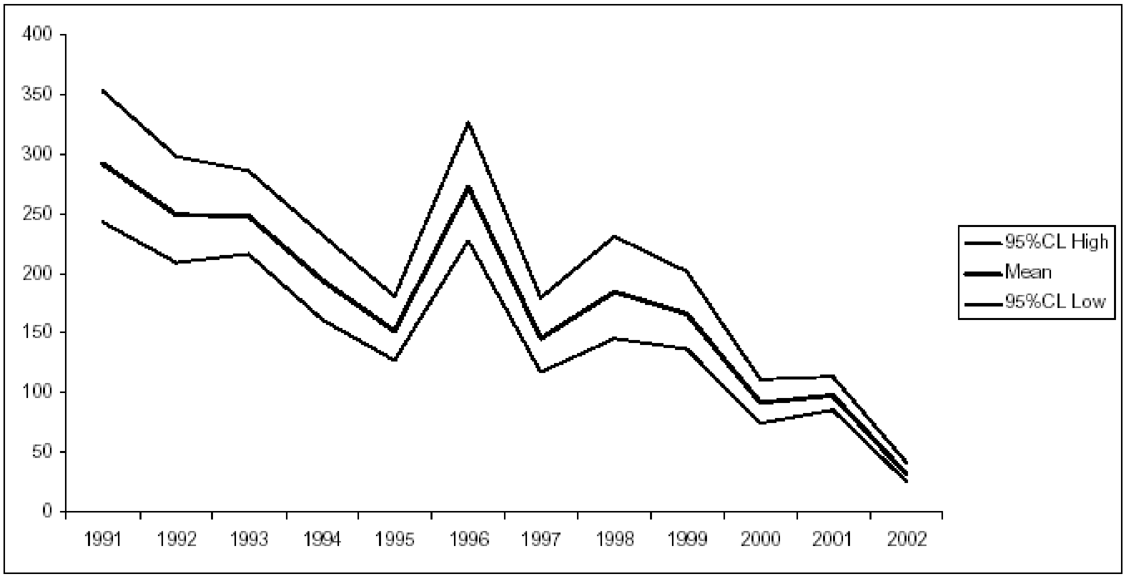


Figure 6.4.17. Brook trout biomass at sites with long-term data records (1990-2002). Biomass data are in kg/hectare. Sampling sites are indicated on map. Data source: MDIFW.

All rivers in Distinct Population Segment



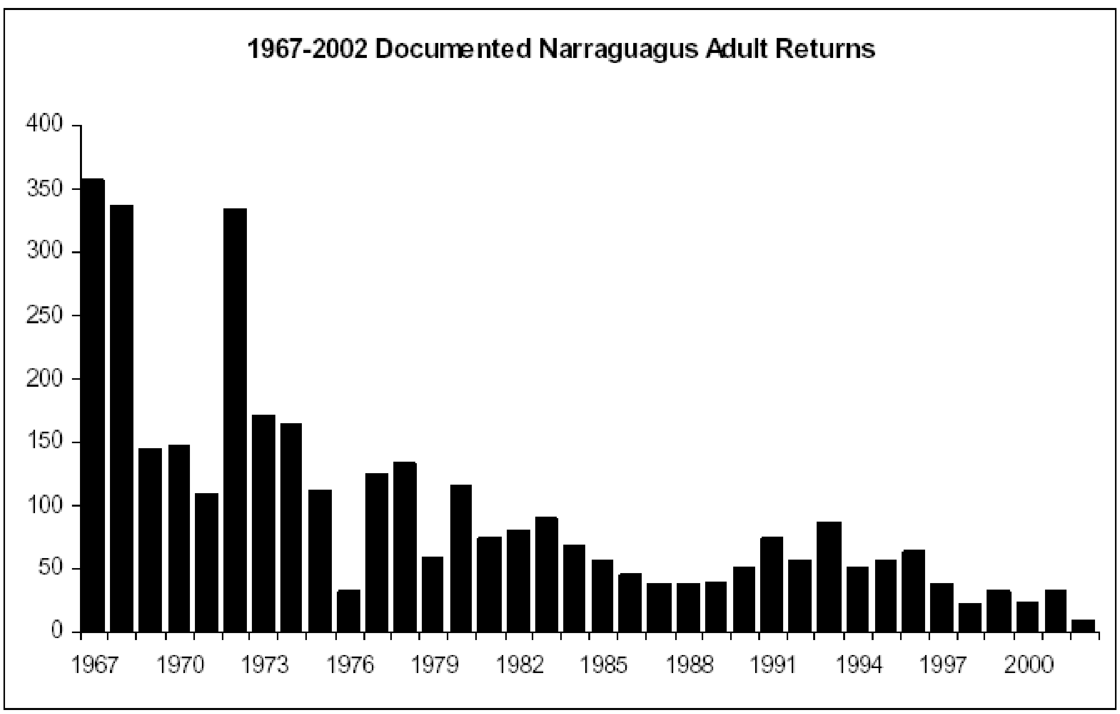


Figure 6.4.18: Upper panel: Estimated returns of adult Atlantic salmon to rivers of the Distinct Population Segment, 1991-2002. Lower panel: Documented returns of adult Atlantic salmon to the Narraguagus River, 1967-2002.
(Figures from NMFS/USFWS 2004.)