MACRO – INVERTEBRATES

The following sections (6.5-6.9) focus on macro-invertebrate diversity in Maine. The following list* provides an overview of freshwater invertebrate groups and indicates which ones are covered in this report.

A. Protozoa	Unicellular organisms
B. Porifera	**Sponges**
C. Cnidaria (=coelenterates)	Hydras and **jellyfish**
D. Turbellaria & Nemertea	Flatworms
E. Gastrotricha	Microscopic forms, in sediments, etc.
F. Rotifera	Important planktonic group
G. Nematoda & Nematophora	Round worms, often microscopic
H. Tardigrada	"Water bears" – microscopic
I. Bryozoans	**Colonial "moss animals"**
J. Mollusca	**Bivalves: Mussels and clams**
	Gastropods: Snails
K. Annelida	**Oligochaetes: worms**
	Leeches
	Branchiobdellidans: crayfish worms
	Polychaetes: few freshwater taxa
L. Arthropoda	**Water mites**
	Insects & Collembola
	Aquatic orders:
	Mayflies (Ephemeroptera)
	Damselflies & dragonflies (Odonata)
	Stoneflies (Plecoptera)
	Caddisflies (Trichoptera)
	Megaloptera (fishflies & alderflies)
	Partially aquatic orders:
	True bugs (Hemiptera / Heteroptera)
	Spongillaflies (Neuroptera)
	Aquatic caterpillars (Lepidoptera)
	Beetles (Coleoptera)
	Flies and midges (Diptera)
	Springtails (Collembola)
M. Crustacea	**Amphipods and isopods**
	Ostracods – mussel and seed shrimps
	Cladocerans – mainly planktonic
	Copepods – mainly planktonic
	Crayfish and shrimps (Decapoda)

* Based on Thorp and Covich (1991). **Groups in boldface** are covered in this report; the others are not. Note that the order in which they appear in this report does not fully follow the order in the above list

6.5 MOLLUSCS

6.5.1 Freshwater Mussels

Mussels are one of two groups of native bivalue molluscs in North America, belonging to the superfamily Unionacea. They are a high-profile element of freshwater biodiversity in North America. In part this is due to the fact that this region contains the greatest diversity of freshwater mussels on earth – roughly one third of all known species. Another reason why mussels have such high conservation value is that they are one of the most endangered faunal groups in the world. Seventy five percent of North American species are listed as being endangered, threatened or of special concern in all or parts of their range (Williams et al. 1992). The number of species believed to have become extinct in North America over the past 100+ years is about 10% of the current number of extant species (Bogan 1993). Pollution and dams are two major threats to freshwater mussels throughout North America. Mussels are also notable for their unusual life histories in which the larval forms (glochidia) parasitisize a vertebrate host (generally fish). In a number of species, elaborate structures and mechanisms have evolved to promote successful contact between glochidia and fish.

Information Sources: Most data on freshwater mussels come from the MDIFW statewide survey conducted between 1992 and 1997, supplemented with more recent records. MABP reviewed/revised coordinates for collection sites that were provided by MDIFW, and also assigned waterbody/watershed codes. Martin (1997b) provides an excellent synopsis of the history of mussel collecting in Maine, as well as a county-level compilation of species records from the literature and museum collections.

Species Diversity, Distribution & Status: Ten of the approximately 300 North American species are found in Maine. Two of these are listed as threatened within the state (yellow lampmussel and tidewater mucket), while three are of special concern (Table 6.5.1). Maine's ten species belong to two families and eight genera. These taxa are part of a series of 16 species that make up the Northern Atlantic Slope group of freshwater mussels (Johnson 1970). Nedeau et al. (2000) provide an excellent review of the distribution, ecology, conservation status of Maine's freshwater mussel species. Only a brief synopsis of this information will be provided here.

Three species occur statewide: the triangle floater (*Alasmidonta undulata*), eastern elliptio (*Elliptio complanata*) and eastern floater (*Pyganodon cataracta*) (Figure 6.5.1). Of these three, the triangle floater is the least common, occurring in 68% of sampled HUC-10 watersheds (Table 6.5.1). The other two species occur in >80% of sampled watersheds. All three species are found in both lakes and streams. The eastern elliptio is found in a very broad range of habitats, ranging from tidal rivers and small streams to ponds and lakes. It is a tolerant species and often rapidly colonizes new habitats. The eastern floater also is a tolerant species and occurs in a wide variety of habitats, although it tends to prefer more quiet water. In lakes, it often occurs in deeper water where it can colonize silty substrates. The triangle floater is more frequently found in streams than in lakes. While widespread in Maine, populations of this species appear to be experiencing significant declines in the southern parts of its North American range (Nedeau et al. 2000); in Maine it is a species of special concern. Some authorities recognize three subspecies within the species *P. cataracta*: *P. cataracta cataracta*, *P. cataracta marginata* and *P. cataracta fragilis* (Turgeon et al. 1988, Stansbery 1996 as cited by Martin 1997). Hoeh and Burch (1989) suggest that these three subspecies should be elevated to the rank of species, a taxonomy that is employed by Williams et al. (1993). Martin (1997b) lists *P. cataracta marginata* as having been recorded from 12 Maine counties, and *P. cataracta cataracta* from 13 counties. However, the status of these two sub-species in Maine remains unresolved (see below, also).

Three species, while not occurring statewide, are relatively widespread in Maine: the eastern lampmussel (*Lampsilis radiate radiate*), eastern pearlshell (*Margaritifera margaritifera*) and the creeper (*Strophitus undulatus*). These three species have been collected from between a third and a half of sampled watersheds (Table 6.5.1). The eastern lampmussel is found with similar frequency in lake and stream habitats; it can tolerate a broad range of environmental conditions. However, it has not been recorded from the western and northern parts of the state (Figure 6.5.1) and is very rare in the southern and Downeast regions. Its distribution in the northeast suggests colonization of Maine occurred from the Acadian region following de-glaciation. The eastern pearlshell is almost exclusively a running-water species, and is typically found in cool water environments where it can withstand rapid water flows. It has not been collected from higher elevation areas in western Maine. The creeper is another species that is virtually always found in lotic (running water) environments (Table 6.5.1). It is absent from northern, southern and Downeast regions (Figure 6.5.1). It is rarely abundant and is listed as a species of special concern because of uncertainty about the long-term viability of its generally small populations.

The remaining four mussel species exhibit restricted distributions in Maine: the brook floater (*Alasmidonta varicosa*), alewife floater (*Anodonta implicata*), yellow lampmussel (*Lampsilis cariosa*) and tidewater mucket (*Leptodea ochracea*). These species occur in between roughly 10-20% of sampled watersheds (Table 6.5.1). The brook floater is found mainly in the central and Downeast regions of the state, where it inhabits lotic environments – streams to large rivers. This species has experienced significant declines in other parts of its range. Furthermore, there appears to be little recruitment in many of these populations. Maine has more populations of the brook floater than occur in the rest of the northeast (Nedeau et al. 2000); consequently, the Maine populations of this species represent a resource with a particularly high conservation value. The alewife floater is a coastal species, extending from the lower Androscoggin to extreme eastern Maine. As might be expected from its distribution, its host fish apparently are restricted to the anadromous alosids: alewife, blueback herring and American shad (Table 6.5.2). It is likely that the absence of the alewife floater from southern Maine is associated with loss of anadromous fish populations resulting from dam construction. The yellow lampmussel is one of two threatened mussel species in Maine. It is found in central and eastern parts of the state, exclusive of the Downeast region (Figure 6.5.1). In Maine, it occurs in both riverine and lake systems. It is listed as threatened in Maine because population densities are low and because this species has been declining in other parts of its range. Until 1999, it was thought to be extirpated from the Kennebec basin (Nedeau et al. 2000). The other threatened species is the tidewater mucket. Maine's rarest mussel species, it has been recorded from just 10% of sampled watersheds (Table 6.5.1). Its distribution is similar to that of the yellow lampmussel, although the tidewater mucket does not extend into the Mattawamkeag and St. Croix drainages. It appears to be more frequently found in lakes than in streams. Although there are some healthy populations, densities are frequently low and this species is declining in other parts of its range.

There are scattered reports from Maine of an eleventh mussel species: the Newfoundland floater (*Pyganodon fragilis*, or *P. cataracta fragilis*, depending on the taxonomic authority used) – indeed the MDIFW mussel database contains records of this taxon from four lakes, two in Aroostook county, and one each in Hancock and Franklin counties. This species is very similar to *P. cataracta* which is common in Maine and there is uncertainty as to whether the two are distinct species. Typical *P. fragilis* appears to be found in Newfoundland and Labrador (Hoeh 1990). Hanlon and Smith (1999) searched for Newfoundland floater in northern Maine at locations that included those from which historic collections had reported this species. From an examination of adult morphology these authors concluded that their collections of *Pygandon* did not differ significantly from *P. cataracta*. Furthermore, their re-examinations of historic museum specimens indicated that these had been previously misidentified as *P. fragilis*. Thus it appears that the Newfoundland floater has yet to be recorded from Maine.

Patterns of Species Richness: The lower Kennebec and Penobscot basins have the highest numbers of mussel species (Figure 6.5.2). The most depauperate regions of the state are the Upper St. John, western and extreme southern Maine. The lower number of species in

the south reflects, in part, the distribution gap in that region for two species that are found in central /eastern Maine and whose ranges extend both to the north (New Brunswick, Nova Scotia) and to the south (lower New England) (see, for example, Figure 9 in Nedeau et al. 2000). Sampling effort and watershed area partially influence documented species richness (Figures 5.14 and 5.15.). Nevertheless, it does appear that the species richness patterns in Figure 6.5.2 reflect real spatial gradients in mussel richness. At the HUC-10 watershed level, three watersheds have been documented with all ten of Maine's mussel species: Sebasticook, Passadumkeag and the lower Penobscot in the region of West Enfield. Nine species have been recorded from an additional five watersheds: St. George, Pleasant River (tributary to the Penobscot), the lower Penobscot / Pushaw Stream and the lower Kennebec (Figure 6.5.2B).

Table 6.5.1: Freshwater mussel species in Maine, with three measures of frequency of occurrence.

Family	Common Name	Scientific Name	% Watersheds (1)	% Lakes (1)	% Stream Sites (1)	Status (2)
Margaritiferidae	Eastern pearlshell	*Margaritifera margaritifera*	47	0.7	21.7	S
Unionidae	Triangle floater	*Alasmidonta undulata*	68	11.6	33.8	SC
Unionidae	Brook floater	*Alasmidonta varicosa*	18	0.2	17.7	SC
Unionidae	Alewife floater	*Anodonta implicata*	22	9.0	6.3	S
Unionidae	Eastern elliptio	*Elliptio complanata*	93	84.4	61.8	S
Unionidae	Yellow lampmussel	*Lampsilis cariosa*	13	5.7	8.3	T
Unionidae	Eastern lampmussel	*Lampsilis radiata radiata*	31	18.7	14.7	S
Unionidae	Tidewater mucket	*Leptodea ochracea*	10	6.4	3.7	T
Unionidae	Eastern floater	*Pyganodon cataracta*	86	74.6	20.2	S
Unionidae	Creeper	*Strophitus undulatus*	30	0.2	23.7	SC

(1) Mussels have been collected from a total of: 165 watersheds (HUC-10), 422 lakes and 1,030 stream sites (stream site = location with distinct set of coordinates).
(2) S = stable; SC = special concern; T = threatened. Status nformation from Nedeau et al. 2000.
Data sources: Multiple, as compiled in MABP database. Majority of data are from MDIFW.

Table 6.5.2: Fish hosts for Maine mussel species.
Only those fish species occurring in Maine are included in this table.

MUSSEL SPECIES	FISH HOSTS
Eastern pearlshell	Atlantic salmon, landlocked salmon, brook trout, brown trout
Triangle floater	Common shiner, blacknose dace, longnose dace, pumpkinseed, fallfish, largemouth bass, slimy sculpin, white sucker
Brook floater	Longnose dace, blacknose dace, golden shiner, pumpkinseed, slimy sculpin, yellow perch
Creeper	Largemouth bass, creek chub, fathead minnow, bluegill, longnose dace, fallfish, golden shiner, common shiner, yellow perch, slimy sculpin, Atlantic salmon
Eastern floater	White sucker, pumpkinseed, bluegill, threespine stickleback, common carp
Alewife floater	Alewife, American shad *, blueback herring *
Eastern elliptio	Yellow perch, banded killifish, largemouth bass
Yellow lampmussel	Unknown
Eastern lampmussel	Yellow perch, largemouth bass, smallmouth bass, black crappie, pumpkinseed
Tidewater mucket	Unknown

* Suspected host. Data sources: Various, as compiled in Nedeau et al. 2000. See also Wick 2005.

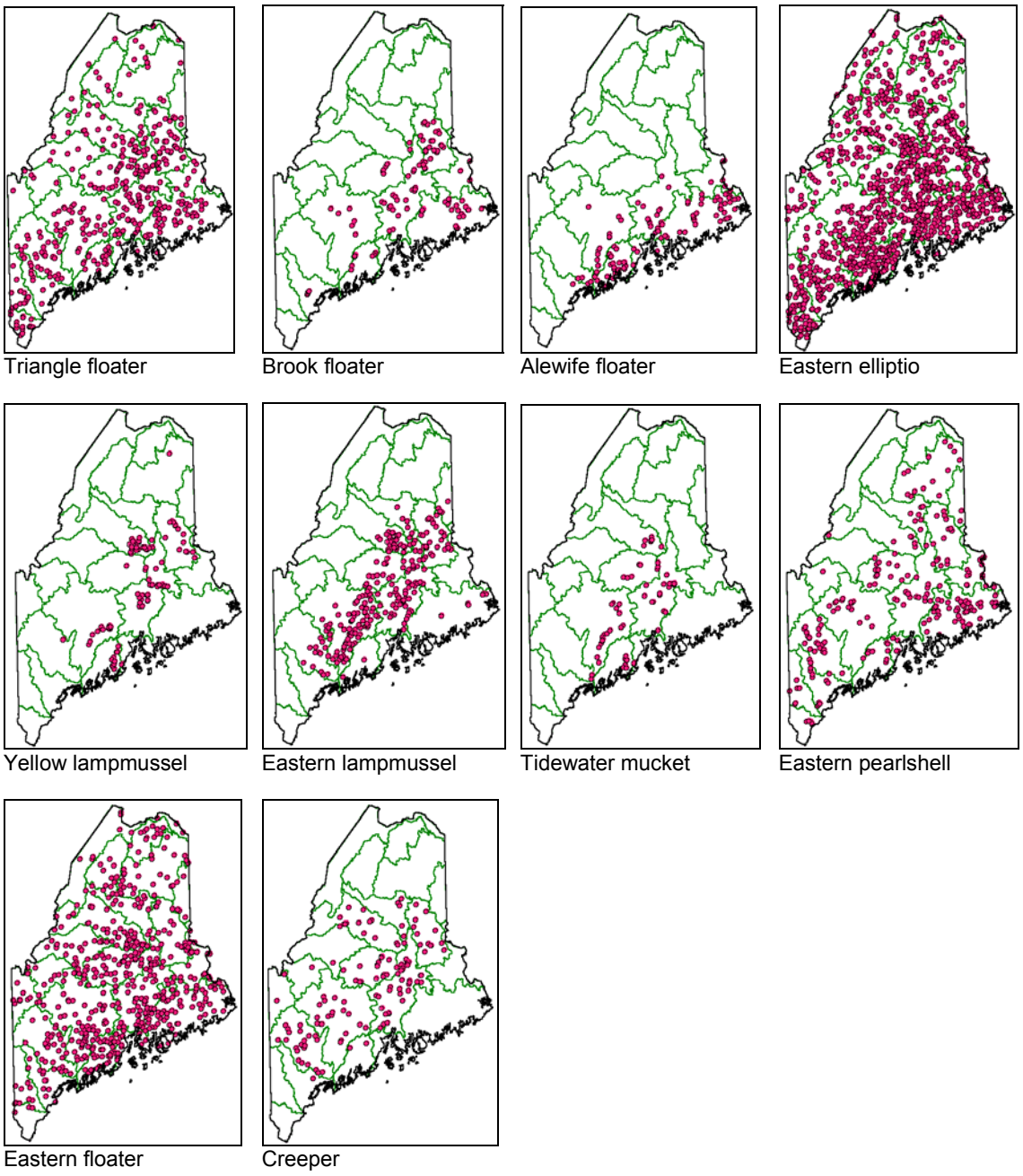
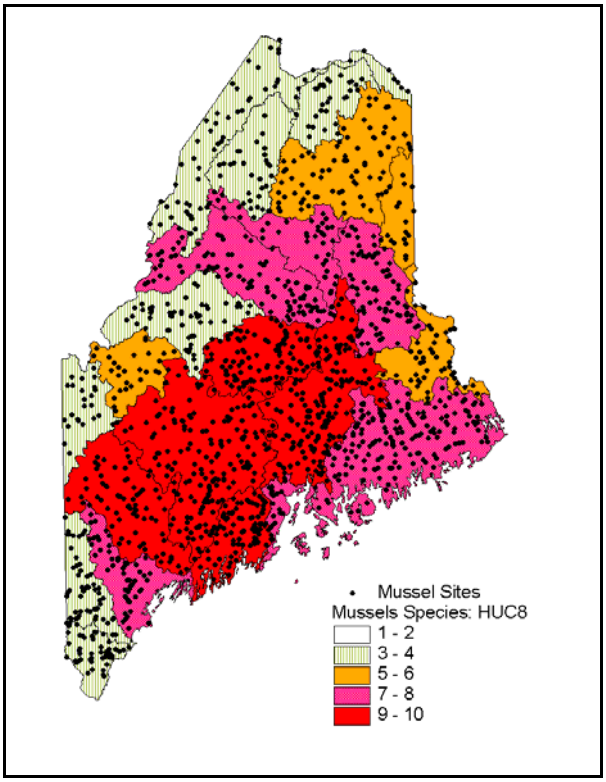


Figure 6.5.1: Distribution maps for Maine's freshwater mussel species.
Scientific names are provided in Table 6.5.1. Data sources: MDIFW and other records as compiled in MABP database.

(A)



(B)

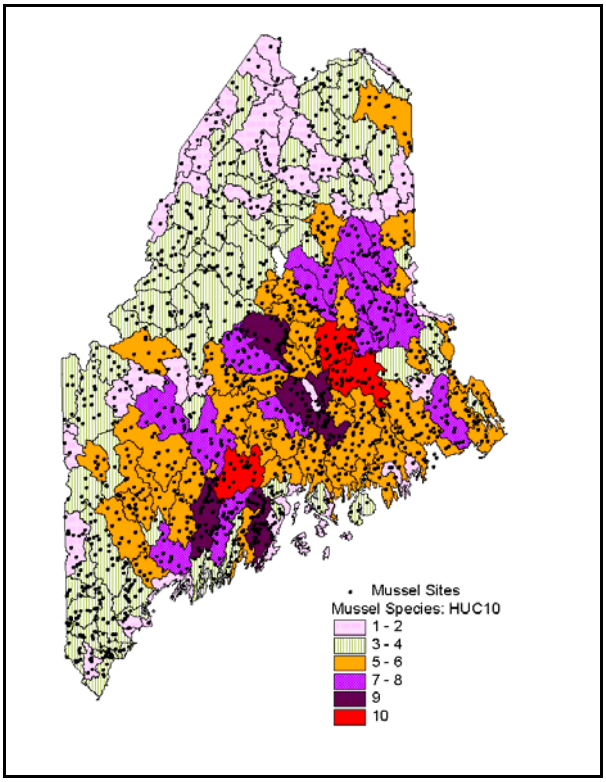


Figure 6.5.2: Mussel species richness at two watershed scales: (A) HUC-8, and (B) HUC-10. Sampling points are indicated by dots. Data sources: MDIFW and other data as compiled in MABP database.

6.5.2 Fingernail & Pea Clams

The other group of bivalve molluscs are the fingernail and pea clams (superfamily: Sphaeracea, family: Sphaeriidae). They are small, filter-feeding animals that are especially abundant in standing water – both permanent and temporary, although a few species are common in running water (Peckarsky et al. 1990). Sphaeriid distribution is influenced by sediment particle size and water depth; most species occur in circumneutral to moderately basic waters (see review in Martin 1998). Some species are useful indicators of lake trophic state, and organic and inorganic contaminants. Sphaerid clams are good dipersers – they clamp onto aquatic insects and waterfowl and some can survive passage through the alimentary tract of birds.

Information Sources: In general, very little is known about sphaerid clams in Maine. The primary source is the synthesis of Martin (1998) which includes an in-depth compilation of data from museum collections and literature sources. The species lists compiled by Martin are provided at the county level. Additional data come from MDEP and a few other sources, as compiled in the MABP database. While most of these records are spatially referenced to point locations, a majority of the taxon data are at the level of genus or higher – 81% in the case of 442 Sphaeriidae records from the MDEP stream biomonitoring database.

Species Diversity & Status: Martin's (1998) compilation includes 26 species of fingernail and pea clams (Table 6.5.3; Appendix 11.4, 11.5 B) – four species each in the genera *Sphaerium* and *Musculium* (fingernail clams) and 18 species in the genus *Pisidium* (peaclams). The MDEP stream sampling records include 11 of these species (and no additional species). Some of these MDEP records add new county-level records to the list of Martin (as shown in Table 6.5.3). The county-level species totals largely reflect sampling effort (e.g. where the early conchologists lived and collected) rather than actual species richness. The high number of peaclams recorded from Aroostook county, for example, result from Olof Olsson Nylander's extensive collections from northern Maine during the late 19th and early 20th centuries.

Based on the point-location data of MDEP, the most common species appears to be *M. securis*, which corroborates historical accounts of its being the most frequently collected taxon (Martin 1998). Most of the other ten species collected (and identified) by MDEP were recorded from less than eight sites statewide. Along with *P. casertanum*, *M. securis* also appears to be the most widely distributed species in Maine (Table 6.5.3). From the existing data record, it is impossible to reliably identify which species of fingernail and pea clams are rare in Maine. All of the Maine sphaerids that are included in the NatureServe database are listed at G5 (demonstrably widespread and secure). It is also likely that future collections will reveal additional species. For example, Martin (1998) suggests that *S. occidentale* is a likely candidate for Maine, in view of its known regional distribution. Also, Kircheis (cited in Gawler et al. 1996) reportedly discovered a new Maine sphaerid record: *Sphaerium transversum*.

Table 6.5.3: Number of fingernail and pea clams (Sphaeriidae) documented in Maine. Data represent combined records from Martin's (1998) compilation and MDEP stream biomonitoring data. Martin totals are shown in parentheses.

County	Number of Species by Superfamily / Genus		
	Sphaeriinae (fingernail clams)		**Pisidiinae (pea clams)**
	Sphaerium	*Musculium*	*Pisidium*
Androscoggin	--	1 (--)	1 (--)
Aroostook	3 (3)	2 (2)	16 (16)
Cumberland	1 (1)	3 (3)	5 (4)
Franklin	--	1 (1)	2 (1)
Hancock	--	--	1 (1)
Kennebec	1 (1)	1 (--)	4 (3)
Knox	1 (1)	3 (3)	8 (8)
Lincoln	--	2 (1)	5 (5)
Oxford	2 (1)	3 (2)	3 (3)
Penobscot	1 (--)	1 (--)	5 (4)
Piscataquis	--	1 (--)	2 (1)
Sagadahoc	--	--	--
Somerset	1 (1)	1 (1)	--
Waldo	--	1 (1)	7 (7)
Washington	--	2 (--)	3 (2)
York	2 (2)	2 (2)	8 (7)
STATE	4 (4)	4 (4)	17 (17) *

* *P. insigne* has been reported from the state, but no location provided (see Martin 1998). Thus, the state total of *Pisidium* species is probably 18.

6.5.3 Snails

There are two broad groups of freshwater snails (gastropod molluscs): the gill-breathing prosobranchs and the lung-breathing pulmonates [20]. The former are thought to be derived from marine ancestors, whereas the latter evolved from land snails (Peckarsky et al. 1990). Freshwater snails are generally herbivores or detritivores. A number of species, including some Maine species, are hosts to parasites that impose significant economic impacts on humans. Aquatic snails have been used as monitors of acidification, as well as lake trophic state.

Information Sources: There is relatively little systematic survey information available to document distributions and frequency of occurrence of freshwater snails in Maine. Martin (1999) nevertheless provides an excellent review of these molluscs, including a history of collecting and a species list compiled from literature sources and museum records. His species list is summarized at the county level. The only other substantial source of information is MDEP stream biomonitoring database which has contributed an additional 13 species to the list of Martin (1999). The MDEP data are also spatially referenced to precise sampling sites.

Species Diversity & Status: A total of 57 freshwater snail species (in 23 genera) have been recorded from Maine, (Table 6.5.4; one further species has been recorded from the state, but without county locale). Of Martin's (1999) list of 44 species with county-level records, 18 also appear in the MDEP database. However, the latter includes an additional 13 species that do not appear in Martin's list. Fifteen species are prosobranchs and the remaining 42 species are pulmonates. The Lymnaeidae is the most species-rich family in Maine with 16 species. Globally, the region of greatest diversity within this family is the northern United States and central Canada (Martin 1999). The Planorbiidae ("rams-horn" snails) is the next most diverse family in the state, with 12 species. The other five families have seven or fewer representatives in Maine. Appendix 11.4 provides the list of snail species recorded from Maine, including distributions by county.

Aroostook County has the highest documented number of species (68% of the state total), likely in large part because of (a) its size, and (b) the relatively high collection effort in this region, and, perhaps, (c) the concentration of calcium rich soils in the eastern part of the county. Fifteen of the state's 57 species have been recorded from just one county, 23 have been recorded from between two and four counties, and 16 species have been recorded from between five and ten counties. Three species have been recorded from most (14-16) counties.

All but three of the Maine species that are included in the NatureServe database have a status of G5 (widespread and secure). One species (*Amnicola decisa*) is listed as critically imperiled globally. In Maine, this species is listed by Martin (1999) as being present in Cumberland county, but its distribution and status there is unknown. The only other locale identified for this species is Pennsylvania. Two other imperiled / vulnerable species globally are *Stagnicola mighelsi* and *S. oronoensis*. Martin (1999) lists these two species as present in three and four Maine counties, respectively, but again their detailed distributions are unknown. *S. mighelsi* is apparently only found in Maine, while *S. oronensis* has also been recorded from Ontario and Quebec (NatureServe data). None of these three species appear in the MDEP records.

It is clear from the foregoing discussion that, while snails are a common component of freshwater systems in Maine, we currently know little about their distribution and relatively little about their habitat requirements. Additional survey effort is very much needed.

[20] Some pulmonates have developed external gills or internal gill-like structures that enable them to remain submerged indefinitely.

Table 6.5.4: Freshwater snails documented in Maine, by family and county.

County	# Species Documented in Maine, by family						
	Prosobranchs			Pulmonates			
	Vivparidae	Valvatidae	Hydrobiidae	Lymnaeidae	Physidae	Planorbiidae	Ancylidae
AND	1	1	1	3	2	1	2
ARO	1	4	2	13	6	9	4
CUM	1	2	4	7	3	7	2
FRA	1				1		
HAN	1		1	1		3	
KEN	3		3	4	3	3	2
KNO	1	3	1	9	4	6	1
LIN	1		1	1	1	2	2
OXF	2		1	4	2	6	2
PEN	1	2	5	7	5	7	4
PIS	1		1	1	1	2	2
SAG	1	1	1	1			
SOM	1	1	1	2		2	
WAL	1	1	1	6	3	7	
WAS	1		2		1	5	
YOR	1		3	4	4	4	1
State	**4**	**4**	**7**	**16**	**7**	**12**	**7**

Data sources: Martin (1999) – a compilation of literature and museum records – and MDEP stream biomonitoring data, as compiled in MABP database. Not included in these totals is *Physella magnalacustris* (family: Physidae) which has been recorded from Maine, but without county locale (Martin 1999).

6.6 CRUSTACEANS

6.6.1 *Crayfish*

Crayfish belong to the group of crustaceans known as decapods (subclass Malacostraca), a group that is primarily marine. The decapods are the best known of the freshwater crustaceans. Crayfish inhabit a broad range of environments where they are typically omnivorous. Adult males occur in two forms (within the Cambarinae – the sub-family to which all Maine crayfish belong): Form I and Form II. The former are the breeding males, whereas the latter are instars that immediately precede reproduction and are difficult to distinguish from juveniles. For an excellent review of crayfish biology, ecology and collection history, see Martin (1997a). Crayfish have been important bait for Maine's inland fisheries and attempts have been made in the past to introduce crayfish to lakes as a forage supplement. It is likely that these introductions expanded the distribution of some species (Reid and Scott, 1996).

Information Sources: Crocker (1979) summarized collection records for ten New England crayfish species and included dot distribution maps for each species. Martin (1997a) provides an excellent synthesis of crayfish information for Maine, including a county-level distribution list for the seven species known at that time to be present in the state. M. Scott and W. Reid have made extensive crayfish collections from around the state and have provided their data to MABP, which were geo-referenced and incorporated into the MABP database. Much of their data is unpublished (although see Reid 1970, 1971, 1977; Reid and Scott 1996) and new records continue to be added to the MABP database. The species distribution maps shown below are based on the Scott and Reid data – some of which correspond to historic collections (e.g. some of those included in Crocker 1979[21]), together with data from MDEP's stream biomonitoring program.

Species Diversity, Distribution and Status: There are currently eight (possibly nine, see below) crayfish species in Maine (Table 6.6.1). These species belong to three genera, and all are within the family Cambaridae. One species, the Appalachian brook crayfish (*Cambarus bartonii bartonii*), occurs primarily in northern Maine, with a few records also deriving from the western mountains (Figure 6.6.1). One species occurs statewide, the virile crayfish (*Orconectes virilis*). The remaining crayfish species have been recorded only from the south, central and Downeast regions of the state. Distributions of the calico crayfish (*Orconectes immunis*), obscure crayfish (*O. obscurus*) and rusty crayfish (*O. rusticus*) are largely overlap each other in southern Maine. All these three species have been recorded with similar frequency. The white river crayfish (*Procambarus acutus acutus*) is currently restricted to Downeast Maine and probably arrived there via the bait trade. The red swamp crayfish (*P. clarkii*) is another recent introduction with, as yet, a very restricted distribution.

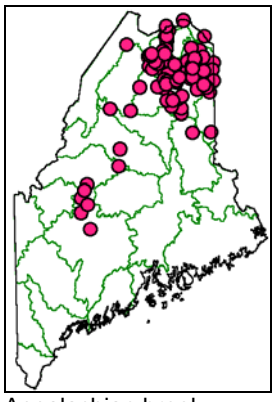
One additional species appears in the MDEP stream biomonitoring database: the northern clearwater crayfish (*O. propinquus*) – a single record from south-central Maine dating from 1987. This record has not been subsequently verified. Johnson (1939) reported stocking this species in a lake tributary. The stocking was considered unsuccessful and the identify of the crayfish cannot be verified.

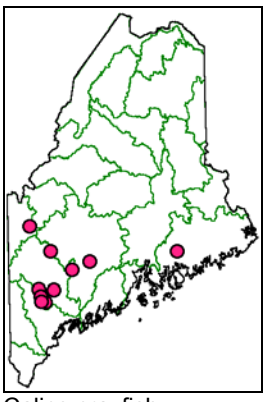
Of the 96 lakes with crayfish data, 83 have just one species. Twelve lakes have 2 species, with eight different species pairings. The two species most commonly participating in 2-species lakes are the rusty and virile crayfishes. One lake (Webb Pond, Hancock county) has three crayfish species (spinycheek, calico and white river crayfishes).

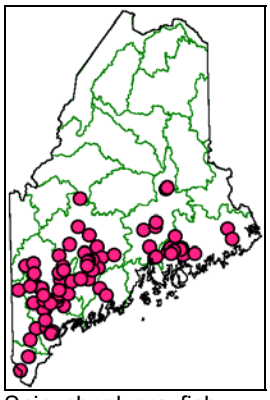
[21] The records shown on Crocker's (1979) distribution maps could not be incorporated into the MABP database because of inadequate resolution in those hardcopy figures. However, some of Scott's and Reid's data appear to represent collections that are in the Crocker publication (M. Scott, pers. comm.).

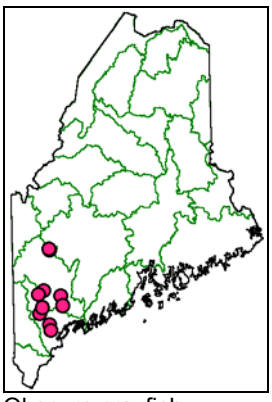
Table 6.6.1: Annotated list of crayfish species recorded from Maine.
Native/introduced status is taken from Reid and Scott (1996). Habitat notes based primarily on Martin (1997). Distribution notes based on MABP-compiled data depicted in Figure 6.6.1.

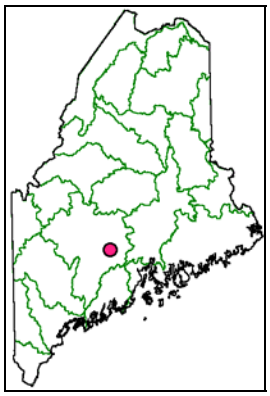
Scientific Name	Common Name	Comments
Cambarus bartonii bartonii	Appalachian brook crayfish	Native. Primarily northern distribution in Maine. Appears to prefer cool, rocky bottomed streams, but is also found in littoral areas of lakes and ponds.
Orconectes limosus	Spinycheek crayfish	Native. South / central distribution in Maine. Prefers slow-moving water and lakes, with silt substrate.
Orconectes virilis	Virile crayfish	Native. Statewide. Prefers stream and lake habitats with rocky bottoms. Is also found in deep waters.
Orconectes immunis	Calico crayfish	Probably native, although may be introduced via bait (Martin 1997). Southern Maine distribution. Prefers stagnant water, with heavy plant growth. Herbivorous.
Orconectes obscurus	Obscure crayfish	Introduced. Southern Maine distribution. Prefers rocky streams and lake shores.
Orconectes rusticus	Rusty crayfish	Introduced. Southern Maine distribution. Inhabits a broad range of lotic and lentic environments. Can negatively impact the aquatic environment for other species, including fish, via reductions in aquatic vegetation.
Procambarus acutus acutus	White river crayfish	Introduced. Native range is the Atlantic coastal plain northward to Massachussets and the Mississippi basin. Distribution in Maine limited to the Downeast region; likely resulting from introduction by human(s).
Procambarus clarkii	Red swamp crayfish	Introduced. Recent new record for the state, probably introduced via the bait trade. Currently very limited distribution.

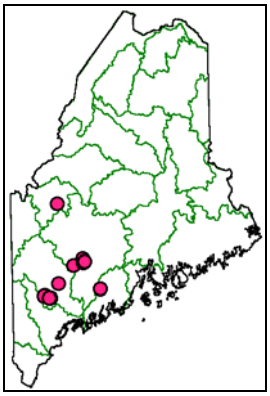

Appalachian brook crayfish

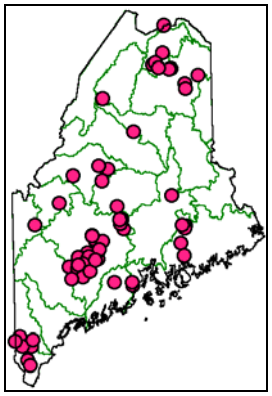

Calico crayfish

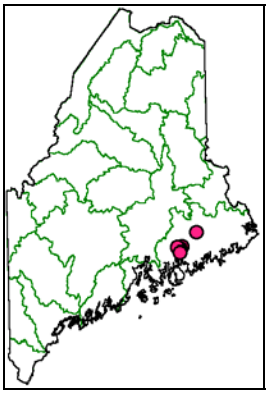

Spinycheek crayfish


Obscure crayfish


Red swamp crayfish


Rusty crayfish


Virile crayfish


White river crayfish


Northern clearwater crayfish
(identify unconfirmed – see text)

Figure 6.6.1: Distribution maps for Maine's crayfish.
See Table 6.6.1 for scientific names. Data are primarily from M. Scott and W. Reid (pers. comm.), supplemented with other sources as compiled in the MABP database. See Appendix 11.4 for full source list.
Maps can also be view on-line at:
http://www.pearl.maine.edu/windows/biodiversity/crayfish_maps.htm

6.6.2 *Other Crustacean Groups*

All other freshwater crustaceans in Maine are small. Amphipods and isopods are distant relatives of the crayfish (being in the same sub-class: Malacostraca). The MABP database has records for eight species (includes *Asellus* sp.) within these two groups (Table 6.6.2, Appendix 11.3). The sparse number of MABP records for these taxa (a total of 217 records) is indicative of the relatively small amount of survey effort focused on these groups. Nevertheless, the low documented diversity within both groups in Maine parallels the levels of diversity seen in the broader northeastern U.S. region (Table 3.2).

Virtually all of the isopod and amphipod records (in the MABP database) come from lower elevation areas of the state (Appendix 11.5.3). It is possible that this pattern reflects distribution of sampling effort, rather than actual species patterns. Nevertheless, the distribution of the relatively common amphipod, *Hyalella azteca*, suggests that this species is absent from higher elevation areas in Maine.

The isopod *Caecidotea* (=*Asellus*) *racovitzae racovitzae* was first recorded from Maine (Mount Desert Island) in the early 1970s, at which time the closest known population was in Lake Champlain (Andrews 1972). Today, it is known from 15 other sites in Maine as a result of MDEP's stream biomonitoring surveys.

The largest of the non-crayfish crustaceans is the opossum shrimp (Mysis relicta), a species that has been introduced to a number of large lakes in the northeastern U.S. in attempts to enhance the forage base for fish (Peckarsky et al. 1990). A few introductions have occurred in Maine, most notably Moosehead Lake in 1975 (Brown 1999) and, less "successfully", in Jordan Pond in the early 1970s – this latter introduction apparently did not "take" (Bowes et al. 1999).

Most freshwater crustacean species are microscopic forms. They include well-known planktonic groups such as copepods and cladocerans, as well as benthic forms such as ostracods. These taxa were not targeted during MABP.

Table 6.6.2: Annotated list of non-crayfish crustacean groups in freshwater systems.

Group	# Genera (Species) Documented in Maine *	Comments
Amphipods (scuds)	4 (4)	Primarily marine group. Freshwater species typically found in littoral benthos. Under-surveyed in freshwater systems in Maine. Sparsely represented in MABP database.
Isopods (pill bugs and sow bugs)	2 (3+)	Primarily a terrestrial and marine group. Most freshwater species are restricted to springs, brooks and subterranean waters. A few species found in ponds or bays of lakes. Under-surveyed in freshwater systems in Maine. Sparsely represented in MABP database.
Mysid shrimp	1 (1)	Single species in N. America: *Mysis relica*, the opossum shrimp. Introduced to few locations in Maine, e.g. Moosehead Lake, as forage for fish.
Micro-crustaceans (incl. copepods, cladocera, fairy shrimp, *Argulus* [fish lice], ostracods)		Planktonic, benthic, or parasitic. Not targeted in MABP.

* i.e. with records in MABP database.

6.7 INSECTS

In five insect orders, all species are aquatic as larvae. These orders are Ephemeroptera (mayflies), Odonata (damselflies and dragonflies), Plecoptera (stoneflies), Trichoptera (caddisflies) and Megaloptera (fishflies and alderflies).

Five other insect orders contain some aquatic species: Heteroptera (true bugs), Neuroptera (spongillaflies), Lepidoptera (moths), Coleoptera (beetles), and Diptera (flies and midges). Another insect-like group that is associated with aquatic ecosystems is the Collembola (springtails)[22]. While most Collembola inhabit moist terrestrial habitats, a few species are semi-aquatic. These forms are generally found on the water surface.

6.7.1 ***Mayflies***

Mayflies (Ephemeroptera) are one of the most primitive aquatic insect groups, probably arising over 280 million years ago (Peckarsky et al. 1990). Adults are terrestrial, but nymphs of all species are entirely aquatic. Mayflies are typically found in unpolluted freshwater systems, where the availability of suitable habitat is a primary factor limiting their distribution (Burian and Gibbs 1991). Some species are found in a broad range of habitat types, while others have adapted to brackish water environments. Mayflies are "often one of the most abundant and diverse groups of benthic macroinvertebrates in rivers and lakes because they are microhabitat specialists" (Burian and Gibbs 1991). As a group, mayflies are an important tool of biomonitoring programs that assess water quality status and impacts using biological communities (Davies et al. 1999).

***Information Sources**:* Three data sources provide the majority of mayfly records in the MABP database:

> (1) Burian (1990) conducted extensive surveys throughout the state and examined specimens from a number of museum collections. Burian and Gibbs (1991) used this material in their annotated faunal list of mayflies of Maine (which includes re-identification of some of the specimens collected from the Narraguagus basin by Mingo and Gibbs [1980]). Supplementing this data source and subsequent published material (Burian et al. 1995), S. Burian (pers. comm..) provided MABP with more recent collection records (together with taxonomic revisions). Burian and Gibbs' monograph includes records from the Procter surveys of Mount Desert Island (Procter 1938, 1946).
>
> (2) Mack (1988; see also Mack and Gibbs 1988, 1989) surveyed the mayflies of Mount Desert Island. His data were included separately in the MABP database since it appears that not all his records were included in the Burian database.
>
> (3) The third major mayfly data source comes from the MDEP stream biomonitoring program. Data were most recently provided to MABP in 2004. *However, MDEP states that these data are subject to revision once final quality assurance of their database is completed.*

Other data sources include various regional surveys: the upper St. John River basin (Mingo et al. 1979); the Narraguagus River (Mingo 1978; Mingo and Gibbs 1980; Siebenmann 1995; Siebenmann and Gibbs 1994); and the Penobscot River (Rabeni 1977; Rabeni and Gibbs 1977; Davies 1987). The Narraguagus, St. John and earlier Penobscot data were also incorporated into the Burian database. Two more recent surveys focusing on individual species are the

[22] Until recently, the Collembola was treated as an order of insects. Now, however, springtails are regarded as a separate class of invertebrates (Entognatha). They are nevertheless included in this section of the report.

statewide survey for the Tomah mayfly (Gibbs et al. 2001), and a search for probably the rarest mayfly species in Maine, the Roaring Brook mayfly (Swartz et al. 2004). Mayfly records are also available from a number of more localized studies.

Taxonomic revisions within the Ephemeroptera complicate the process of data integration and comparison (e.g. Mack 1988). While the MABP database includes all known taxonomic updates as of March 2005, it has clearly not been possible to adequately deal with older records of taxa that have been subsequently split into two or more species.

Species Diversity and Distribution: Prior to Burian's survey of Maine mayflies (Burian 1990), approximately 114 species had been recorded from the state (Burian and Gibbs 1991). The Burian and Gibbs checklist brought this total to 160 species in 43 genera (including 48 new State records). Current records in the MABP database total 170 species, belonging to 47 genera and 13 families (Table 6.7.1)[23]. Based on taxa known to be present in the Maritimes and southeastern Canada, Burian (1990, Table 9) listed 38 species as likely to be present in Maine, but uncollected at that time. Seven of these species have been subsequently collected in the state. Edmunds et al. (1976) predicted that a total of 200 species would be expected to occur in this region of the Northeast.

The most speciose family in Maine is the Baetidae with 40 species (this is also the family with perhaps the most taxonomic uncertainties and revisions). Following in terms of species richness are the Heptageniidae (43 species) and Ephemerellidae (34 species). Eight families have less than ten species in Maine.

Although Maine has a relatively rich mayfly fauna, there is just one endemic species, the Roaring Brook mayfly (*Epeorus frisoni*). At the time of Burian's survey in the late 1980s, this species was known only from type material; even its identity as a valid species was uncertain (Burian 1990). Since that time, however, the species has been collected in Baxter State Park at approximately the same location from which the original samples were taken (Swartz et al. 2004; see also Chapter 3.3).

Most of Maine's mayfly species are of boreal origin (Edmunds et al. 1976). Three genera (*Callibaetis, Hexagenia* and *Tricorythodes*) are considered to be of southern origin, and the origin of *Baetis* is uncertain. Burian (1990) characterized seven distributional patterns for Maine's mayfly species (Table 6.7.2A) – his analysis included all species regardless of rarity. About 50% of species were considered to be broadly distributed across the state, whereas 18% appeared restricted to the western and northern regions. Approximately 13% of species exhibited a disjunct distribution between the north/west and east – this interesting pattern is further discussed below.

Appendix 11.5.4 presents species distribution maps for Maine's mayflies. (Maps can also be viewed on-line at: http://www.pearl.maine.edu/windows/biodiversity/mayfly_distribution.htm)

We re-evaluated species distributions using the updated data (and current taxonomy) depicted in the maps of Appendix 11.5.4. Spatial variations in sampling effort were considered when evaluating species distributions. Burian's (1990) distributional categories were revised in an attempt to better reflect the updated distribution maps. Furthermore, we did not assign rare species (those occurring in <5 HUC-10 watersheds) to these spatial classes – as described below, a different approach was used for these taxa.

[23] Species designations in the MABP database reflect current taxonomy available in the Integrated Taxonomic Information System (ITIS) and NatureServe as of March 2005. This total of 170 species excludes the following taxa: *Rhithrogena amica*, *Tricorythodes atratus*, and *Isonychia notata.* This is because Burian and Gibbs (1991) believe that the Narraguagus basin records from Mingo and Gibbs (1980) represent mis-identifications. The latter two species occur only in the Narraguagus records of Mingo and Gibbs (1980). *R. amica* has also been recorded from the upper St. John River, by Mingo et al. (1979). It is assumed that these records are also suspect.

Table 6.7.2B summarizes the results of the current distribution analysis for 93 non-rare species. There appear to be four primary patterns (see maps in Appendix 11.5.4)

.

Ubiquitous: 16% of species occur across the state, e.g. *Libobrancha recurvata* (Ephemeridae), *Maccaffertium mediopunctatum*, *M. vicarium*, *Stenacron interpunctatum* (Heptageniidae), and *Isonychia bicolor* (Isonychiidae).

Statewide minus northwest: another 16% of species occur statewide except for the northwest, e.g. *Acerpenna pygmaea*, *Plauditus punctiventris* (Baetidae), *Caenis macafferti* (Caenidae), *Seratella seratoides* (Ephemerellidae), and *Maccaffertium modestum* (Heptageniidae).

North/west – east disjunct: this pattern is exhibited by 12% of species, e.g. *Plauditus cingulatus* (Baetidae), *Baetisca lacustris* (Baetiscidae), *Ephemerella aurivillii* (Ephemerellidae), and *Metretopus borealis* (Metretopidae).

Mid-state band: 34% of species are found primarily in a band from east to west across the mid section of the state, but tend not to occur in the north or south. This is a pattern that was not recognized by Burian (1990). Examples include: *Callibaetis furrugineus*, *Diphetor hageni*, *Heterocloeon curiosum* (Baetidae), *Brachycercus lacustris*, *Caenis tardata* (Caenidae), and *Drunella lata* (Ephemerellidae). Two variants of this pattern are where mid-region distributions extend either to the north (8 species) or south (5 species.

For rare species (those recorded from <5 HUC-10 watersheds), it is difficult to characterize distributions in the same way as for the more common taxa. Instead, we investigated geographic patterns in the occurrence of 77 rare species by counting the number of these taxa recorded from each of the six regions of the state depicted in Figure 2.3. Table 6.7.2C summarizes these results. Western Maine contains the greatest number of rare mayfly species, followed by the Downeast region. Southern Maine contains the fewest rare species. One southern Maine species that is of special interest is *Callibaetis pretiosus*. This species occurs primarily in the southeastern U.S. and, prior to Burian's (1990) survey, its most northern record was in Connecticut.

The reasons for the distribution patterns summarized in Table 6.7.2 are unclear. Burian (1990) concluded that spatial patterns were unrelated to dispersability, even though mayflies are known to be relatively sedentary. While pollution can negatively impact mayfly assemblages (e.g. Davies et al. 1999), it seems unlikely that it is a significant factor driving broad-scale distributional patterns in Maine at this time. Many species tend to be associated with particular habitat types, for example erosional or depositional stream reaches (e.g. Rabeni 1977), and deep-water lake habitats. However, Burian (1990) observed that rare species were, in general, not associated with rare habitat types. Past dispersal events and changes in climate may be responsible for the contemporary distributions of some species, including those that exhibit the north/west – east disjunct populations (Burian 1990). Warmer temperatures in the southern and lower-elevation inland parts of the state likely maintain these disjunct patterns. A good example of a species with a disjunct pattern is *Metretopus borealis* (Appendix 11.5.4 – Metretopodidae) which is found almost exclusively in the upper St. John basin and in the Downeast region.

When summarized at the HUC-8 watershed level, documented mayfly species richness is highest in the mid-regions of the state (Figure 6.7.1A). At the smaller watershed level (HUC-10), the richness pattern appears much more patchy (Figure 6.7.1B). In part, this reflects uneven sampling effort – most mayfly collections derive from southern, central and northeastern regions of the state (Figure 6.7.1). In particular, there are major data gaps north of the Moosehead Lake area and in extreme western Maine. Aside from the Narraguagus River, there has been relatively little sampling in the Downeast region. As might be expected, species richness summarized at the watershed level is positively associated with sampling effort (Figure 5.13). Consequently it is important to not infer too much from the geographic patterns of documented species richness

shown in Figure 6.7.1. For example, the relatively high richness associated with the Maine coastal HUC-8 watershed (extending across the Downeast region to just west of Ellsworth) is the result of the large numbers of species recorded from Mount Desert Island (MDI) and the Narraguagus basin. This can be clearly seen at the smaller watershed (HUC-10) level. Notwithstanding the issue of sampling effort, the higher species numbers documented for the mid-regions of the state do reflect the relatively large number (34%) of species that seem to be restricted to an east-west band across central Maine, as discussed above (Table 6.7.2B).

Six areas of the state have been surveyed relatively intensively and consequently provide a more accurate framework for quantifying spatial patterns of species diversity (Table 6.7.3). The area around Kingfield, in Franklin and Somerset counties, has the highest documented mayfly diversity (97 species) among the six areas shown in the map of Table 6.7.3. This species total is especially noteworthy since it was derived from a relatively low number of sampling sites. The one HUC-10 watershed that contributes the majority of species to this regional total can be seen in Figure 6.7.1B – it is centered on Kingfield and Lexington townships. The next highest richness is in the Orono-Bangor area (85 species). The other four areas exhibit similar species richness, values that are approximately half those of the Kingfield area.

Using the Jaccard Coefficient of Similarity[24], we compared the similarity among these six areas in terms of their mayfly assemblages (i.e. species composition, not simply species richness) (Table 6.7.3). The coefficient can vary between 0 (no shared species) and 1 (identical assemblages). The Kingfield area is most similar to the Orono area – they share 50% of their aggregated species pool. The most dissimilar areas are the south (Portland area) and MDI vs. the upper St. John which share just 18% of their species. Interestingly, dissimilarity between Caribou area and the upper St. John is about the same as between Caribou and either Kingfield, Orono or MDI. The fact that Caribou shares a greater percent of species with the Portland area than with all the other areas is probably an artifact of the low richness in southern Maine.

Although not captured in the six focus areas discussed above, the Moosehead Lake area is another region with high documented species richness (again, derived from relatively few sampling sites). Burian (1990) also commented on high diversity in this area and suggested that it may reflect patterns of colonization from both the Mississippi and Alaskan refugia following de-glaciation.

Most of the mayfly species recorded from Maine appear to be rare in the state (Figure 6.7.2). (Note that the shape of this species-frequency distribution may be influenced by insufficient sampling effort.) Just under half (47%) of the species have been recorded from <5 HUC-10 watersheds. Twenty five species (belonging to 20 genera and 8 families) have been recorded from only one watershed (Appendix 11.4 lists the number of watersheds each species has been collected from). Only five species have been collected from >50 watersheds: *Maccaffertium modestum*, *Baetis flavistriga*, *Acerpenna pygmaea*, *M. vicarium* and *B. intercalaris*.

Broad-scale regional differences in the frequency of occurrence of mayfly species are summarized graphically in Figure 6.7.3. This figure is intended to highlight major regional patterns, rather than providing individual species comparisons. As the measure of relative abundance, we used the % of HUC-10 watersheds in each region from which each species has been recorded. Species were ranked from most to least common for central Maine and this species order was maintained constant for the other five regions. Most species that are common in southern Maine are also (relatively) common in the other regions of the state. The mayfly assemblage of northwestern Maine appears to be the most distinctive in terms of species composition and relative abundance – a pattern that was seen earlier in the discussion of the six focus areas. The diversity of the mayfly fauna in western Maine is further underscored in this figure.

[24] Jaccard Coefficient of Similarity = # species shared among N areas / aggregate number of species in the N areas.

Temporal Trends in Mayfly Assemblages: Little is known about temporal variability in Maine's mayfly fauna. Interpretation of available data is complicated by changes in sampling techniques and taxonomy (and taxonomists). The most complete attempt to examine temporal changes in mayfly assemblages is that of Mack (1988) who compared his collections from Mount Desert Island with those made forty years earlier by Procter (1946). Thirteen of the species collected by Procter in 1946 were not re-collected by Mack, whereas 24 species collected in the 1980s had not been recorded in the earlier survey (Table 6.7.4). Burian's (1990) survey provides a valuable baseline from which to document future temporal shifts in mayfly assemblages – particularly in those areas of the state that were intensively sampled during the 1980s.

Table 6.7.1: Mayflies, dragonflies, damselflies, stoneflies and caddisflies in Maine.
Numbers of documented genera and species by family. Sub-species were counted as separate species for this table. Data are from multiple sources as compiled in the MABP database.

Family	# Genera	# Species	# Species Endangered, Threatened or of Special Concern in Maine	# G1, G2 or G3 Species [1]
EPHEMEROPTERA (Mayflies)				
Baetidae	11	40	-	4
Baetiscidae	1	6	-	1
Caenidae	2	8	-	-
Ephemerellidae	6	30	-	-
Ephemeridae	3	6	-	-
Heptageniidae	10	40	1	4
Isonychiidae	1	2	-	-
Leptohyphidae	1	3	-	-
Leptophlebiidae	5	15	-	-
Metretopodidae	2	2	-	-
Polymitarcyidae	1	1	-	-
Potamanthidae	1	2	-	-
Siphlonuridae	3	15	1	5
TOTALS: 13	**47**	**170**	**2**	**14**
ODONATA (Dragonflies / Damselflies) [2]				
Calopterygidae	2 (2)	4 (5)	-	-
Coenagriondae	7 (7)	31 (35)	7	3
Lestidae	1 (1)	10 (10)	-	-
Aeshnidae	8 (8)	20 (20)	4	-
Cordulegastridae	1 (1)	3 (4)	1	-
Corduliidae	7 (7)	26 (28)	3	3
Gomphidae	9 (10)	25 (27)	8	3
Libellulidae	13 (13)	37 (37)	5	-
Macromiidae	2 (2)	2 (3)	-	-
TOTALS: 9	**50 (51)**	**158 (169)**	**28**	**9**
PLECOPTERA (Stoneflies) [3]				
Capniidae	6	15	-	2
Chloroperlidae	6	18	-	4
Leuctridae	2	13	-	-
Nemouridae	9	16	-	1
Peltoperlidae	2	2	-	-
Perlidae	8	18	-	3
Perlodidae	7	27	-	3
Pteronarcyidae	1	5	-	1
Taeniopterygidae	5	9	-	-
TOTALS: 9	**46**	**123**	**0**	**14**

TRICHOPTERA (Caddisflies)				
Beraeidae	1	1	-	
Brachycentridae	2	11	-	-
Calamoceratidae	1	1	-	-
Dipseudopsidae	1	3	-	-
Glossosomatidae	4	10	-	-
Goeridae	1	2	-	-
Helicopsychidae	1	1	-	-
Hydropsychidae	8	41	-	-
Hydroptilidae	12	66	-	1
Lepidostomatidae	1	15	-	-
Leptoceridae	7	44	-	-
Limnephilidae	19	60	-	-
Molannidae	1	5	-	-
Odontoceridae	1	3	-	-
Philopotamidae	3	5	-	-
Phryganeidae	7	18	-	-
Polycentropodidae	5	28	-	-
Psychomyiidae	3	6	-	-
Rhyacophilidae	1	14	-	-
Sericostomatidae	1	2	-	-
Uenoidae	1	6	-	-
TOTALS: 21	**81**	**342**	**0**	**1**

1) Global conservation rankings, as provided by NatureServe (www.natureserve.org): G1 = critically imperiled; G2 = imperiled; G3 = vulnerable. Species listed as a combination of two rankings (e.g. G3G4) are included in these totals if one of the two rankings is G1, G2 or G3.

2) For odonates, two sets of numbers are provided for genus and species totals. Numbers outside of parentheses reflect the list of taxa recognized by P. Brunelle and P. DeMaynadier (MDIFW) as occurring in Maine (as of March 2005). Numbers within parentheses include additional taxa for which there are geo-referenced records in the MABP database, but which are not included in the Brunelle list. However, these totals within parentheses do NOT include species that have been excluded from the Maine list by Brunelle and DeMaynadier because these records were based on apparently mis-identified specimens.

3) Stonefly totals include 19 species that Mingo (1983) lists as being present in neighboring states and provinces, but not actually documented for Maine at that time. The MABP database has subsequent geo-referenced records for only one of these 19 species. All 19 are included in this table, however, since it is likely that they do occur in Maine. An additional four taxa (2 forms of *Isoperla*, one each of *Shipsa* and *Paranemoura*, appear in the literature as new, undescribed, species. It is uncertain whether these specimens have been subsequently described.

Table 6.7.1 (cont.)

Table 6.7.2 A-C: Three analyses of geographic distributional associations of mayfly species:

A: Distributions assigned by Burian (1990).

B: Distributions of common and moderately common species, assigned by MABP using all available data.

C: Regional distribution of rare mayfly species.

(A) Distributions assigned by Burian (1990). Species added to the list of Maine mayflies since 1990 are excluded from this table.

Distribution (Burian 1990)	# Genera	# Species	% Species
Ubiquitous	35	81	50
North / West	18	28	18
North / Central	6	6	4
North / West-East	15	15	13
Coastal / Eastern	8	8	5
Central / Southern	7	7	5
Central / Eastern / Southern	7	7	5

B. Distributions assigned by MABP, using current data and taxonomy: 94 common and moderately common species, only (i.e. recorded from ≥ 5 HUC-10s).

C. See maps in Appendix 11.5.7.

Distribution (Current analysis): 93 species occurring in ≥ 5 HUC-10 watersheds.	**Example Distribution**	**# Species**	**% Species**
Ubiquitous		15	16 %
Ubiquitous excl. NW		15	16 %
Northwest – East disjunct		11	12 %
Middle		32	34 %
Middle + North		8	9 %
Middle + South		5	5 %
Other, more localized distributions		8	8 %

C. Regional distribution of 77 rare mayfly species.
Data are number and % of rare species (defined as taxa recorded from <5 HUC-10 watersheds) that have been documented from six regions of Maine. See text for more information.

Region	# Species	% Species *
South	8	10 %
Central	24	31 %
Downeast	29	38 %
Northeast	11	14 %
West	45	58 %
Northwest	12	16 %

* % do not sum to 100% because some species are present in >1 region.

Table 6.7.3: Comparison of mayfly assemblages in six well-sampled areas of Maine.

Numbers below the diagonal are total (pooled) species recorded from each pair of areas. Numbers in red above diagonal are the proportion of total species that are shared by both members of each pair (=Jaccard Coefficient of Similarity).

Survey areas are shown in the map, together with measures of odonate diversity and sampling effort for each area. "Total Species" is the number of taxa recorded from each area. "Unique Species" are those recorded from that area but none of the other areas.

	Portland	MDI	Orono	Caribou	St. John	Kingfield
Portland		**.30**	**.29**	**.42**	**.18**	**.22**
MDI	66		**.36**	**.25**	**.18**	**.40**
Orono	94	99		**.29**	**.21**	**.50**
Caribou	53	71	96		**.24**	**.25**
St. John	67	79	106	66		**.25**
Kingfield	109	105	121	109	112	

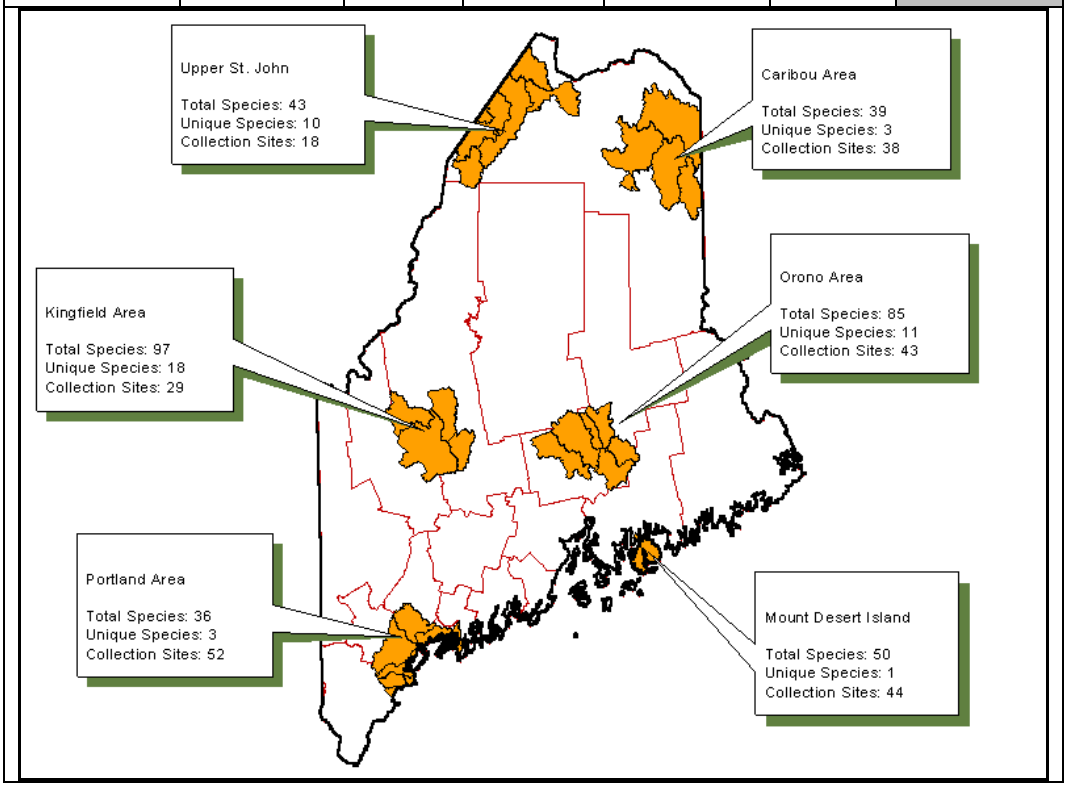


Table 6.7.4: Comparison of mayfly collections on Mount Desert Island in the 1940s and 1980s*

Family	# Species recorded by:		
	Procter, only (1946)	Procter & Mack	Mack, only (1988)
Siphlonuridae	1	3	2
Baetidae	4	3	8
Heptagenidae	6	5	5
Leptophlebiidae	1	8	2
Ephemerellidae	1	3	5
Caenidae	0	1	1
Ephemeridae	0	1	1
TOTAL	*13*	*24*	*24*

* Data are derived from Table 2 in Mack (1988). Taxa identified only to the genus level have been excluded from these totals.

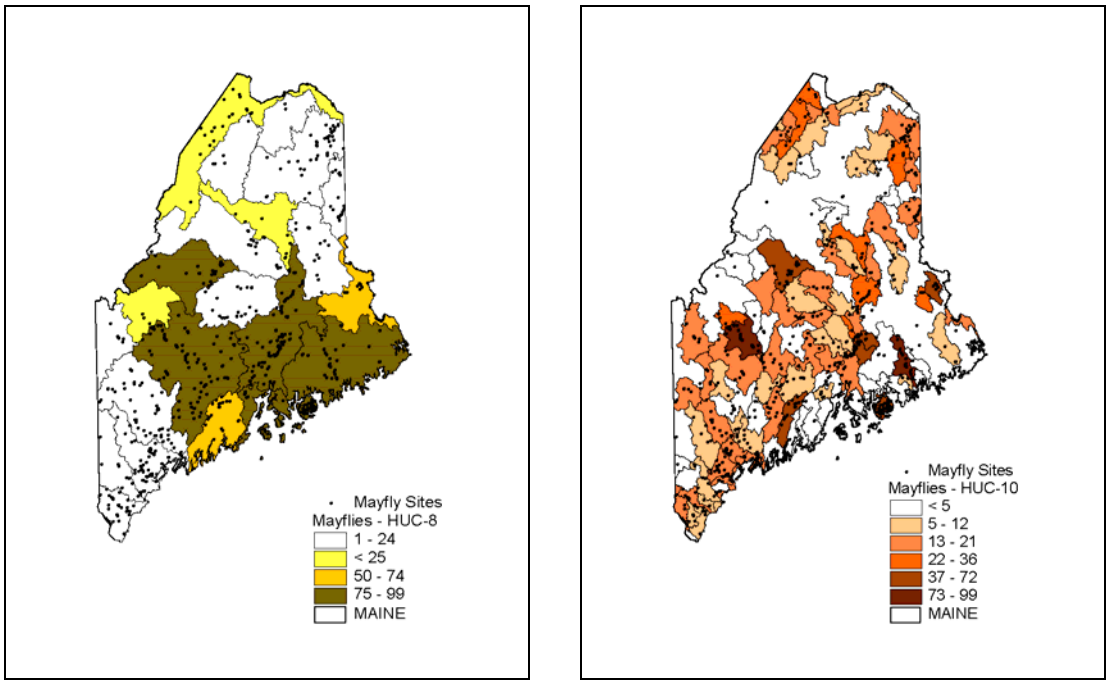
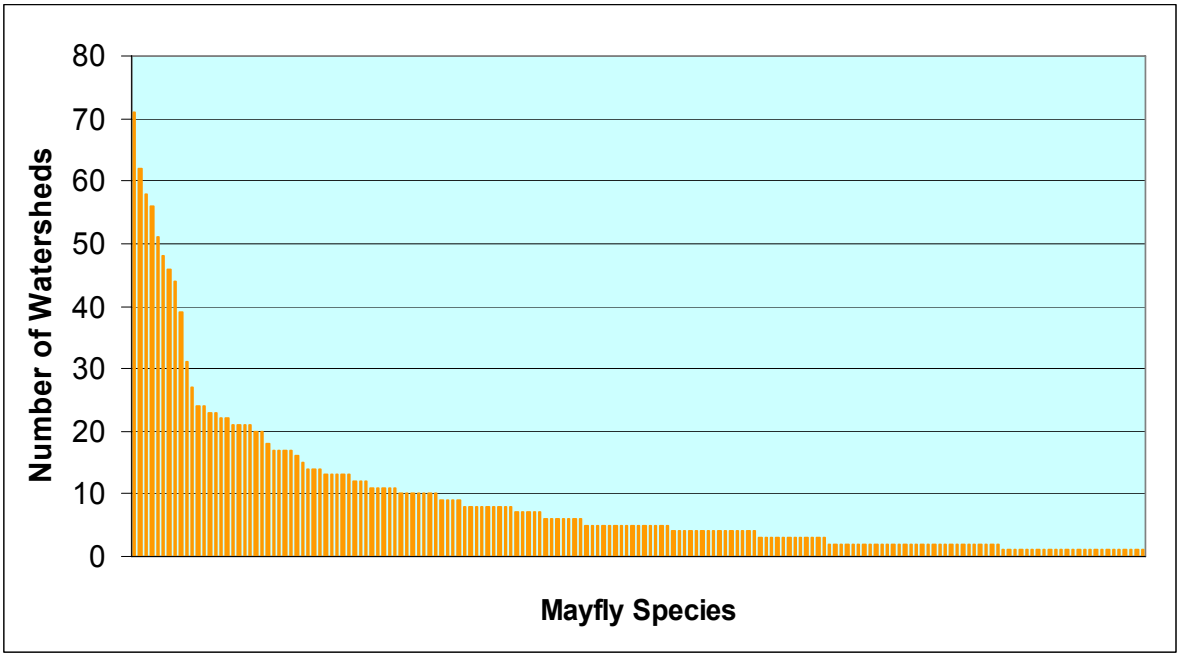


Figure 6.7.1: Documented mayfly species richness at two watershed scales: (A) HUC-8, (B) HUC-10. Collection sites are indicated by dots in both panels.

(A)



(B)

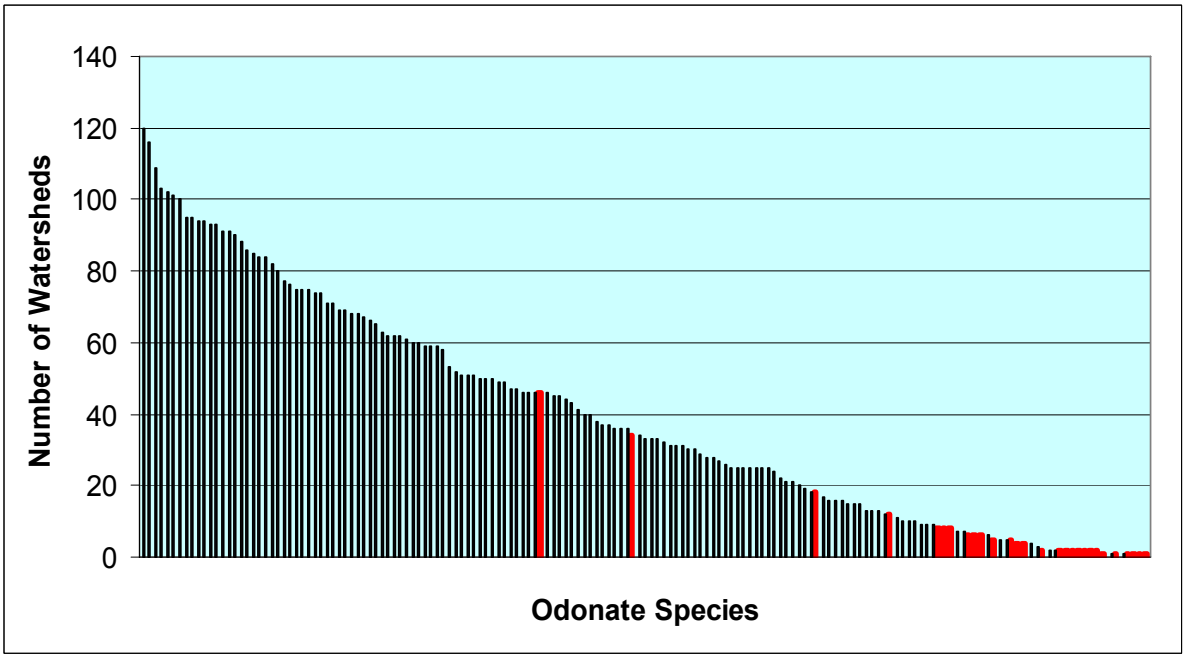


Figure 6.7.2: Frequency of occurrence of (A) mayfly, and (B) odonate species in Maine. Data are number of watersheds (HUC-10) in which each species has been recorded. Each column represents a species, ranked from most to least common. Odonate species that are "tracked" by MDIFW are shown in red in lower panel. Taxonomy of MABP records current as of March 2005. Tracked odonate species reflect the list updated as of March 7, 2005 (P. DeMaynadier, MDIFW, pers. comm.). Data sources: multiple as compiled in MABP database.

Figure 6.7.3: Frequency of occurrence of mayfly species in major regions of Maine.

Frequency of occurrence is shown as % of regional watersheds in which a species has been recorded (watersheds without any mayfly collections were omitted from the totals). Each column in the graphs represents a species. Species are ordered by the frequency of occurrence in central Maine; the order in which species are displayed remains constant in all six panels. (Note: Central Maine was selected for the initial ordering because fewer species have been collected from southern Maine.) Regions are shown in Figure 2.3.

Data sources: multiple, as compiled in MABP database.

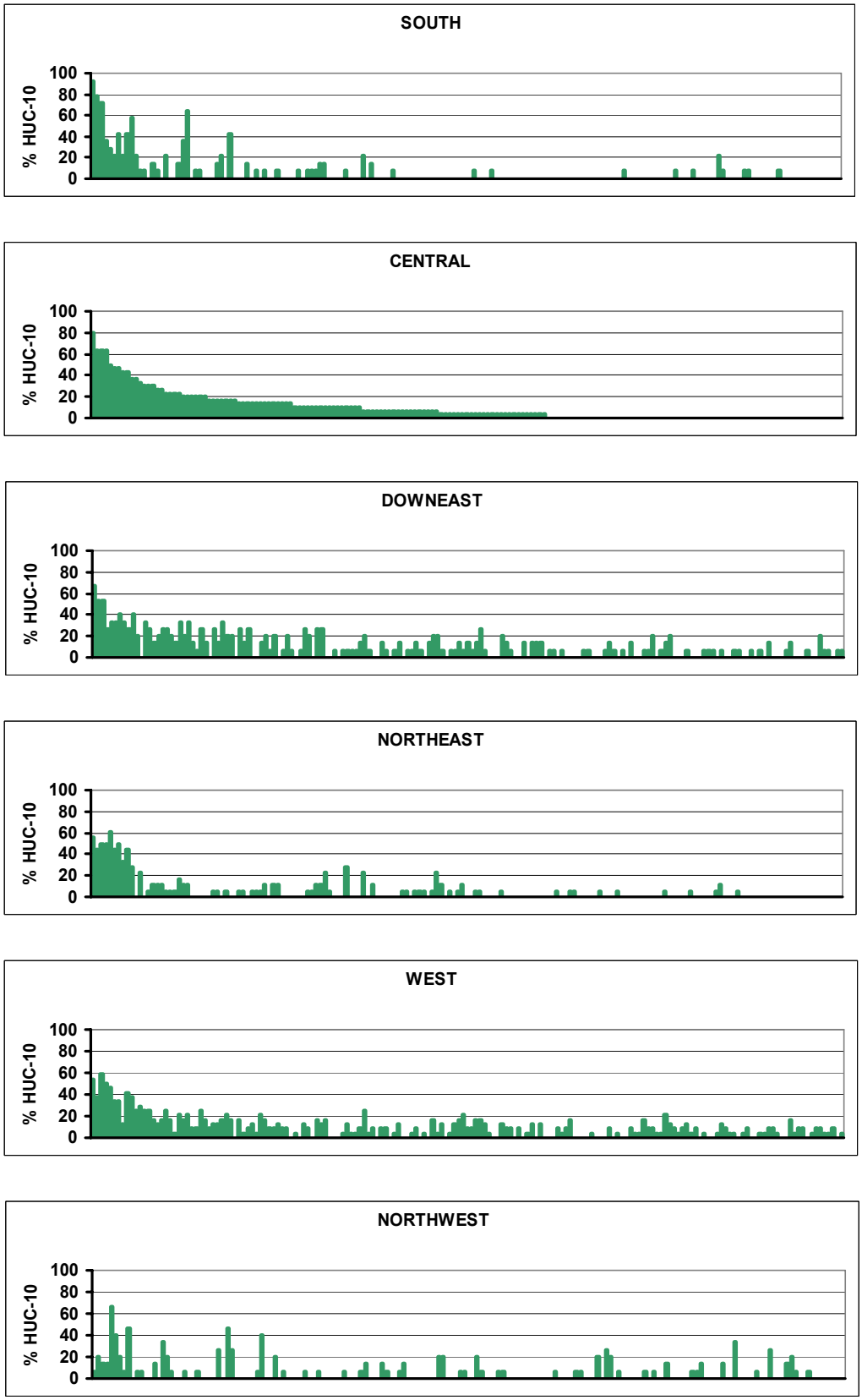

SOUTH
% HUC-10
100
80
60
40
20
0
CENTRAL
% HUC-10
100
80
60
40
20
0
DOWNEAST
% HUC-10
100
80
60
40
20
0
NORTHEAST
% HUC-10
100
80
60
40
20
0
WEST
% HUC-10
100
80
60
40
20
0
NORTHWEST
% HUC-10
100
80
60
40
20
0

Figure 6.7.3

6.7.2 ***Dragonflies & Damselflies***

Odonates are among the most ancient of flying insects, their ancestors appearing during the Carboniferous period, 280-350 million years ago (Peckarsky et al. 1990). There are two suborders in North America – the Anisoptera (dragonflies) and Zygoptera (damselflies). When at rest, adult dragonflies hold their wings horizontally while damselflies hold them vertically. There are about 415 species known from North America. Larvae of all species are aquatic, with about two thirds of North American species living in lentic environments and one third in lotic habitats (Thorp and Covich 1991). All larvae (known as nymphs) attain a relatively large size and all are predaceous; they are often top predators in freshwater invertebrate communities. Life cycles are relatively long, generally one year in damselflies and one to four years in dragonflies. Odonates usually overwinter as eggs or as nymphs. Adults are relatively long-lived – several weeks to several months.

Information Sources*:* Until recently, most information on Maine odonates came from a few collectors who were surveying starting in the 1890s (Brunelle 1999). Historical records were reviewed by Borror (1944) and, most recently, by Brunelle (1999). Today, as a result of the Maine Damselfly and Dragonfly Survey (MDDS, coordinated by MDIFW), odonates are now the most collected and best documented invertebrate group in Maine. Since late 1998, volunteers and professionals have collected almost 17,000 species records from about 1,600 sites across the state. The MDDS database includes both contemporary and historical records. Most records are of odonate adults. Habitat data are available for samples collected during the recently completed survey[25]. Prior to MDDS, Mount Desert Island (MDI) was one of the most intensely surveyed regions of the state, in large part because of the collections of H.B. White (White 1969, 1974, 1989). As a result, MDI also has the longest time span of odonate records for Maine (Brunelle 1999). Another source of odonate data is the MDEP stream biomonitoring program database. However, because of the difficulty in identifying many larval odonates to species, many of the MDEP records are at the level of genus or even family.

Species Diversity and Distribution: A total of 158 species – 45 Zygoptera and 113 Anisoptera – are currently known to be present in Maine. These species belong to 50 genera and nine families (Table 6.7.1). The current species total reflects the recent withdrawal of seven species[26] that are now considered not to be present in the state – original records appear to have been incorrect identifications (P. Brunelle and P. DeMaynadier, MDIFW, pers. comm.. March 2005). An additional six species, not in the current MDDS list, appear in the MDEP stream biomonitoring database[27]. Appendix 11.5.5 presents species distribution maps for Maine's odonates.

The three most species-rich odonate families are all within the Anisoptera: Libellulidae (skimmers; 37 species), followed by Corduliidae (emeralds; 26 species) and Gomphidae (snaketails and clubtails; 25 species). At the other end of the diversity spectrum, one damselfly family (Calopterygidae) and two dragonfly families (Cordulegastridae and Macromiidae) have <5 species each (Table 6.7.1).

The number of HUC-10 watersheds from which each species has been recorded is a useful measure of its frequency of occurrence in the state (and probably a more accurate representation than the number of collection sites or site-date combinations, because of highly concentrated sampling in some areas, e.g. MDI and the upper Saco). When Maine's odonate species are arranged in decreasing order of commonness, they exhibit a monotonic decrease (Figure 6.7.2).

---

[25] The most recent version of the MDDS database, used for this report, was provided to MABP by MDIFW in November 2004 and contains data on samples collected through 2003.

[26] *Enallagman recurvatum, Gomphus fraternus, Gomphus lividus, Libellula vibrans, Sympetrum ambiguum, Stylurus amnicola, Stylurus notatus.*

[27] *Gomphus vidrifrons, Macromia taeniolata, Neurocordulia virginiensis, Calopteryx dimidiata, Argia sedula, Ariga tibialis, Enallagma antennatum.*

Seven species have been recorded from >100 watersheds, while 37 species have been collected from <10 watersheds. Three of Maine's most common odonates are damselflies (*Ischnura verticalis*, *Enallagma hageni* and *Calopteryx maculata*), while the other four species recorded from >100 watersheds are dragonflies (*Ladona julia*, *Libellula quadrimaculata*, *Boyeria vinosa*, *Basiaeschna janata*). Within the group of the 37 rarest species (those recorded from <10 watersheds), 12 (32%) are damselflies and 25 (68%) are dragonflies – a ratio that mirrors the Zygoptera : Anisoptera ratio for the entire Maine odonate list.

The monotonic decrease in odonate occurrence frequencies contrasts strongly with that of mayflies (Figure 6.7.2). With odonates, approximately equal numbers of species occur at various frequency-of-occurrence levels (i.e. numbers of watersheds). This is not the case for mayflies, where there appear to be a few very common species and many very rare species – the mayfly species curve is notably "concave". One reason for this difference may be associated with the fact that the odonate data are based on sampling effort that is more intensive, and more broadly distributed, than is the case for the mayfly data. A biological explanation for the difference might be the greater dispersability of odonates relative to mayflies – odonates are stronger fliers and live longer than mayflies.

Twenty three odonate species are currently listed as being of special concern status in Maine – six damselflies and 17 dragonflies[28]. Four species are considered to be threatened in the state and one species, the ringed boghaunter (*Williamsonia lintneri*), found only in southern Maine, is listed as endangered (Tables 3.4 and 6.7.1). Most of Maine's "tracked" species have so far been recorded from <10 HUC-10 watersheds (Figure 6.7.2). Figure 6.7.4 illustrates the documented distributions of 24 of Maine's rarest odonates. Some of these species appear to be widely dispersed across the state (e.g. *Ophiogomphus colubrinus* and *Enallagma carunculatum*). Other rare odonates have been recorded from highly localized regions (e.g. *Williamsonia lintneri* and *Progomphus obscurus* in southern Maine). Four species have been collected from just one site each, and six species from two sites each. Seven of the 28 state-listed species are considered to be vulnerable globally (G3 ranking) – another two G3 species (*Enallagma recurvatum* and *Stylurus notatus*) are not included in the state list (Table 6.7.1). The endangered ringed boghaunter has been recorded from nine other U.S. states, while the four species listed as threatened in Maine are known from between 17 and 32 other U.S. states (NatureServe, accessed December 2004).

Maine represents the southeastern range extremity of many northern species and the northeastern extreme of many southern species (Brunelle 1999). Using data summarized in the species distribution maps of Appendix 11.5.5, we identified (subjectively) 13 distribution patterns for Maine odonates (Table 6.7.5). Only those species occurring in ≥5 HUC-10 watersheds were included in this analysis. Of these 142 non-rare species, just over one third (37%) occur statewide - some of these taxa are relatively uniformly distributed across the state, whereas others appear to be more common in some regions than others. Approximately 25% of species are largely restricted to either the northern or the southern halves of the state. A further 30% of species have been recorded primarily from lower elevation areas extending from southern to Downeast Maine. One species is exclusively coastal. Six species appear to exhibit disjunct distributions, with records coming from widely separated areas of the state.

When odonate species richness is summarized at the watershed level, there is a clear north-south gradient, with highest documented species totals occurring in the southern half of the state (Figure 6.7.5). The three HUC-10 watersheds with the highest documented richness are Mount Desert Island, the upper Saco River, and a sub-watershed of the lower Penobscot in the Veazie / Orono area (Figure 6.7.5 B). However, these are also areas with relatively high levels of sampling effort, as illustrated in Figure 6.7.5 B. In fact, documented species richness at the watershed level, statewide, is highly significantly associated with sampling effort, as discussed in

[28] Four of these special concern species are included in the list only on account of their G3 list status – they are not considered to be potentially endangered or threatened in Maine (P. DeMaynadier, MDIFW, pers comm.).

Chapter 5 (see Figure 5.13). All of the most intensively sampled HUC-10 watersheds (those with >100 site-date sampling events, c.f. Figure 5.13) are in the southern half of the state. Furthermore, because the odonate data are not based on consistent ("replicated") sampling "units", it is not possible to adequately correct for variable sampling effort using techniques such as jack-knife re-sampling (McCune and Grace 2002). Consequently, when using watershed-level species totals, it is difficult to distinguish true geographic variation in species richness from the influence of variable sampling effort. Nevertheless, inspection of the species distribution patterns summarized in Table 6.7.5 does suggest that the apparent north-south gradient of increasing richness is real. For example, of the 63% of (142 non-rare) species that are not found statewide, only 8.4% (7.7% + 0.7%) appear to be restricted to the northern half of the state. The remaining species are mostly found either in the south or in lower elevations through south, central and Downeast Maine.

To more fully investigate regional patterns in odonate assemblages, we selected eight areas around the state that have been well-sampled, aggregating HUC-10 watersheds to provide regional "units" with overall levels of sampling effort that are as consistent as possible (Table 6.7.6). Of these eight areas, MDI and the southwest unit (upper Saco) have the highest species numbers, while the upper St. John region has the lowest. Although sampling effort does vary among these eight composite areas, species richness is not significantly associated with effort ($p<.001$). When species totals for pairs of areas are compared (Table 6.7.6, upper panel, below diagonal), the highest values are for those pairs that include the southwest area. The lowest values are for the northeast + northwest and northwest + west. This pattern underscores the north-south species richness gradient discussed above.

Using the Jaccard Coefficient of Similarity (defined in section 6.7.1), we compared the similarity among these eight areas in terms of their odonate assemblages, i.e. species composition, not simply species richness (Table 6.7.6). The coefficient can vary between 0 (no shared species) and 1 (identical assemblages). As might be expected from the species totals, pairs of areas that include the upper St. John exhibit the lowest similarity values (with the exception of this area and the northeast). Among all other pairs of areas, there is relatively little variation in the degree of similarity of their odonate assemblages. Overall, within each pair of areas, about 50-60% of species were shared by both members of the pair. This is about twice the equivalent value of shared species derived from the previously discussed analysis of regional mayfly assemblages (Table 6.7.3).

While the eight areas compared in Table 6.7.6 were selected to provide some degree of uniformity in sampling effort, they do not incorporate the entire complement of Maine odonates. The species overlap data in Table 6.7.6 also do not quantify the relative abundance (frequency of occurrence) of individual species. To provide a broader-scale, more inclusive, comparison of regional differences in odonate assemblages, we calculated the frequency of occurrence of species for each of the six major regions depicted in Figure 2.3. As the measure of frequency of occurrence, we used the % of HUC-10 watersheds in each region that each species has been recorded from. Figure 6.7.6 provides a graphical summary of results from this analysis. This figure is intended to highlight broad-scale regional patterns, rather than providing individual species comparisons. In Figure 6.7.6, species are ranked from most to least common in southern Maine and this species order is maintained constant for the other five regions. As expected, the patterns shown in Figure 6.7.6 reflect the area-specific comparisons of species overlaps (Table 6.7.6). For example, odonate assemblages in central and Downeast regions are similar to each other, as are those of the northern regions. A group of species that are uncommon in the south become much more common in central and Downeast Maine – these include six *Somatochlora* species, two *Aeshna* species and *Sympetrum obtrusum*. Several species not found in southern Maine occur in all other regions (those at the right edge of the species axis). These include three other *Somatochlora* species, together with *Coenagrion resolutum*).

Most of our knowledge of odonate assemblages in Maine derives from collections of adult specimens and exuviae – relatively little is known about community structure of odonates in their

aquatic phase. A recent study by Gibbs et al. (2004) provides an insight into community structure of larval gomphid dragonflies in the Aroostook River. Six species of *Ophiogomphus* coexist in a 137 km stretch of the river extending from the confluence of Munsungan and Millinocket Streams (T8 R8) to 19 km below Presque Isle. Gibbs et al. (2004) found distinct spatial segregation between *O. mainensis* (most abundant at upstream stations) and *O. rupinsulensis* (most abundant in the lower reaches). Two species (*O. anomalus* and *O. carolus*) were present at all 16 sites, whereas the remaining two species (*O. howei* and *O. aspersus*) were collected at only a few sites and in low abundance. (Of these six species, *O. howei* and *O. aspersus* are also the least common statewide when distributions are summarized by number of HUC-10 watersheds occupied [see Appendix 11.4].) Gibbs et al. (2004) found little evidence of temporal segregation among the six species – all species emerged during the morning and early afternoons of June.

Distribution by Elevation. To characterize the number of species present at different elevations in Maine, we used GIS (digital elevation model data coverage) to assign elevations to all 2448 odonate collection sites in the MDDS database. Eighty seven percent of these sites are <1000 ft, while 0.7% are >2000 ft. We then summarized species richness gradients in two ways. First, we simply totaled the number of species recorded from each of ten elevation zones. Second, we excluded from these totals any species that was relatively infrequently captured within a particular zone, i.e. any species for which the weighted number of sites in the zone represented <5% of the total weighted number of species-sites statewide. For this second analysis, we normalized species distributions to reduce the effect of unequal sampling effort at different elevations[29].

Elevations below 600 ft. show the highest numbers of species (Figure 6.7.7). Elevations above 1600 ft. are home to less than one third as many species as at the lower elevations. This pattern is essentially unchanged when infrequently-collected species (within any particular elevation zone) are excluded from the species totals (Figure 6.7.7, “>4.9%” data category).

Distribution by Habitat. The MDDS database contains extensive habitat information for most of the samples collected during the recent survey. We summarized this information by calculating the ratio of lotic to lentic sites (“%stream:%pond”) for each species (only species collected from >10 sites characterized as either lotic or lentic were included in this analysis). A site was characterized as lotic if the habitat description included the terms stream, river or flowing water. Lentic sites included the descriptors lake or pond. A site could be characterized as both lotic and lentic. Sites not containing any of these habitat descriptors (e.g. descriptor restricted to “wetland” or “terrestrial”) were excluded from this analysis. For each species, the numbers of lotic and lentic sites were expressed as percentages of the total number of lotic and lentic sites in the full database.

Of the 127 species included in this analysis, 15 (12%) are primarily associated with lotic habitats (stream:pond ratio greater than 10:1) (Figure 6.7.8). The four species most frequently associated with flowing water all belong to the genus of snaketail dragonflies, *Ophiogomphus* (*O. carolus*, *O. anomalus*, *O. howei* and *O. mainensis*). Ten species (8%) were collected principally from lentic habitats (stream:pond ratio less than 1:10). Of these ten species, seven belong to the genus of pond damsels, *Enallagma* (*E. cyathigerum*, *E. civile*, *E. minusculum*, *E. vesperum*, *E. pictum*, *E. aspersum* and *E. laterale*). The remaining species were recorded from a variable mix of habitat types. Overall, 34% of the 127 species tended to be collected from lotic sites (stream:pond ratio >1), whereas 66% tended to be found in lentic sites (stream:pond ratio <1). In contrast to these findings, Brunelle’s (1999) analysis of historical data suggested that 54% of records were from running waters and 36% from lakes and ponds. From the available MDDS habitat data, there is little evidence that rarer species tend to be found more in wetland habitats than in lotic or lentic

[29] Normalization of the data was done as follows. The number of sites at which each species has been collected within each elevation zone was first expressed as a percentage of the total number of collection sites (species disregarded) within the zone. For each species, the normalized percent occurrences were then summed across all elevation zones. Finally, the normalized occurrence for each species in each was was expressed as a percentage of the summed occurrences statewide. This procedure in effect produces the percent occurrence of each species in each elevation zone, corrected for the total amount of collection effort in each elevation zone.

habitats, as predicted by Brunelle (1999). For the 36 rarest species (recorded from <20 HUC-10 watersheds across the state), 34% of sites were characterized as lotic, 30% as lentic, and 36% as wetlands. In contrast, for the 67 most common species (recorded from >100 watersheds), the values are 25%, 42% and 33%, respectively.

Temporal Trends in Odonate Assemblages: Little is known about temporal shifts (or lack thereof) in odonate assemblages in Maine. Mount Desert Island has the longest collection record for the state (Brunelle 1999). Prior to 1950, 49 species had been documented for this region (Table 6.7.7). By 1970, the species total had grown to 74; by 1990, it was 92 species. Through 2003, the MDI species total stands at 105 (the MDDS total for MDI is actually 110 "recognized" species; however, five of these have no dates attached to their records). Each year of MDDS collections on MDI between 1999 and 2003 recorded an average of 29 species, with a cumulative total of 69 species over this five-year period (Table 6.7.7). A total of 48 species recorded from MDI since 1990 were not collected prior to 1950. Conversely, 12 species recorded prior to 1950 have not been collected on MDI since 1990. These species are:

> *Somatochlora forcipata* (25), *S. minor* (31), *Stylogomphus albistylus* (75), *Sympetrum corruptum* (1), *S. danae* (16), *S. rubicundulum* (33), *Williamsonia fletcheri* (30), *Epiaeschna heros* (6), *Lanthus parvulus* (25), *L. vernalis* (8), *L. dryas* (46) and *L. unguiculatus* (19).

The numbers in parentheses in the foregoing list are the total HUC-10 watersheds from which each species has been recorded statewide. Nine of these 12 species are relatively common in the state, two are uncommon and one (S. corruptum) has only been recorded from MDI. Brunelle (1999) considered the latter to be a vagrant species in Maine (not a year-round resident).

Almost certainly, the increase over time in MDI's documented odonate richness reflects, to a large degree, the expanded collection effort. It is impossible to adequately separate the influence of improved documentation from any real temporal trends in assemblage composition.

Table 6.7.5: Distributions of 142 non-rare odonate species.
Only species that have been recorded from ≥5 watersheds (HUC-10) are included in this table. Example distributions are shown (see Appendix 11.5.5 for all distribution maps).

Distribution Pattern	# Species	% Species	Example Maps
Ubiquitous	53	37.3	 *Boyeria grafiana*  *Chromagrion conditum*
Mid + North	11	7.7	 *Somatochlora minor*
North	1	0.7	 *Coenagrion interrogatum*
Mid + South	23	16.2	 *Aeshna verticalis*
South	3	2.1	 *Williamsona lintneri*
West	1	0.7	 *Somatochlora albicincta*

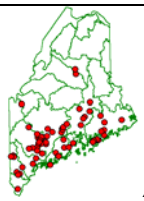
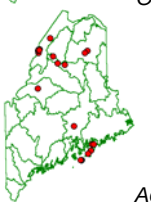
Lowlands: South, Central + East	26	18.3	 *Aeshna clepsydra*
Lowlands: South + Central	12	8.4	 *Enallagma laterale*
Lowlands: Central + East	2	1.4	 *Celithemis martha*
Lowlands: East	1	0.7	 *Aeshna subarctica*
Lowlands: Central	2	1.4	 *Aeshna constricta*
Lowlands: Coastal	1	0.7	 *Erythrodiplax berenice*
Disjunct	6	4.2	 *Ophiogomphus howei*  *Aeshna sitchensis*

Table 6.7.5 (continued)

Table 6.7.6: Comparison of odonate assemblages in eight well-sampled areas of Maine.

Top panel: numbers below the diagonal are species totals recorded from each pair of areas. Numbers in red above diagonal are the proportion of total species that are shared by both members of each pair. These values are equivalent to the Jaccard Coefficient of Similarity. Bottom panel: map shows the survey areas included in this analysis. Also shown in the bottom panel is the number of species recorded from each area, as well as the number of "unique" species, i.e. those recorded from that area but none of the other areas. See text for additional information on selection of survey areas.

	SW	Central	MDI	Narrag.	Orono	NE	NW	West
SW		.66	.58	.59	.60	.56	.41	.56
Central	122		.68	.68	.69	.54	.41	.52
MDI	137	124		.64	.69	.52	.41	.58
Narrag.	122	111	122		.70	.57	.47	.67
Orono	129	118	126	112		.59	.47	.62
NE	120	116	127	109	116		.69	.68
NW	122	116	126	106	115	88		.59
West	122	120	125	106	116	100	96	

Southwest: Total Species = 105
Unique Species = 10
Collection Sites = 81

Central: Total Species = 97
Unique Species = 2
Collection Sites = 74

MDI: Total Species = 111
Unique Species = 5
Collection Sites = 149

Narrag.: Total Species = 89
Unique Species = 0
Collection Sites = 84

Orono: Total Species = 102
Unique Species = 2
Collection Sites = 68

NE: Total Species = 82
Unique Species = 0
Collection Sites = 119

NW: Total Species = 67
Unique Species = 3
Collection Sites = 81

West: Total Species = 86
Unique Species = 1
Collection Sites = 50

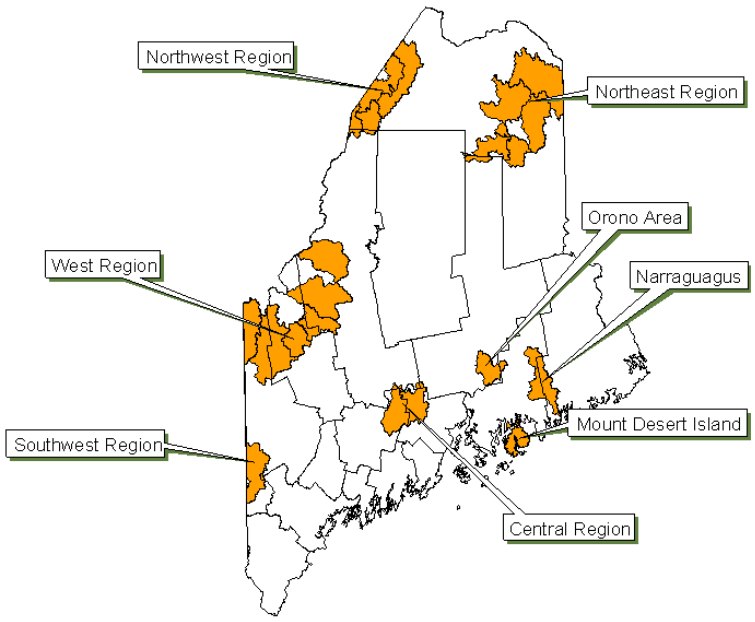


Table 6.7.7: History of odonate records from Mount Desert Island *.
This analysis includes only data from the MDDS database and only species that are currently recognized by Brunelle and DeMaynadier as being valid Maine taxa. MDDS collections started in 1999.

Year(s)	# Species Recorded in Period	Cumulative Species Since 1890	Cumulative Species Since 1999
1890-1949	49	49	--
1950-1969	44	74	--
1970-1989	80	92	--
1990-1998	58	96	--
1999	24	97	24
2000	45	99	51
2001	24	101	57
2002	27	104	65
2003	27	105	69

* Data are for HUC-10 # 0105000215, which includes all of MDI, together with a small amount of the mainland.

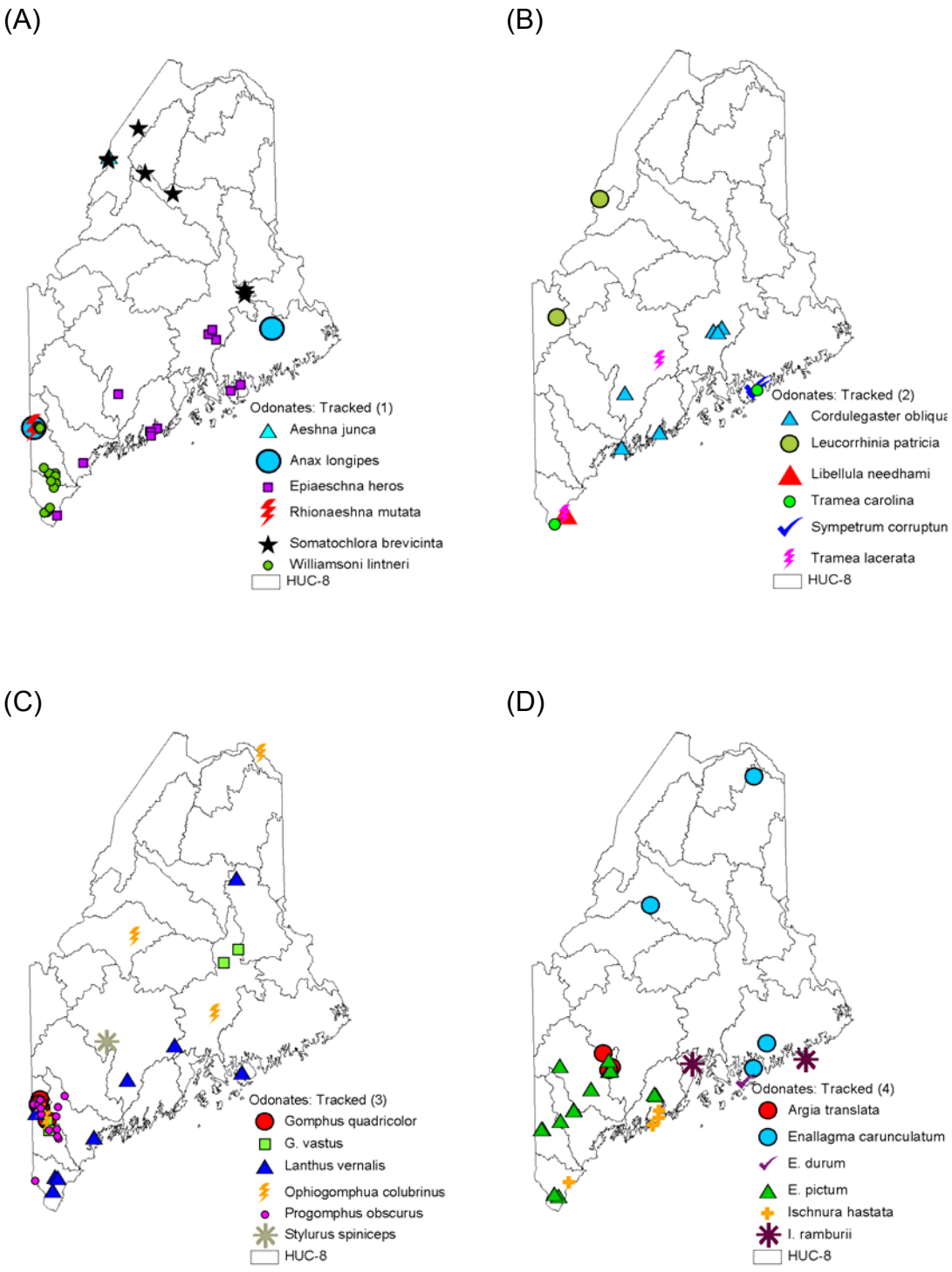
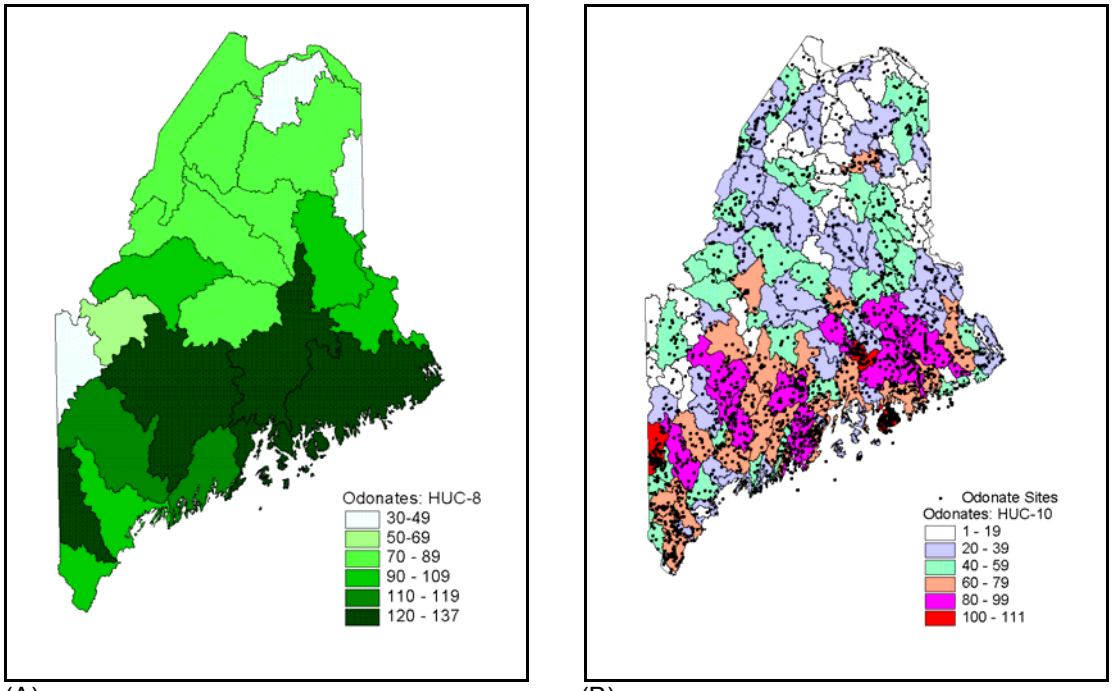


Figure 6.7.4: Distribution maps for rare odonate species tracked by MDIFW.
Panels A-C show dragonfly species; panel D shows damselfly species. Not shown are four species that, although tracked by MDIFW, are not considered to be rare in Maine.



(A) (B)

Figure 6.7.5: Documented odonate species richness at two watershed scales: (A) HUC-8, (B) HUC-10.
Collection sites are indicated by dots in panel B.

Figure 6.7.6: Frequency of occurrence of odonate species in six regions of Maine.

Frequency of occurrence is shown as % of regional watersheds (HUC-10) in which a species has been recorded. 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. Regions are shown in Figure 2.3.

Data sources: MDIFW damselfly and dragonfly survey database (updated data provided to MABP 11/2004).

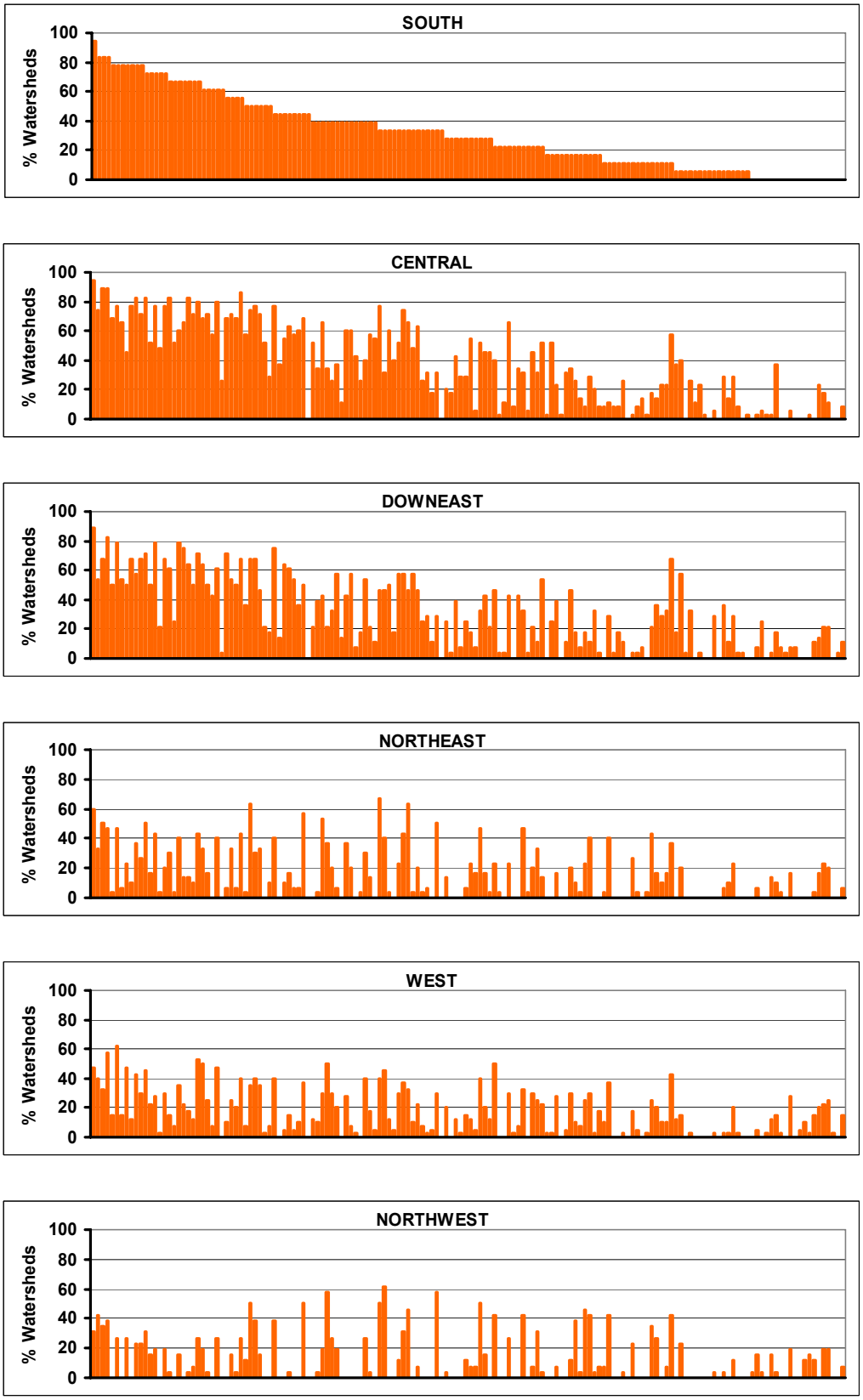

SOUTH
CENTRAL
DOWNEAST
NORTHEAST
WEST
NORTHWEST
% Watersheds
100
80
60
40
20
0

Figure 6.7.6

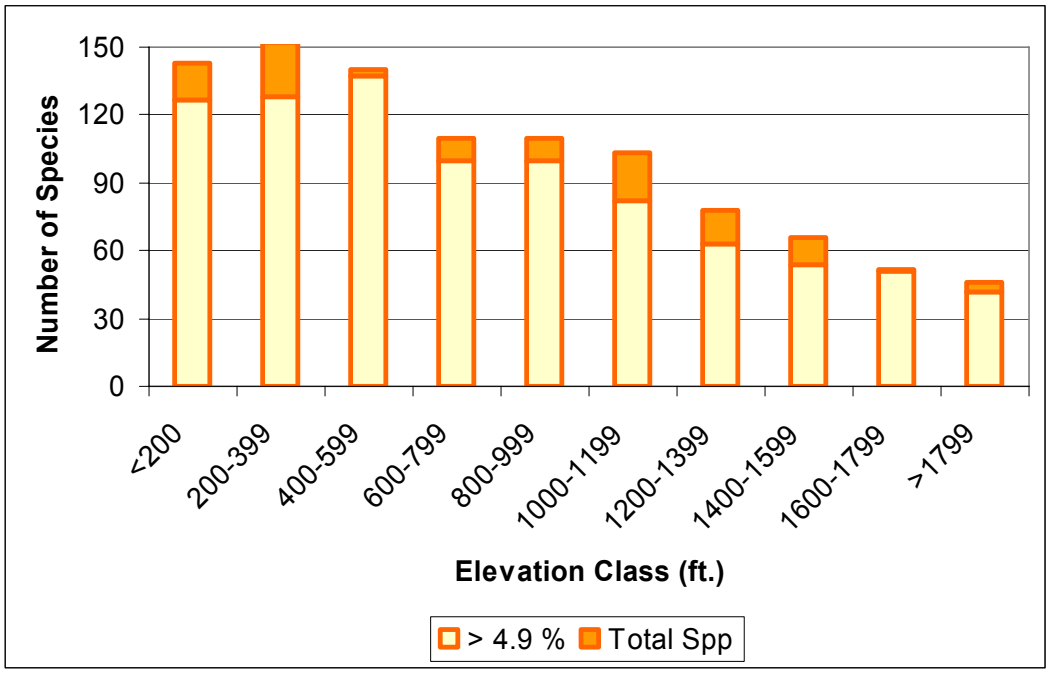


Figure 6.7.7: Number of odonate species recorded from different elevation zones.

Total species numbers include all species recorded from sites within each elevation zone. ">4.9 %" refers to the number of species for which the weighted number of sites within the elevation zone exceeds 4.9% of sites from which that species has been recorded statewide. Weighting was used to reduce the effect of unequal sampling effort in different elevation zones. See text for additional information on weighting factors.

Odonate and site coordinate data are from MDIFW Dragonfly and Damselfly Survey database. Elevation data were derived by MABP using GIS and a digital elevation data coverage. Numbers of collection sites per elevation class are as follows:
<200ft: 769; 200-399ft: 736; 400-599ft: 351; 600-799ft: 157; 800-999ft: 117: 1000-1199: 163; 1200-1399: 73; 1400-1500: 40; 1600-1799: 21; >1799: 21.

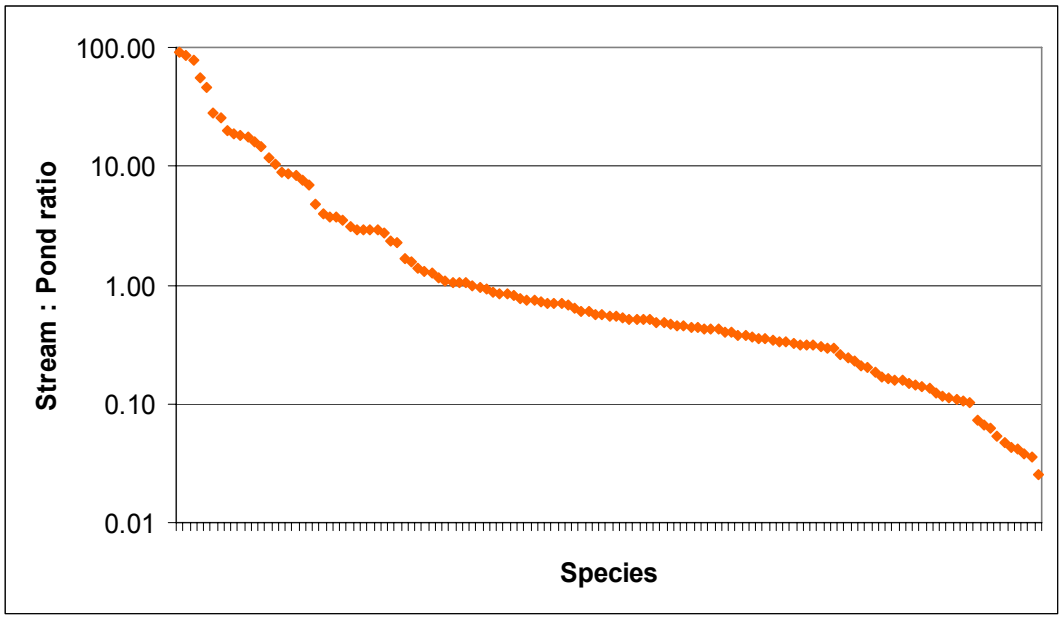


Figure 6.7.8: Odonate species by habitat type.

Graph shows the ratio of % stream records to % pond records, by species. Species are arranged sequentially by decreasing ratio. Habitat descriptions are from the MDIFW Maine Dragonfly and Damselfly Survey database (P. Brunelle et al.; 2004 update provided to MABP 11/2004). See text for additional information.

6.7.3 ***Stoneflies***

There are about 550 species of stoneflies (Plecoptera) known from North America (Stewart and Stark 1988, cited Thorp and Covich 1991). Stark's (1998) web-based stonefly list includes 618 species. As is the case with mayflies, the taxonomy of this order is poorly known and it is likely that many additional species will be described in the future. Larvae of all species are aquatic and almost all are stream dwellers, although a few species have adapted to cold oligotrophic lakes (Thorp and Covich 1991). Since stoneflies are generally restricted to cool, clean streams (the larvae lack extensive gills), this group is an important component of biomonitoring programs. Stonefly larvae are an important part of stream ecosystems, providing food for fish and often being top predators in the invertebrate food chain. They crawl on the substrate and, in general, are weak swimmers. The order Plecoptera is divided into two sub-orders. In one (containing the families Capniidae, Leuctridae, Nemouridae and Taeniopterygidae), the larvae are primarily herbivores-detritivores. In the other, there is a variety of trophic types; however, the Perlidae and Chloroperlidae are predators. Larvae can be identified to species only in some genera. Overall, just over half of North American Plecoptera species are known in the larval stage (Thorp and Covich 1991).

Information Sources*:* Stoneflies are less-well surveyed in Maine than are mayflies and odonates. Mingo (1983) compiled a species checklist from literature reports and his own collections. Included in this compilation are data from the regional studies of Proctor (1946), Mingo et al. (1979), Rabeni and Gibbs (1979) and Mingo and Gibbs (1980). Mingo's (1983) checklist includes county-level locational information. MDEP's biomonitoring program includes stonefly data from numerous sites around the state – 28 Plecoptera taxa in this database are identified to the species level, whereas 29 are at the genus level. The University of New Hampshire's insect collection database (UNH 2004) contains some stonefly records from Maine – specimens were not examined by MABP, so location identity is restricted to the state level. Published stonefly holdings of the University of Maine's insect collection (UMIC 1983) mirror the Mingo (1983) compilation.

In addition to the foregoing data sources, there are one hardcopy and three on-line checklists of Maine stoneflies: Chandler and Loose (2001; hardcopy), Stark (last updated 1998), USGS (last accessed 3/05) and NatureServe (last accessed 3/05). The Stark list was incorporated into the MABP database because a few of its species did not appear in other data sources accessed by MABP. The other lists contain no additional species[30].

Species Diversity and Distribution: Because of sparse survey effort in many parts of the state, coupled with the difficulty of identifying many larval taxa, the number of Maine stonefly species indicated in this report is likely to be an under-estimate. Mingo's (1983) checklist includes a total of 92 species, 21 of which were new state records. The current stonefly list in the MABP database extends to 123 species, in 46 genera and 9 families (Table 6.7.1). This species total includes 19 species that Mingo (1983) reports as being present in adjacent states and provinces, but which, at the time of his publication, had not been recorded from Maine. The MABP database has a geo-referenced Maine record (subsequent to 1983) for only one of these 19 species, *Oemopteryx glacialis*. While the other 18 "extra-Maine" species do appear in the Stark (1978) list of Maine stoneflies, it is possible that these were included simply on the basis of their appearance in the Mingo (1983) list. Without the sources for the Stark list, it is impossible to confirm the presence of these species in Maine. Ninety nine species have records in the MABP database that are geo-referenced to the county or finer level. The remaining species are referenced only at the state level and, as noted above, include the 18 species that have been collected from adjacent states and provinces. The USGS (2005) stonefly list includes 92 species. An additional four species appear in the literature (e.g. Mingo 1983) as undescribed taxa; it is unclear if these have been subsequently described. The most species-rich family is the

[30] Only 19 of Maine's species are listed on NatureServe as being present in Maine.

Perlodidae (27 species). Five families each contain between 13 and 18 species, while the remaining three families contain less than ten species each (Table 6.7.1). Six of Maine's stonefly species have been assigned a global status of G2 (imperiled) and eight are listed as G3 (vulnerable) (Table 6.7.1). No stonefly species is state-listed.

Species distribution maps for 99 species are shown in Appendix 11.5.6 – the remaining 24 species are geo-referenced only to the state level in the MABP database. Distribution maps can also be viewed on-line at:
http://www.pearl.maine.edu/windows/biodiversity/stonefly_distribution.htm

Most (73%) of the 99 mapped species have been recorded from ≤ 3 counties; 20 species have been collected from between 4 and 9 counties, and 6 species from ≥ 10 counties. The county-level data from Mingo's (1983) compilation do not always provide an accurate representation of currently known distributions. For example, Mingo's records for *Leutra ferruginea* show this species as being present only in northern Maine, while MDEP records (the source for most of the point locations in the distribution maps) suggest that this is primarily a southern species. Similarly, Mingo shows a northern / eastern distribution for *Agnetina capitata*, whereas the other data indicate a more statewide distribution (Appendix 11.5.6). Because of patchy data record, it is impossible to adequately characterize geographical distributions for any more than a few species. Some taxa appear to be restricted to lower elevation regions of the state (e.g. *Leuctra truncata*, *Acroneuria mela* [only in the Kennebec and Penobscot basins], *Attaneuria ruralis* and *Paragnetina media*). In contrast, *Pteronarcys biloba* is largely absent from lower elevation regions. Other species are clearly distributed statewide, for example *Acroneuria abnormali* and *Agnetina capitata*.

Figure 6.7.9 illustrates the documented number of stonefly species by county. Most species have been recorded from Piscataquis and Washington counties. While there is no independent measure of survey effort, this pattern undoubtedly in part reflects the amount of sampling effort. Given the fact that stoneflies tend to prefer cool stream habitats, it is likely that future sampling will substantially raise the number of species documented from the western regions of the state. Section 6.9 provides additional information on stonefly assemblages in streams.

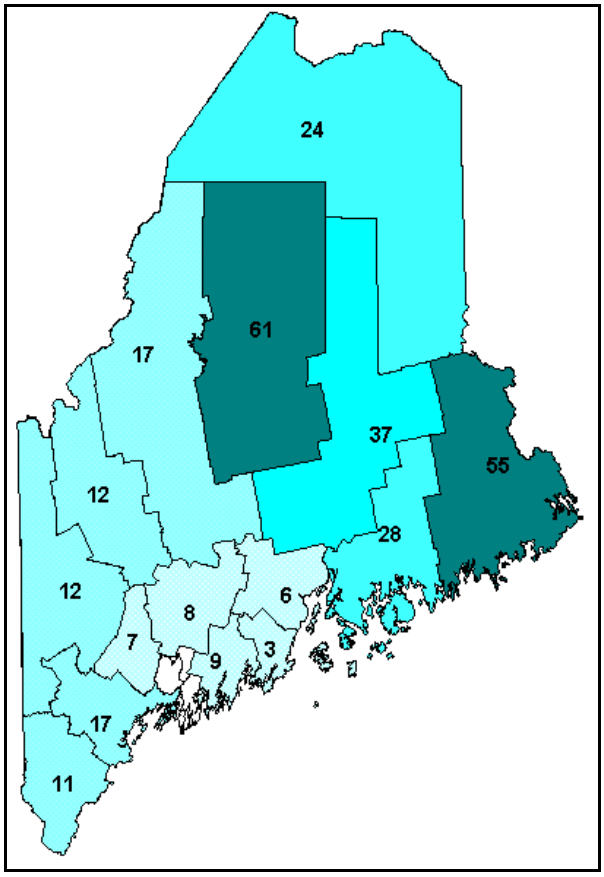


Figure 6.7.9: Documented number of stonefly (Plectoptera) species by county. Stoneflies have been inadequately surveyed in many parts of the state, so these species numbers should not be regarded as a measure of true species richness.

6.7.4 ***Caddisflies***

Caddisflies (Trichoptera) are closely related to the Lepidoptera (butterflies and moths). In contrast to mayflies, odonates and stoneflies, caddisflies develop their wings internally instead of externally in wingpads. Larvae and pupae of virtually all species are aquatic and represent an important component of the insect fauna of freshwater ecosystems. They are an important source of food for game fish, often comprising >45% of stomach contents of trout and salmon (LaFontaine 1981). Most caddisflies species occur in lotic habitats, although there are some species in half of the North American families that inhabit lentic habitats (Thorp and Covich 1991). The more primitive forms tend to be restricted to cold, fast-flowing streams (Peckarsky et al. 1990). Some caddisfly larvae are free-living, while many species build elaborate cases, tubes, nets and other structures. Many species inhabit temporary ponds. Caddisflies are excellent indicators of water quality. Within the order, there is very high diversity of feeding types. Adults are terrestrial and moth-like, and generally crepuscular in habit.

Over 1400 species of caddisflies are known from North America, and on average about 10 new species are discovered annually (Wiggins 1995). Trichoptera are divided into three sub-orders, based in part on the type of structures built by the larvae. Many larvae have never been associated with adults; consequently, many larvae cannot be identified to species.

Information Sources*:* The primary sources for Maine caddisfly data are the publications of Blickle (1964) and Blickle and Morse (1966). These represent author-collected samples and compilations of historical data, including the Proctor collections from Mount Desert Island. Records are geo-referenced to township (although more precise spatial information is provided for some of the Proctor data). Most of the data come from collections of adult caddisflies because identification of larval Trichoptera is problematic for many species. Nelson and Burian (1997) re-identified one of the species listed in Blickle and Morse (1964) – the MABP database reflects this revision. A recent study by Huryn and Harris (2000) provided an extensive list of caddisflies from the Tomah Stream area in Washington County. Huryn also compiled a list of Maine caddisfly species from literature and museum records (A. Huryn, University of Alabama, pers. comm.). Although species records are not geo-referenced (beyond the state level) in the Huryn list, MABP database does include this species list. Caddisfly data are also available in the MDEP stream biomonitoring database – of the 156 Trichoptera taxa in this database (data current through 2002), 75 are identified to species and 67 to genus (the remaining records are at the family level). Finally, the NatureServe database was queried for Maine species (most recently in March 2005) and the data incorporated into the MABP database. Seven caddisfly species in NatureServe are not represented in the other MABP data sources. Conversely, the other MABP data sources contain 60 species that do not appear in NatureServe.

Species Diversity and Distribution: Maine has a very rich caddisfly fauna. As of the early 1960s, the list of Maine caddisflies included 216 species (including sub-species and undescribed taxa), but Blickle and Morse (1966) acknowledged that the real total likely exceeds 300 species. This prediction was correct. Huryn and Harris (2000) indicate a state total of 309 species. The most recent estimate (reflecting the multiple sources in the MABP database) suggests that a total of 342 caddisfly species are currently known from Maine, belonging to 21 families and 81 genera (Table 6.7.1)[31]. This richness is phenomenal in comparison to many other states in the Northeast and Midwest, and is more similar to southern regions of the U.S. (A. Huryn, University of Alabama, pers. comm.). Maine's species total is equivalent to about 25% of the North American fauna. The recent Tomah Stream study (Huryn and Harris 2000) recorded 148 species; for 11 of these, this area was the only known location in Maine. One species was new to science and the Tomah records represented northeast range extensions for four others.

[31] Species and genus totals reflect recent separation of the genus *Plectrocnemia* from *Polycentropus*, as documented in NatureServe and ITIS (last accessed 3/2005). The total of 342 species includes the NatureServe list for which collection-site data are not provided. Excluding the NatureServe data, the Maine list totals 335 species in 82 genera. The MABP database has geo-referenced data (at the township level or finer) for 283 species in 73 general.

Only one caddisfly species is currently considered to be globally vulnerable (*Leucotrichia pictipes*, G3G4 status; Table 6.7.1) – it has been recorded from two sites in Maine. However, because of inadequate information, the global status of most of Maine's caddisflies are not ranked by NatureServe at this time. Presumably, the new species (*Hydroptila tomah*) collected from Tomah Stream by Huryn and Harris (2000) may become a candidate for global rare/endangered status in the future. Two species (*Hydroptila tomah* and *H. blicklei*) are listed in NatureServe as having been recorded only from Maine. None of Maine's caddisfly species are currently state-listed as threatened or endangered.

The Hydroptilidae is the most species-rich family (66 species), followed by the Limnephilidae (60 species), Leptoceridae (44 species), Hydropsychidae (41 species) and Polycentropidae (28 species) (Table 6.7.1). Nine families have ≤ 5 species each.

Documented caddisfly richness is summarized by township in Figure 6.7.10 (records with point locations have been aggregated into this township-based summary in order to be able to integrate the town-based data of Blicke [1964] and Blickle and Morse [1966]). There has been only sparse survey effort in much of western and northern Maine. Apart from the Tomah study, sampling in the Downeast region has focused primarily on two river systems (Narraguagus and Machias). Most of the remaining parts of this region are currently unsurveyed. After the Tomah Stream area (currently the area with the highest caddisfly diversity in the state), the town of Allagash has the greatest documented number of species. In part, this is because of the areal extent of this township – approximately three times that of neighboring units. Three other townships (Rangeley and Dennistown Plantation in western Maine, and East Machias) have high documented caddisfly richness – possibly in part a result of relatively more intensive survey effort there, although it is impossible to adequately assess sampling effort during the Blickle and Morse collections.

With current data, it is difficult to adequately assess the relative frequency of occurrence of caddisfly species in Maine. This is because (i) survey effort is variable across the state, and (ii) many larval species are unidentifiable as larvae and thus do not appear (as species-level records) in MDEP and other stream data. With these caveats, however, Figure 6.7.11(A) illustrates the number of townships from which each of 276 species (those for which township-level data are available) have been collected. The concave shape of this distribution mirrors that of mayflies (Figure 6.7.2) – i.e. a few common species and many rare ones, a common distribution in ecological assemblages. Six species have been recorded from > 50 townships – the four most commonly documented species are *Ceratopsyche morosa*, *C. sparna*, *Hydropsyche betteni* and *H. scalaris*. All these four species belong to the family Hydropsychidae – a large family of generally omnivorous caddisflies. Seventeen species have been collected from between 20 and 50 townships. At the other end of the spectrum, 147 species have been recorded from < 3 townships (and about half of these from just one township).

In Huryn and Harris's (2000) Tomah Stream study, species' relative abundances show an analogous concave pattern to the statewide pattern (in Figure 6.7.11, compare lower right and upper panels). However, the species order at Tomah Stream – i.e. which species are common, which are rare - is very different from the statewide order. This is illustrated by the lower left panel of Figure 6.7.11 in which the species are ordered in the same sequence as for the statewide graph of panel (A).

Species distribution maps for caddisfly species appear in Appendix 11.5.7. (Maps can also be viewed on-line at: http://www.pearl.maine.edu/windows/biodiversity/caddisfly_maps.htm) Because of the sampling effort and species identification caveats referred to above, these maps should not be "over-interpreted". However, a number of distribution patterns are evident:

> Statewide: Some taxa occur through most of the state, for example *Chimarra obscura*, *Certaopsyche morosa*, *C. bronta*, *Helicopsyche borealis,* and *Oecetis inconspicua*.

Lower elevations, south, central and downeast: Examples include *Nyctiophylax celta*, *Macrostemum zebratum* and *Psilotreta frontalis*.

Lowlands as in previous category, but also extending through to northeastern part of state: Examples include *Ceratopsyche sparna*, *Hydropsyche betteni*, *H. scalaris*, *Brachycentrus numerosus* and *Oecetis persimilis*.

West, north and downeast: Some species appear to be restricted to the northern half of the state, occurring especially in a band extending from western Maine, through the northern parts of the state and into the downeast region. Presumably, enhanced sampling effort would also document these species from the central part of northern Maine. Examples here include several species in the family Polycentropidae: *Plectrocnemia* (=*Polycentropus*) cinerea, *P. remotus* and *Polycentropus flavus*. *Triaenodes injustus* is another example in this category.

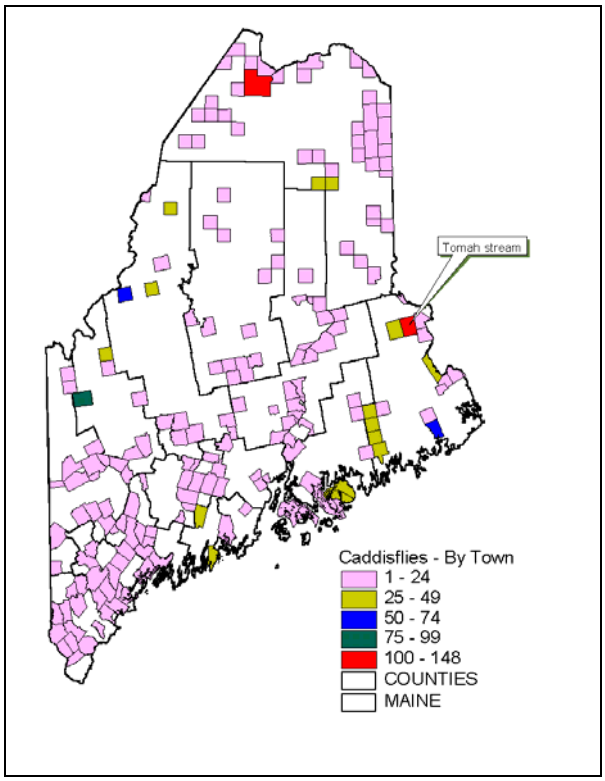
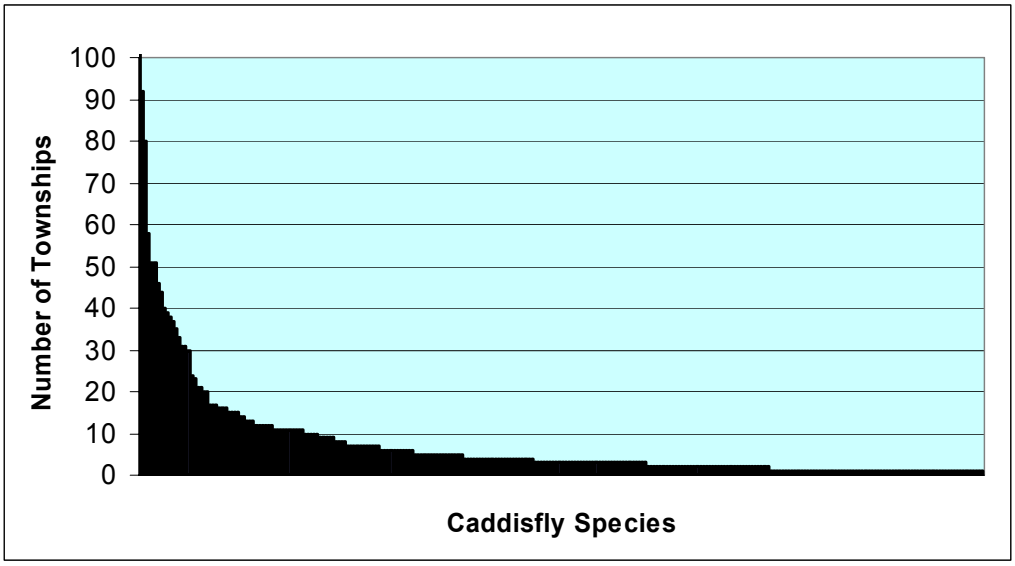
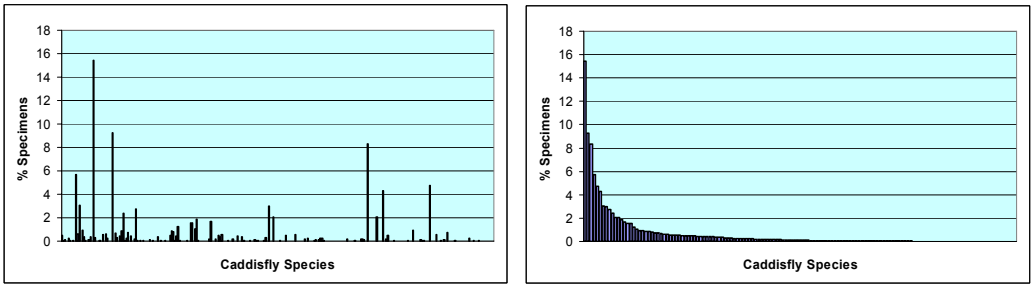


Figure 6.7.10: Map showing number of documented caddisfly species by township. Tomah stream is probably the most intensively sampled site in Maine. Note that geo-referenced (township-level or finer resolution) data are available in the MABP database for only 276 of Maine's 342 species. Data sources: multiple, as compiled in MABP database.



(A)



(B)

Figure 6.7.11: Frequency of occurrence of caddisfly species in (A) Maine and (B)Tomah Stream.

(A) Data in upper panel are number of townships from which each species has been recorded. Each column represents a species, ranked from most to least common. Data are from multiple sources as compiled in the MABP database – which contains township-level data for 276 species (80% of Maine's total species list).

(B) Two graphs in lower panel were developed from data from Huryn and Harris (2000) and represent frequency of collection of species at Tomah Stream (as % specimens examined). In the panel at left, species are ordered in same sequence as in upper panel (A). In the panel at right, species are ordered from most to least common.

6.7.5 ***Fishflies & Alderflies***

Fishflies and alderflies (Megaloptera) are a small order that contains just two families. The aquatic larvae are distinctive, having several pairs of lateral filaments and large, conspicuous mandibles. Larvae of all species are aquatic, while all other stages are terrestrial. Larvae often grow to a very large size and, because all are predators, they can exert significant pressure on macroinvertebrate populations (Thorp and Covich 1991). The larvae of most species (including all of the corydalids) are restricted to oxygen-rich environments. Some species occur in lentic habitats which may at times have lower oxygen levels. These species have long caudal respiratory tubes which are used to obtain air from the surface. Some species can survive in temporary streams and ponds by burrowing into the substrate during dry periods.

Information Sources*:* There have been no "dedicated" surveys of Megaloptera in Maine. Instead, available data come from a series of studies of aquatic invertebrate assemblages. These include: MDEP's stream biomonitoring program, several regional stream-based studies (e.g. Mingo and Gibbs 1980, Mingo et al. 1979, Rabeni 1977, Davies 1987, Siebenmann 1995, Garman 1984), and lake surveys (Davis et al. 1978, and the series of Cooper and Fuller surveys).

Species Diversity & Distribution*:* Five species of fishflies (Corydalidae; 3 genera), and five species of alderflies (Sialidae; 1 genus) are known from Maine[32]. Many of the geo-referenced Megaloptera records in the MABP database are identified only to the genus level. Consequently, distribution maps have been prepared only by genus (Appendix 11.5.8). Two genera (*Nigronia* and *Sialis*) have been recorded statewide, whereas *Chauliodes* and *Corydalus* spp. occur only at lower elevations from southern to downeast regions of the state.

[32] NatureServe lists only two Megaloptera species from Maine, including one – *Sialis sialis* – which does not appear in the other sources accessed by MABP.

6.7.6 *True Bugs*

All aquatic and semiaquatic bugs belong to the Heteroptera sub-order of Hemiptera. Less than 10% of species in this group are aquatic, living either in water or walking on its surface (Thorp and Covich 1991). Most species breed in lentic habitats, but there are also several lotic species. Most are predators – larger species may even prey on small fish.

***Information Sources**:* Hemiptera are only sparsely represented in the MABP database. The compilation of Chandler and Loose (2001) provides the majority of the Maine species list, but these records are not attributed with collection locations. Boobar (1997) provides some information from northern Maine, as does Mairs (1957) from further south. The MDEP stream biomonitoring database contains very few records of Hemiptera, presumably because the rock basket sampling methodology used in this program is ineffective for bugs.

***Species Diversity**:* Fourty four species and 27 genera of aquatic and semi-aquatic Hemiptera have been recorded from Maine (Table 6.7.8, Appendex 11.4). These belong to ten families, one of which is primarily riparian. Because of the inadequate data record, no distribution maps have been prepared for this group.

Table 6.7.8: Aquatic and semi-aquatic Hemiptera documented from Maine.
Note that for some genera, only genus-level data are available. Numbers in parentheses in the # Species column include genera which have no species-level records (i.e. these genera represent 1 or more species).

FAMILY	# GENERA	# SPECIES
Aquatic Groups		
Belostomatidae (giant water bugs)	2	2
Corixidae (water boatmen)	7	22 (25+)
Naucoridae (creeping water bugs)	No Maine records; primarily a southern family.	
Nepidae (water scorpions)	2	4
Notonectidae (backswimmers)	2	4
Pleidae (pygmy backswimmers)	No Maine records, but widespread in N..America.	
Semi-Aquatic Groups		
Gerridae (water striders)	5	5 (8+)
Hebridae (velvet water bugs)	1	? (1+)
Hydrometridae (marsh treaders)	1	1
Mesoveliidae (water treaders)	1	? (1+)
Veliidae (short-legged water striders)	2	5
Saldidae (a riparian family)	3	1 (3+)
TOTALS	27	44 (54+)

6.7.7 ***Spongillaflies***

Spongillaflies are aquatic representatives of the primarily terrestrial order Neuroptera – all these aquatic forms belong to one family (Sisyridae). The larvae live in several genera of freshwater sponges occurring in permanent lotic and lentic environments. Using their sucking mouthparts, they feed on the sponges.

Almost nothing is known about aquatic Neuroptera in Maine. The MABP database includes two genera, each with one species (Appendix 11.4). Larvae are rarely collected by standard sampling techniques – generally sponges have to be collected and larvae removed (Thorp and Covich 1991).

6.7.8 ***Aquatic Caterpillars***

The Lepidoptera (butterflies and moths) is primarily a terrestrial order. However, the larvae of several genera are associated with aquatic habitats, for example feeing on the emergent or submerged parts of aquatic plants. Only those species feeding on submerged plant material are considered truly aquatic. All are in the family Pyralidae. Larvae inhabit a broad range of permanent aquatic habitats, ranging from fast-flowing streams to macrophyte beds in ponds and along stream margins. Adults are generally inconspicuous small moths. The primary literature source for the Lepidoptera of Maine (both terrestrial and aquatic taxa) is the publication of Brower (1983). This checklist provides information on collection locations for only some of the species. Additional information on the aquatic Lepidoptera of Maine comes from several museum records and the Narraguagus River study of Mingo and Gibbs (1980)[33]. Eight genera have been recorded from the state, five of which have associated species-level identifications (Appendix 11.4).

6.7.9 ***Water Beetles***

Only about 3% of Coleoptera (beetle) species have an aquatic stage. However, since this is the largest insect order, water beetles represent a significant component of the aquatic insect fauna (Thorp and Covich 1991). Adult water beetles range from 1 to 40 mm in length and all have chewing mouthparts. All rely on atmospheric oxygen and use a variety of approaches for air entrapment – ranging from carrying bubbles to having a plastron, a layer of air trapped around hydrofuge hairs. In some groups, there is no way to definitively distinguish truly aquatic species – many species, for example, feed both below and above the water surface. Few larvae can be reliably identified to the species level (Thorp and Covich 1991). The number of North American water beetles exceeds 1100 species in 18 families.

Information Sources*:* Using museum and literature records, as well as his personal collections, Malcolm (1971) compiled a list of Maine's water beetles. For some species (apparently the rarer taxa), collection sites are summarized by township – other species, however, are not geo-referenced beyond the state level. Mingo (1979) summarized the distribution of aquatic Dryopoidea in Maine. More recently, Boobar and colleagues developed an updated compilation for predaceous diving beetles (Dytiscidae) (Boobar 1997, Boobar et al. 1998). Other records for aquatic beetles come from a variety of regional surveys and MDEP's stream biomonitoring program (Appendix 11.4), and from the records of Maine Forest Services's Entomology Laboratory (Dearborn and Donahue 1993).

[33] The recent "bioblitz" of Lepidoptera conducted by Acadia National Park on the Schoodic Peninsula may have collected aquatic members of the Pyralidae (David Manski, Acadia National Park, pers comm.). However, these data were unavailable to MABP prior to preparation of this report.

Species Diversity and Distribution: A total of 278 species of aquatic beetles have been documented from Maine, belonging to 14 families and 83 genera. Seven of these families are truly aquatic groups. The others have some representatives which are aquatic at some stage in their life history. The predaceous diving beetles (Dysticidae) is the most species-rich group (112 species), followed by the Hydrophilidae (59 species), Elmidae (29 species), Gyrinidae (27 species) and Haliplidae (20 species). The remaining nine families each have ≤ 11 species. As noted in Table 6.7.9, there is some uncertainty about the number of species of predaceous diving beetles (Dytiscidae) actually documented from Maine. Although the MABP list includes 112 species, the recent compilation by Boobar et al. (1998) contains only 67 species.

Because of the limited number of geo-referenced records, distribution maps have been prepared only for two beetle families: Elmidae and Psephenidae (Appendix 11.5.9). Many of the species in these families occur statewide (e.g. *Promoresia* spp, *Stenelmis crenata* and the two psephenids). The elmid *Ancyronyx variegates* is an example of a species that appears to be restricted to southern Maine, while *Optioservus trivittatus* appears to be a northern species.

Table 6.7.9: Aquatic beetles documented from Maine.
The seven truly aquatic families are listed in bold face. Species totals include genera for which no species-level identifications are available.

FAMILY	# GE NERA	# SPECIES
Dytiscidae (predaceous diving beetles) *	30	112
Elmidae (riffle beetles)	10	29
Gyrinidae (whirligig beetles)	2	27
Haliplidae (crawling water beetles)	2	20
Hydrophilidae (water scavenger beetles)	19	59
Noteridae (burrowing water beetles)	1	1
Psephenidae (water pennies)	2	3
Chrysomelidae **	3	6
Curculionidae	2	2
Dryopidae	2	3
Hydraenidae (minute moss beetles)	1	1
Limnichidae	2	2
Ptilodactylidae	2	2
Scirtidae (marsh beetles)	5	11
TOTALS: 14	83	278

* There is some uncertainty about the list of Dytiscidae species in Maine. Boobar et al. (1998) list a total of 67 species belonging to 20 genera, together with a further 2 genera not identified to the species level. However, Boobar (1997) includes an additional 8 species as being present in Maine (but not included in the 1998 paper). Of these 8 additional species, the MABP database contains records from other (non-Boobar) sources for 4 species. Boobar et al. (1998) also list a total of 80 other Dytiscidae species that "probably occur in Maine, but have not yet been collected, [and] have been reported from the nearby States of Massachusetts, New Hampshire, Vermont, and the Canadian Provinces of New Brunswick, Nova Scotia and Quebec". Of these 80 neighboring species, the MABP database has Maine records for 15, leaving another 65 species that could reasonably be expected to be recorded from the state in the future. Thus the Maine list of Dytiscidae might eventually be close to 175.

** Many additional species of Chrysomelidae are known from Maine (e.g.. Dearborn and Donahue 1993). This is not a primarily aquatic family and the genus / species totals listed in this table represent only records from aquatic datasets in the MABP database.

Data sources: Multiple, as compiled in MABP database.

6.7.10 ***Flies and Midges***

The Diptera is a large insect order and one that is mostly terrestrial. However, larvae and pupae of many species are aquatic. Overall, about 40% of all aquatic insect species belong to this order – and at least one third of these species are in one family, the Chironomidae (Thorp and Covich 1991). Diptera inhabit virtually all conceivable aquatic habitats. Because of their very short development periods, many species can be found in ephemeral environments. Adults in many aquatic families transmit disease or cause severe nuisance problems. In most families, many species can only be identified as adults. Consequently it is not known whether the larvae of these species are aquatic or terrestrial. In the Northeast U.S., there are 25 families with aquatic species (Peckarsky et al. 1990). Twenty two of these families are thought to present in Maine (Table 6.7.10).

Information Sources*:* The majority of species-level Diptera records in the MABP database are for four families: Chironomidae (midges), Culicidae (mosquitoes), Simuliidae (blackflies) and Tabanidae (deer flies and horse flies). Most of the species-level chironomid data come from MDEP's stream biomonitoring program. Courtemanch (1982) studied the associations between profundal chironomids and lake water quality, but reported only genus-level data. Data on the Culicidae derive primarily from the checklists of Bean (1946), McDaniel (1975) and the recent update of Foss and Dearborn (2003). The largest number of geo-referenced dipteran records is for the Simuliidae. The regional surveys of Mingo et al. (1979), Mingo and Gibbs (1980), Gibbs et al. (1988), Bauer (1977), Waters (1968) and Boyer (1989) all contain blackfly data, as does MDEP's stream biomonitoring program database. Bauer and Granett (1979) reviewed multiple data sources to derive a county-level compilation of Maine blackflies. Data on the Tabanidae come from three sources: Mingo and Gibbs (1980), and the compilations of Chandler and Loose (2001) and, notably, of Pechuman and Dearborn (1996).

One other family with some aquatic species, the Tipulidae (craneflies), has been reviewed in detail by Alexander (1962) who provides township-level data for many taxa. However, while some cranefly species are known to have aquatic larvae, the larvae of fewer than 10% of North American species have been described (Thorp and Covich 1991). Consequently, it is impossible to reliably extract from Alexander's data (based on adult samples) the subset of aquatic taxa recorded from Maine. Cranefly records from all other sources in the MABP database are at the level of genus or higher.

The family Chaoboridae (phantom midges) is poorly represented in the MABP database because this group is typically collected in plankton samples (and thus not included within MABP).

Species Diversity and Distribution*:* This section focuses on the four families for which MABP has extensive species-level data..

Chironomidae (midges) – A total of 163 midge species, belonging to 128 genera, are known to occur in Maine (Table 6.7.10)[34]. Most of these species occur infrequently in samples – 133 species have been recorded from fewer than 10% of the total number of sites from which chironomid data are available (Figure 6.7.12). Twenty species are moderately to very common, occurring at 10% or more of sampled sites. Only two of these, *Cricotopus bicinctus* and *Polypedilum flavuum*, are present at >40% of sites.

[34] The actual number of species is almost certainly higher than 163 because records in the MABP database do not include species-level records from lakes that have been sampled for benthic chironomids. For example, Courtemanch (1982) notes that *Zalutschia zaluschiacola* was present in some of his lake samples, although the published data for each of his lakes are presented aggregated at the genus level. *Z. zaluschiacola* does not appear in the database of MDEP's stream biomonitoring program. Furthermore, lake benthos data from EPA's Environmental Monitoring and Assessment Program were not available for inclusion in the MABP database.

Distribution maps for chironomid species are presented in Appendix 11.5.10. These maps need to be interpreted with caution because sampling effort is sparse in several parts of the state, particularly the west, northwest and Downeast regions. In large part, this pattern of sampling effort reflects that fact that MDEP sampling sites are selected subjectively, often emphasizing streams impacted by point source or non-point source pollution. Furthermore, the distribution maps were compiled from many years' of data. At some sites, environmental conditions have changed markedly over time (because of pollution abatement). Consequently, mapped distributions of some taxa may not fully reflect their current status.

Unlike the distributions of many other macro-invertebrates, there is little evidence of geographic patterns in chironomid distributions. All of the moderately common and common species appear to be found statewide, for example *Ablabesmyia mallochi*, *Eukiefferiella devonica* and *Microtendipes* spp., as well as the two most common taxa noted above. Note that while the distributions of many of these taxa appear to emphasize a diagonal band extending from southern Maine to northeastern Aroostook County, this pattern almost certainly reflects sampling effort.

Water quality is well known to be an important factor influencing chironomid distributions. Chironomid species assemblages consequently are an important indicator group for biomonitoring programs (e.g. Davies et al. 1999, Rabeni et al. 1985). The most commonly recorded species in Maine, *Cricotopus bicinctus*, for example, is known to be very tolerant of many pollutants (Peckarsky et al. 1990). Other taxa are relatively intolerant of poor water quality. Courtemanch (1982) demonstrated that chironomid assemblages in Maine lakes are closely associated with lake trophic status as well as with a number of other water quality parameters. The chironomid lake types used by Courtemanch were modified from Saether's (1979) original set of assemblage types. Courtemanch's (1982) study was particularly useful in discriminating among lakes within the oligotrophic-mesotrophic range of the trophic spectrum.

The number of chironomid taxa present in stream samples collected during July and August using MDEP's rock basket methodology (Davies et al. 1999) ranges between zero and 36 (only 7 out of 1007 sample-dates contain no chironomids). Most commonly, samples contain between 6 and 15 taxa (Figure 6.7.13)[35]. Highest species richness occurs at sites (and dates) that are classified as being not Class A (i.e. Class B, C or non-attaining; see Chapter 4 for definition of these water quality classes).

Culicidae (mosquitoes) – Maine has 42 mosquito species belonging to 9 genera[36] (Appendix 11.4). Five of these species represent new Maine records since 2001[37]. A relatively intensive survey of mosquitoes in Androscoggin County during 2001-2002 collected 32 species (Foss and Dearborn 2002). In this study, carried out between May and October, three species (*Ochlerotatus canadensis*, *Anopheles punctipennis* and *Coquillettidia perturbans*) represented about 65% of adult collections, whereas a different set of three species dominated the larval collections: (*O. japonicus* [an introduced species, first recorded from Maine in 2001], *O. triseriatus* and *Culex restuans*).

Eight of Maine's mosquito species rarely or never bite humans – adult hosts of these taxa include birds, frogs and occasionally turtles and small mammals. For two species, the larval habitat includes salt marshes; for the remaining species, larval habitat is a range of ephemeral, semi-

[35] Taxa identified to the level of genus are included in the taxon totals only if there are no species-level records for that genus in the sample. Similary, family-level records are counted as a taxon only if there are no species- or genus-level records in the sample for that family. This taxon-counting protocol is similar to the one employed by MDEP (Davies et al. 1999).

[36] McDaniel (1975) includes an additional species, *Aedes trichurus*, which does not appear in the recent compilation of Foss and Dearborn (2003).

[37] *Ochlerotatus japonicus*, *O. taeniorhynchus*, *Culiseta minnesotae*, *Psorophora ferox* and *Uranotaenia sapphirina*.

permanent and permanent waterbodies, including snowmelt pools. Twenty two species are vectors of West Nile virus, while 10 species are vectors of eastern encephalitis (Table 6.7.11).

Simuliidae (blackflies) – Forty nine blackfly species, belonging to seven genera have been recorded from Maine (Table 6.7.10)[38]. Based on available geo-referenced records (Table 6.7.12 and the distribution maps presented in Appendix 11.5.11), the most common species in the state are *Simulium tuberosum*, *S. fibrinflatum*, *S. jenningsi*, and *S. vittatum*. Other moderately common taxa include *S. aureum*, *S. decorum*, *S. nyssa*, *S. venustum* and *S. verecundum*. Two other species (*Cnephia mutata* and *Prosimulium fuscum*) were common in Bauer and Granett's (1979) survey, although based on the composite geo-referenced data in the MABP database they are appear to be present in relatively few HUC-12 watersheds (Table 6.7.12). There are few records for the remaining species, which may indicate actual rarity or difficulty of sampling and/or identification.

In terms of human nuisance value, Boobar (1979) and Bauer (1977) indicate that *S. penobscotensis* is the major biter in central regions of the state during the summer. Interestingly, however, this species has not been recorded from as many sites or watersheds as several other blackfly species (Table 6.7.12 and Appendix 11.5.11). Both Bauer and Granett (1979) and Boyer (1989) found that the most common species collected in the Penobscot River watershed were *S. jenningsi* and *S. fibrinflatum*. The former species was also the most abundant in the Piscataquis River watershed (Bauer and Granett 1979).

Several species appear to have highly localized distributions (e.g. *Prosimulium magnum*, *S. decorum*, *S. emarginatum* and *S. latipes*; see maps in Appendix 11.5.11). It is difficult to determine whether these restricted distributions reflect actual ranges, the spatial pattern of sampling effort, or differences in taxonomic resolution within the various studies that contributed data to these maps.

At the county level, Washington, Penobscot, Piscataquis and Somerset counties show the highest documented species richness (Figure 6.7.14). The high number of species recorded from Somerset County is especially notable in view of its smaller area and the fact that sampling effort has not been heavy in this region of the state. Species richness in the smaller counties is typically about one half that of the larger counties – presumably reflecting the species-area effect.

At the site level, the samples collected by MDEP's stream biomonitoring program generally contain three or fewer blackfly taxa (taxon totals include both species and genera for which no species-level identifications were made in the sample). Out of 557 site-date combinations analyzed by MABP, 424 collections contained only one taxon, while 96 and 27 contained two and three taxa, respectively.

For many blackfly species, larvae are present in streams for varying periods between May and October (Bauer and Granett 1979). However, larvae of other species appear earlier in the spring – included in this earlier group are several *Prosimulium* species.

Tabanidae (deer flies & horse flies) – A total of 76 species of deer flies (*Chrysops* spp.) and horse flies are known to occur in Maine, while another 11 are expected to be here based on their presence in neighboring states and provinces (Pechuman and Dearborn 1996). Only a few of these species are truly aquatic, however. *Tabanus fairchildi* lives in swifly flowing streams, while *Chrysops atlanticus*, *C. fuliginosus* and *T. nigrovittatus* are coastal and tend to be associated with salt marshes (Pechuman and Dearborn 1996). The larvae of most species within this family, however, are found in habitats that are closely associated with aquatic systems. Adults generally lay egg masses on vegetation over water or in swampy areas. The larvae are

[38] An additional species (*Simulium congareenarum*) was recorded by Boyer (1989) from the Penobscot River, but does not appear in any other data sources accessed by MABP. Accepting this record would bring the species total for the state to 50.

most often found in mud or moss at the edge of ponds and streams, and in swamps. A few species, e.g. *Atylotus thoracicus*, are restricted to sphagnum bogs (Pechuman and Dearborn 1996). Tabanids overwinter as larvae. Of the 40 species that are most likely to bite humans, about three quarters are active (as adults) between mid-June and mid- to late-August. The remainder are active somewhat earlier in the year – May or early June.

As with many other faunal groups, deer fly and horse fly species present in Maine include some southern species for which Maine represents the northern end of their range, and some northern species that are at the southern end of their range. Based on data presented by Pechuman and Dearborn (1996), 24% of Maine's species appear to occur statewide, whereas 13% have been recorded from only one county. Twenty nine percent of species have been recorded from between 2 and 5 counties.

Table 6.7.10: Families of aquatic Diptera, with numbers of genera and species documented from Maine *.

Family	# Genera	# Species **	General Notes
Blephariceridae (net-winged midges)	1	1	Larvae are flattened and cling to rocks using a ventral sucker disc.
Ceratopogonidae (biting midges)	13	1	Number of aquatic species not known because larvae of most taxa are not identifiable to the species level.
Chaoboridae (phantom midges)	3	5	These are the only insects frequently found in the open-water areas of lakes. Some species are good indicators of fishless lakes. Five *Chaoborus* species have been collected in Maine by E. Schilling (pers. comm.). DEP zooplankton data contain 2 species + one or more unidentified taxa. MAPB database contains very few chaoborid records because these taxa are generally not sampled with the techniques used for most of the source studies.
Chironomidae (midges)	128	163	Largest family of aquatic insects and frequently the dominant insect group in the profundal and sublittoral zones of lakes. Larvae are an extremely important component of aquatic food webs. Larvae of most species are tolerant of reduced dissolved oxygen concentrations. Larval taxonomy has improved substantially in recent years.
Culicidae (mosquitoes)	9	42	Larvae of all species are aquatic. Adults of many species are disease vectors.
Dixidae (dixid midges)	2		Typically found near surface in lentic and densely vegetated lotic habitats. Characteristically form U-shape when at rest.
Nymphomyiidae	1	1	Rare. In N. America, known only from Maine, Quebec and New Brunswick.
Psychodidae (moth flies)	2		Larvae of most species develop in semi-aquatic and moist terrestrial habitats. Larvae of a few forms are aquatic, however the number of aquatic species is not known since larvae cannot be identified to the species level.
Ptychopteridae (phantom crane flies)	2		Generally uncommon and typically live in very shallow water. Life histories poorly known.
Simuliidae (black flies)	7	49	Unique body form, attaching to substrate with a caudal sucker. Inhabit a broad range of lotic habitats; most species are filter feeders. Females require a blood meal for maturation of eggs.
Tanyderidae (primitive crane flies)			Rare in eastern N. America. Apparently not recorded from Maine. Life history and feeding habits virtually unknown.
Thaumaleidae (solitary midge)	1		Very rare. Typically found in mountain streams in very shallow water. Larvae resemble chironomids.

Family	# Genera	# Species **	General Notes
Tipulidae (crane flies)	51	290	Largest Diptera family, but most species are not aquatic. Since the larval stages of many species have not been described, it is currently impossible to classify many taxa into aquatic or terrestrial categories. Aquatic forms are typically found in lotic habitats, although a few genera inhabit shallow lentic habitats. Genus and species totals include all taxa regardless of habitat.
Athericidae	1	2	Typically occur in stream riffles and among vegetation. Eggs are laid on vegetation and structures above the stream, with the larvae dropping into the stream upon hatching.
Dolicopodidae (long-legged flies)			Mostly terrestrial family, but with a few aquatic species. Occur in Northeast, but no records present in MABP database. Larval taxonomy very poorly known.
Empididae (dance flies)	5		Most aquatic larvae live in fast-flowing water. Larval taxonomy very poorly known, so number of aquatic forms is unknown.
Ephydridae (shore flies)	2	1	Most larvae are semi-aquatic, but a few species are aquatic, living in vegetation, detritus and algal mats. Larval taxonomy poorly known.
Muscidae	4	1	Extremely large terrestrial family with a few aquatic representatives. Typically predators inhabiting a broad range of lotic and lentic habitats.
Sciomyzidae (marsh flies)	13	4	Predators or parasitoids of snails, slugs and fingernail clams. Typically found in lentic habitats and stream margins. Have been extensively studied as possible biological control agent for disease-carrying snails.
Stratiomyidae (soldier flies)	6	1	Mostly terrestrial family, but with many aquatic representatives. Typically inhabit shallow, vegetated lentic habitats. Larval taxonomy very poorly known.
Syrphidae (rat-tailed maggots)	2		Aquatic larvae easily recognizable by very long, extensile, caudal breathing tube. Generally found in shallow lentic habitats and stream margins.
Tabanidae (deer flies, horse flies)	7	87	Larvae of most species are not truly aquatic, but rather live in mud or moss on the edige of ponds and streams, and in swamps. One Maine species is unusual in that it lives in swiftly flowing streams. Genus and species totals in this table include all Maine taxa, regardless of habitat. Many species are significant biting pests. Only females suck blood.

* General information is based on material in Thorp and Covich (1991) and Peckarsky et al. (1990), supplemented by Pechuman and Deaborn (1996).
** Many taxa in the MABP database are identified only to the genus level. Consequently, the number of documented species may be less than the number of genera.

(Table 6.7.10, continued)

Table 6.7.11: Mosquito vectors of West Nile virus and Eastern Encephalitis.

Species	WNC vector	EE vector
Aedes cinereus	X	X
A. vexans	X	X
Ochlerotatus atropalpus	X	
O. canadensis	X	X
O. cantator	X	
O. japonicus	X	
O. sollicitans	X	X
O. stimulans	X	
O. taeniorhynchus	X	X
O. triseriatus	X	
O. trivittatus	X	X
Anopheles punctipennis	X	
A. quadrimaculatus	X	
A. walkeri	X	
Coquillettidia perturbans	X	X
Culex pipiens *	X	
C. restaurans	X	
C. salinarius	X	X
C. territans *	X	
Culiseta inornata		X
C. melanura *	X	X
Psophora ferox	X	
Uranotaenia sapphirina *	X	

* Rarely bite humans.
Data source: Foss and Dearborn (2003).

Table 6.7.12: Two measures of frequency of occurrence of selected blackfly species in Maine.

Species	# Watersheds (MABP) * (N=117)	# Sites (Bauer & Granett) ** (N=?) *
Simulium tuberosum	83	169
Simulium vittatum	58	117
Prosimulium fontanum	5	102
Simulium venustum	39	97
Cnephia mutata	9	91
Prosimulium fuscum	3	91
Simulium nyssa	15	64
Simulium fibrinflatum	44	59
Prosimulium magnum	13	42
Simulium latipes	5	37
Simulium jenningsi	68	29
Simulium verecundum	22	29
Simulium decorum	11	28
Prosimulium multidentatum	8	24
Simulium penobscotensis	9	21
Simulium corbis	6	16
Simulium aureum	15	14
Simulium emarginatum	7	11
Simulium gouldingi	4	11
Prosimulium rhizophorum	1	8
Simulium croxtoni	3	8
Cnephia dacotensis	1	7
Simulium quebecense	2	7
Simulium rivuli	1	7
Prosimulium gibsoni	4	6
Prosimulium decimarticulatum	1	5
Simulium parnassum	4	4
Simulium euryadminiculum	1	3
Simulium rugglesi	1	3
Simulium pictipes	3	2
Prosimulium pleurale	1	1
Simulium excisum	1	1
Simulium furculatum	1	1

* Number of HUC-12 watersheds from which species has been recorded according to composite data in MABP database.

** Number of sites from which Bauer and Granett recorded the species in their 1979 study. Some of the Bauer and Granett sites are included in the HUC-12 summary. Others are not, because they are not geo-referenced in Bauer and Granett (1979).

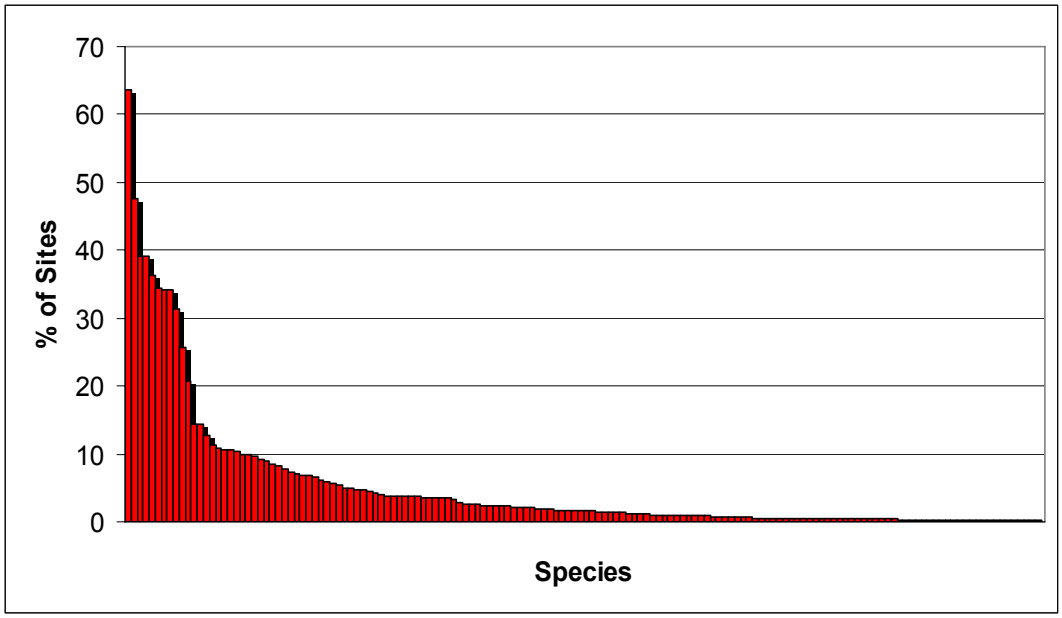


Figure 6.7.12: Frequency of occurrence of chironomid species in Maine.
The figure shows the percent of sites at which each species has been recorded in Maine (data are those in the MABP database; most records are from MDEP's stream biomonitoring program). Total number of sites with chironomid data is 446. Some sites have been sampled in >1 year. Each column represents a species. There are 152 species represented in this figure. An additional 11 species in the MABP database are geo-referenced only to the state level.

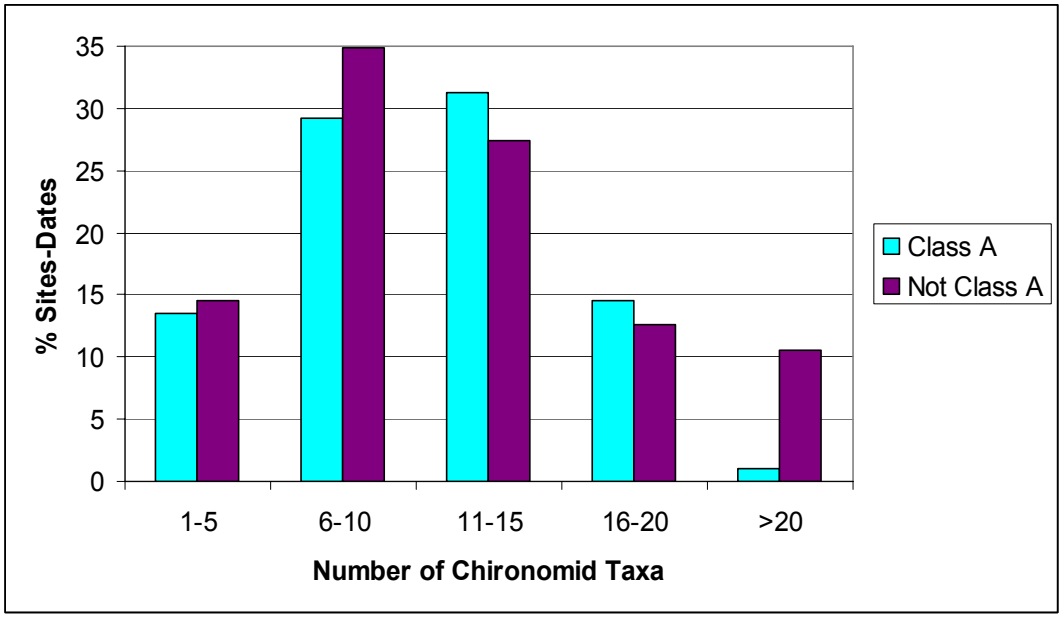


Figure 6.7.13: Number of chironomid taxa in stream macroinvertebrate samples.
Data are from MDEP's stream biomonitoring program. All samples were collected during July or August using rock basket method. Where data span multiple dates at a site, each date constitutes a separate site-date record. Chironomid taxa numbers include species-level records and genus-level records – see text for more information. Water quality classes for each site-date were provided by MDEP and reflect the output of the agency's aquatic life model. Total number of Class A site-dates = 96; number of non-Class A site-dates = 255.

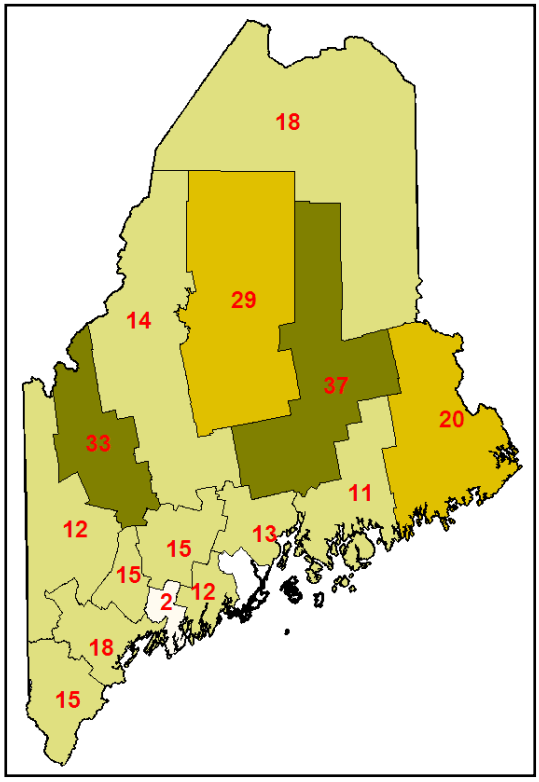


Figure 6.7.14: Number of blackfly species documented by county.
Data are from multiple sources, as compiled in MABP database.

6.8 OTHER INVERTEBRATE GROUPS

6.8.1 *SPRINGTAILS*

Previously considered insects, the springtails (Collembola) are now considered as a separate class (or sub-class) or arthropods. The group is only partially aquatic since most species inhabit moist terrestrial habitats. Springtails are small, wingless arthropods, generally <3 mm length. Aquatic forms are actually better considered as semi-aquatic, since they live on the water surface of both running and standing waters. At least five genera occur in the Northeast (Peckarsky et al. 1990). The MABP database contains records for three of these (Appendex 11.4) – no records are at the species level.

6.8.2 *WATER MITES*

Water mites are in the sub-class of the Arachnida, called the Acari. They belong to five unrelated groups, the most successful of which is the Hydrachnida. In many habitats, water mites are some of the most abundant and diverse benthic arthropods. Larvae are ecoparasites, often on species of Diptera. The larvae frequently parasitize up to 50% of adults in selected families of several insect groups, including bugs, beetles, odonates, mosquitoes and chironomids (Smith and Cook 1991). Adults can be voracious predators. Water mites are generally not a significant prey group for freshwater vertebrates – indeed, red-colored mites are usually rejected by fish.

Water mites occupy an extremely diverse range of habitat types, including springs, riffles, interstitial habitats, lakes and ephemeral pools. Some larvae live on the surface film and essentially function as terrestrial organisms (Smith and Cook 1991). Mites are highly sensitive indicators of water and habitat quality – populations are substantially reduced in areas with chemical pollution or habitat disturbance.

Smith (1989) lists 76 genera (in 31 families) as being present in the Northeast. Water mites are under-collected in Maine, with 27 genera (in 17 families) appearing in the MABP database (Appendix 11.4). Most of the records in this database come from MDEP's stream biomonitoring program and most are at the genus level. Appendix 11.5.12 presents distribution maps for the more common genera. Most genera are broadly distributed through the state, but three appear to be more restricted: *Arrenurus* – recorded only from the northern half of the state; *Hydroma* only from the eastern regions; and *Sperchonopsis* from southern/central areas. However, further interpretation of water mite distributions in Maine should await additional data, particularly from the west and northwest regions of the state.

6.8.3 *ANNELIDS*

Oligochaeta

Oligochaete worms (considered by different authorities either as an order or as a class within the phylum Annelida) are a significant component of freshwater ecosystems but are often underemphasized during aquatic surveys because of concerns over taxonomy (Peckarsky et al. 1990).

Four oligochaete families commonly occur in freshwaters of the northeastern U.S. (Table 6.8.1). Best known are the tubificid worms (family: Tubificidae) which are typically found in soft sediments ranging from sand to mud. The tubificids also include a number of groundwater species. Individual tubificid species typically occupy both flowing and standing waters – they

cannot be divided into characteristically riverine or lacustrine groups (Thorp and Covich 1991). Several species are characteristic of habitats with organic pollution – some taxa can even tolerate anoxic conditions. Because there is a well documented sequence of species inhabiting progressively polluted or eutrophic conditions, tubificids (and other oligochaetes) represent a valuable tool for biomonitoring programs. Eleven species are known to occur in Maine, but it is certain that additional species exist in the state – 38 species are found in the Northeast (Table 6.8.1). Species distribution maps are shown in Appendix 11.5.12. Most tubificid records are from the southern and central regions of the state.

The naidids (family: Naididae) are an ecologically diverse family of worms commonly found in both running and standing waters. While many species live in the sediments, others are closely associated with aquatic plants. Thirty four species are known from Maine, just over half the Northeast regional total. Nine of these species are common (see distribution maps in Appendix 1.5.12), while the others have been collected from just a few sites each.

The Lumbriculidae is a small family, with only three species known from the Northeast (Table 6.8.1). Two of these are common and widespread although only one of them appears in the MABP database (*Lumbriculus variegatus*). These are large worms, found in both running and standing waters, are ecologically similar to the tubificids (Peckarsky et al. 1990).

The fourth family of aquatic oligochaetes is the Enchytraeidae which are common in marshes, small streams, springs and riparian areas. They are occasionally found in lake and river sediments. The taxonomy of this group is poorly understood which is presumably a reason why no records appear in the MABP database.

Branchiobdellida

The branchiodellidans, or crayfish worms, are a small group of leech-like organisms that live primarily on crayfish. While approximately 100 species are known from North America, only 6 occur in the New England – and all of these are present in Maine (Table 6.8.1; Gelder et al. 2001). An individual crayfish host can be infested with several different species. Branchiobdellidans in Maine have been collected from six of Maine's eight crayfish species (Gelder et al. 2001). Most Maine records come from the Appalachian brook crayfish (*Cambarus bartonii bartonii*), but this may simply reflect the fact that many of Gelder et al.'s samples come from northern Maine where this crayfish species is dominant (see Figure 6.6.1). Three branchiobdellidan species are common in northern Maine, whereas the other three appear to be much less common and also restricted to the southern half of the state (see distribution maps in Appendix 11.5.13).

Hirudinea

Leeches are the most highly specialized of the major annelid groups (Klemm 1990). They are most frequently found in warm, protected waters – lakes, slow-flowing streams and marshes. Silty substrates are avoided and leeches tend to be uncommon in calcium-poor waters. Many species are truly aquatic, whereas others are considered amphibious because they can leave the water to feed on invertebrate prey. Each of the five North American families is represented in Maine, which has a total of 25 species (Table 6.8.1). Among the families, there are differences in feeding behavior (Klemm 1990). Within the Glossiphonidae, some species are carnivorous whereas others are temporarily parasitic. All members of the Piscicolidae are parasitic on fish and crustaceans. Members of the Erpobdellidae feed on small invertebrates, while species in the Haemopidae and Hirundinidae are either predators or blood suckers.

The most commonly recorded species in Maine is *Helobdella stagnalis*, which occurs at 60% of stream sites from which any leeches have been encountered (Figure 6.8.1 A). Two other species

are moderately common while the remaining 14 species included in the MDEP stream data occur at 10% or few sites (see also distribution maps in Appendix 11.5.13). Since most geo-referenced records come from stream samples (from MDEP's stream biomonitoring program), distributions in lakes are unknown. Most (80%) stream samples contain no leeches, while about 10% contain a single species and 5% contain two species (Figure 6.8.1 B).

Polychaeta

Polychaetes are primarily a marine group, with relatively few species occurring in the freshwaters of North America (12 species in 8 genera; Davies 1991). Underscoring the marine nature of this family, the freshwater forms inhabit either ocean-connected streams or lake that were connected to the sea in the relatively recent past (Davies 1991). One group of polychaetes consists of species that are active crawlers and swimmers, while a second group includes tube-dwellers. Many freshwater species are small (a few mm).

There are virtually no data on freshwater polychaetes in Maine. A few records from MDEP's stream samples include the genus *Aeolosoma*. While this is a valid genus, its family (Aeolosomatidae) is not one of the four families recognized by Davies (1991) as having freshwater representatives in North America.

6.8.4 *BRYOZOA*

Bryozoans ("moss animals") are sessile, colonial invertebrates that have ciliated tentacles for capturing suspended food particles. They are very common in freshwaters, and their growth forms range from thread-like to large masses weighing several pounds (Scott 1965). The individual animals are minute. Most species occur in both running and standing water. A few species are highly tolerant of highly polluted conditions (Wood 1991).

Little is known about the bryozoans of Maine. Massachusetts is the closest state for which a systematic survey of this group has been undertaken (Smith 1989). This survey revealed a total of 17 species (in 10 genera) and included a number of new records for North America (Wood 1991).

6.8.5 *SPONGES*

Although sponges are primarily a marine group, they are also found in freshwaters where they are often common and at times abundant. In some habitats they are a major component of the benthic fauna and can play important roles in ecosystem processes (Frost 1991). Functionally, sponges are colonial organisms, although from some perspectives these colonies can be considered individual organisms. North America has about 27 sponge species. Smith (1989) lists 15 species (in 8 genera) for Massachusetts.

6.8.6 *JELLYFISH*

Although there are many freshwater coelenterate species, most are minute hydras. One species, however, can be considered a macro-invertebrate: the freshwater jellyfish, *Craspedacusta sowerbyi*. Its life history involves two forms: the free-floating medusa and the minute sessile hydroid. The jellyfish has been recorded from most of the U.S. states. In Maine, it is known from at least 22 sites spanning much of the state (IUP 2005) – it undoubtedly occurs in many other locations.

Table 6.8.1: Aquatic annelids: number of genera and species in Maine and the Northeast, by family.

Order / Family	# Genera *	# Species **
OLIGOCHAETA (worms)		
Lumbriculidae	2 (3)	1 (3)
Naididae	14 (20)	34 (51)
Tubificidae	6 (15)	11 (38)
Enchytraenidae	0 (?)	0 (?)
HIRUDINEA (leeches)		
Haemopidae	1 (1)	1 (4)
Hirudinidae	1 (1)	1 (2)
Erpobdellidae	4 (3) ***	5 (8)
Glossiphoniidae	8 (9)	14 (22)
Piscicolidae	4 (4)	4 (7)
BRANCIOBDELLIDAE (crayfish worms) ****		
Bdellodridae	1 (1)	1 (1)
Branchiobdellidae	1 (1)	1 (1)
Cambarincolidae	2 (2)	4 (4)
POLYCHAETA		
Aeolosomatidae	1 (?)	0 (?)

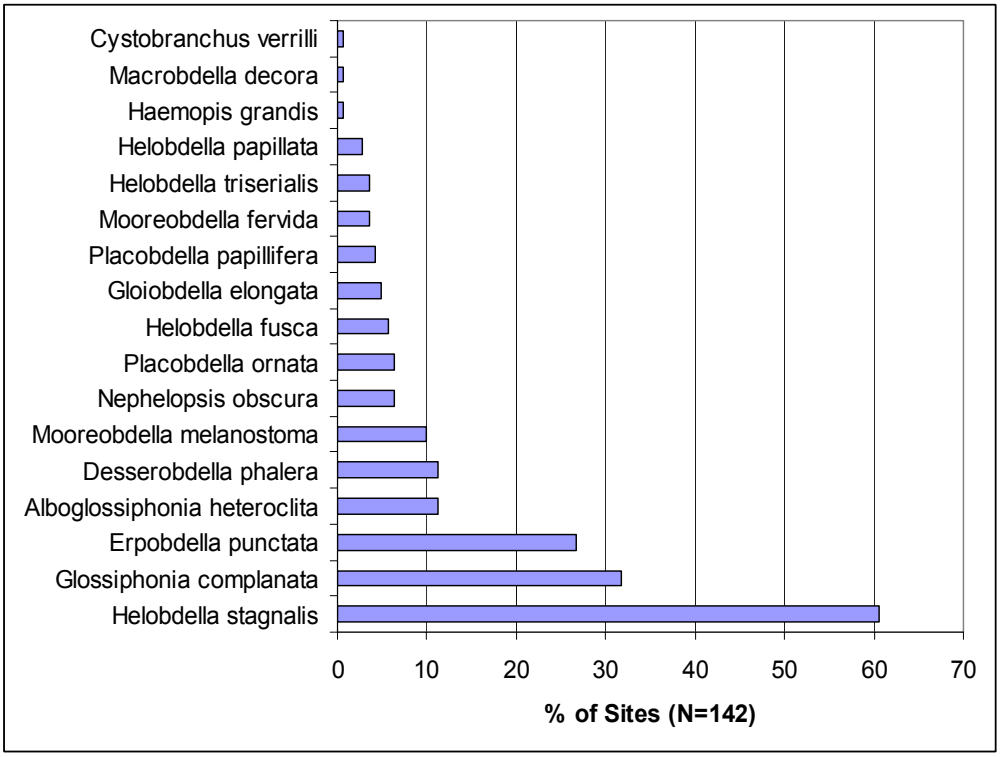
* Numbers outside parentheses are genera recorded from Maine (per MABP database). Numbers in parentheses are genera considered present in the northeast (Peckarsky et al. 1990).

** Numbers outside parentheses are species recorded from Maine (per MABP database). These totals include only taxa identified to the species level (i.e. do not include genera lacking species-level records). Numbers inside parentheses are species considered present in the northeast (Peckarsky et al. 1990).

*** Difference in these two totals simply reflects taxonomy: Peckarsky et al. (1990) treat the genus *Dina* as *Erpobdella*, whereas MABP retains the separate generic name for this taxon, as indicated by Integrated Taxonomic Information System (ITIS).

**** Northeast totals are from Gelder et al. (2001).

(A)



(B)

# Species	% Samples (N=1020)
0	80.3
1	11.0
2	5.7
3	2.0
4	0.7
5	0.3
6	0.1

Figure 6.8.1: (A) Frequency of occurrence of leech species at stream sampling sites. (B) Number of leech species per sample.
In (A), data are aggregated across all sampled years, i.e. the number of sites at which each species occurs disregards the number of years in the data record – which varies among sites. Only sites with leech records are included in the analysis.
In (B), a sample refers to a collection from a site during a single sampling event. Data are derived from MDEP's stream biomonitoring program database.

6.9 MACRO-INVERTEBRATE COMMUNITIES

Characterizing the group of species that comprises a community (or assemblage) is critically dependent on spatial scale – a lake, the lake's littoral area, a stream segment, a stream pool or riffle, an area of fine sediments, or a rock, for example. The previous sections of this Chapter have focused on individual taxonomic groups and have included descriptions of species groups occurring at various spatial scales – e.g. small groups of watersheds around the state, Mount Desert Island, Tomah Stream, St. John River, etc. This section provides several examples of the broader mix of macro-invertebrate taxa that have been documented in some of Maine's freshwater systems. The number of examples is limited by the fact that there have been relatively few attempts to describe whole-assemblage composition – and even with these, the data are presumably influenced by the types and extent of sampling effort used during the study.

We make no attempt here to summarize the extensive scientific literature dealing with the interrelationships between invertebrate assemblage structure and habitat, water quality, etc. Rather, we focus on Maine-based data that provide some examples of spatial and temporal patterns in freshwater macro-invertebrate assemblages.

Stream macroinvertebrates: MDEP biomonitoing program data.

The most extensive source of information on stream macro-invertebrate communities in Maine comes from MDEP's stream biomonitoring program. Samples are generally collected by inserting a "habitat" (e.g. rock basket, riffle bag) into a stream and waiting for it to become colonized by invertebrates. Sampling sites are selected subjectively and target "problem" sites, along with corresponding reference sites. While the sampling methodology is highly effective for documenting the key taxonomic groups used for MDEP biomonitoring, it does not pretend to collect representatives of all species groups present at any site.

Many analyses of these data have already been published elsewhere (e.g. Davies et al. 1999, Rabeni et al. 1985). For example, the number of mayfly, stonefly and caddisfly taxa (EPT richness) has been shown to be associated with water quality – sites that are classified as Class C or are non-attaining have lower EPT richness than Class A or B sites. Total generic richness also is lower in non-attaining sites, as is Shannon-Weiner diversity. The abundance (density) of stoneflies is much lower in Class C and non-attaining sites than elsewhere.

To supplement published analyses, we analyzed the MDEP data to characterize taxonomic richness per sample in different regions of the state. We included in the richness values the following taxa: species, genera for which no species-level records were present in the sample, and families for which no genus- or species-level records were present. Because some groups are identified only to the genus or even family level, the taxon totals likely underestimate the total number of species actually present in the sample. For this analysis, we used data from the months of July and August, from 1990 to 2003, and from samples collected with two methods: rock basket and riffle bags. Sites were assigned to the six regions of the state described in Chapter 2 and shown in Figure 6.9.1.

In most samples, rock baskets collected between about 30 and 70 taxa (Figure 6.9.1). Sites in the northeastern part of the state show the highest richness, while sites in Downeast and western Maine exhibit the lowest richness. Again, it is important to underscore the fact that sites are selected subjectively, so the box plots of Figure 6.9.1 should not be over-interpreted in terms of evaluating regional patterns.

To further describe the composition of MDEP samples, we used data from the Sheepscot River (MDEP site # 74), which has the longest data record in the state. This site (at the North

Whitefield USGS gauging station) is subject to some enrichment from agricultural and road crossing sources. Over the years, the invertebrate community has varied between typical Class A and Class B assemblages (Davies et al. 1999). Data are displayed in three ways (Figure 6.9.2). When normalized by sampling effort across all sampled months (panel A), the total number of taxa generally varied between 30 and 60, with about half of these numbers being represented by mayflies, stoneflies and caddisflies (EPT taxa). In 1988 and 1989 sampling effort was higher, resulting in higher total richness (aggregated across all samples) in these two years (panel B). The data are displayed in this way to underscore the importance of sampling effort in documenting species richness – a topic discussed in detail in Chapter 5. The relative numbers of four taxonomic groups (mayflies, stoneflies, caddisflies and chironomids) are shown in panel C, again, uncorrected for sampling effort. In general, samples contained similar numbers of caddisfly and chironomid taxa, somewhat few mayflies and fewer stoneflies. While the larger number of caddisflies and chironomids is to be expected from the higher regional species pools (see section 6.8), the extent to which the taxa in the different groups were identified to the species level likely also influenced these patterns.

Invertebrate assemblages of the upper St. John.

The MDEP biomonitoring data described above were collected with carefully controlled, quantitative, sampling methods. Other stream surveys have used a variety of collection methods in an attempt to sample all available habitat types. One example is the survey of the upper St. John conducted by Mingo et al. (1977). We summarized their data by aggregating sites into four groups and counting the number of genera present in various taxonomic groups[39]. The sampling sites are shown in the map of Figure 6.9.3, and the taxon richness summaries in the associated pie charts.

At riverine sites, the fauna was dominated by mayflies, caddisflies and Diptera. Generic richness in the other insect groups was <50% that of these three orders. There were no major differences in the fauna of the main strem sites vs. the tributary sites. As would be expected, the pond site had many fewer mayflies and stoneflies than the riverine sites; here, Hemiptera, caddisflies, Diptera and molluscs exhibited the highest generic richness.

Watershed disturbance, land-use, and macro-invertebrate diversity.

Many factors influence the diversity of macro-invertebrate communities. Among these factors is watershed disturbance (see Chapter 4) and, in particular, increasing urban density and its corollary, the amount of impervious surface. Morse has shown that above a threshold of about 7% impervious surface, stream macro-invertebrate community structure and richness is affected (Morse 2001, Morse et al. 2003). Figure 6.9.4 displays some of his data. At sites where the amount of impervious surface is above the threshold of ca. 7%, total taxon richness is reduced by approximately 50%. Richness of the sensitive EPT groups is even more affected, being reduced by about 75%. Once the threshold has been crossed, however, there are few significant additional impacts on invertebrate diversity (Figure 6.9.4).

Associations between macro-invertebrate assemblage structure and catchment land-use was studied by Huryn et al. (2002) in the Penobscot basin. Mirroring the results of Morse's study, these researchers also found that total number of taxa diversity was substantially reduced in urban catchments, relative to forest, wetland and agricultural areas. Richness of mayflies, stoneflies and caddisflies (EPT), as well as the richness of shredder taxa. was similarly reduced in urban streams. Overall, the biomass of leaf-shredder species did not differ significantly

[39] Note that these summaries are based on current taxonomy, not the original taxon names published in Mingo et al. (1977); thus, whenever generic names have undergone revision, the genus totals may not fully match those developed directly from the original data.

between land-use types. However, different shredder species were dominant in different catchment types. Forest streams, for example, were dominated by the leaf-shredding stonefly *Tallaperla maria*, while a different stonefly species, *Taeniopteryx* sp., was the dominant shredder in agricultural and wetland streams. In urban streams, the dominant leaf-shredder was the dipteran *Tipula abdominalis*.

Lake benthic invertebrate communities

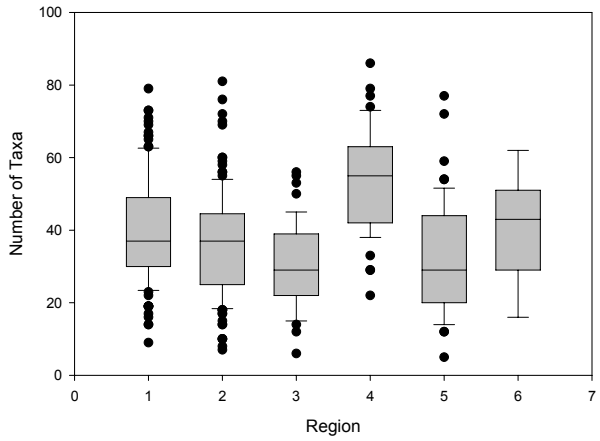
In the early 1970s, Davis et al. (1978) sampled the profundal (deep water) benthos in a series of lakes, mainly in south and central regions of the state. Samples were collected over several seasons and average values calculated for a number of metrics describing the invertebrate communities. Some of their data are shown in Figure 6.9.5. Using a series of biological and chemical metrics, the lakes were ranked in terms of their trophic state (approximately, lake productivity). As lake productivity increased, the density of benthic invertebrates also tended to increased – invertebrates in the more productive lakes were, in general, between about four and five times more abundant than in the least productive lakes (Figure 6.9.5 – upper panel). However, taxon richness (generic richness, mainly) did not show a similarly clear trend (Figure 6.9.5 – lower panel). Species diversity, as measured by the Shannon-Weiner Index, was slightly reduced in the more productive lakes.

The primary conclusions of Davis et al. (1978) were that:

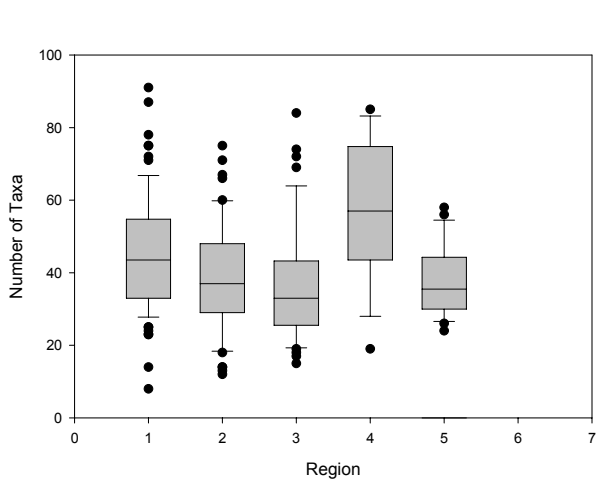
(a) The most common and widespread genera were *Chaoborus* and four chironomid genera (*Chironomus, Limnodrilus, Tanytarsus and Procladius*).
(b) In the shallower lakes, the littoral benthos extended to the deepest areas of the lake, producing a mix of typically profundal and littoral taxa (e.g. gastropods and mayflies).
(c) As would be expected, summer oxygen depletion influenced the fauna. Oxygen depletion resulted in higher abundance of the phantom midge (*Chaoborus*) and lower diversity of other taxa.
(d) At none of these lakes was anoxia prolonged enough or widespread enough to completely eliminate benthic macroinvertebrates.
(e) Densest invertebrate populations were generally found in those lake having the lowest profundal oxygen concentrations.
(f) Oligotrophic lakes were characterized by large numbers of the following genera: *Tanytarsus* and/or *Micropsectra* and/or *Phaenopsectra* and/or *Metriocnemus*. These same lakes had low numbers of *Chaoborus* and/or *Chironomus*.

Following on from the study of Davis et al. (1978), Courtemanch (1982) showed that profundal chironomid assemblages are sensitve indicators of lake trophic state (as discussed in section 6.7.10).

(A)



(B)



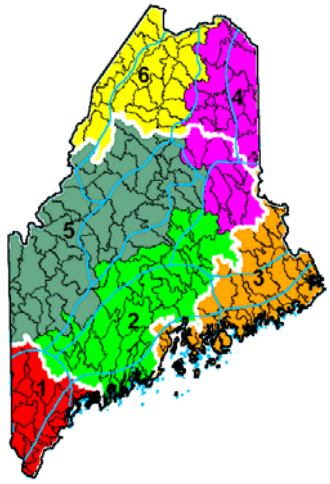
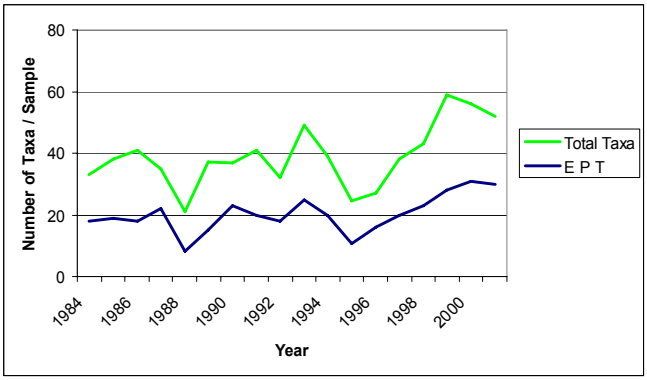
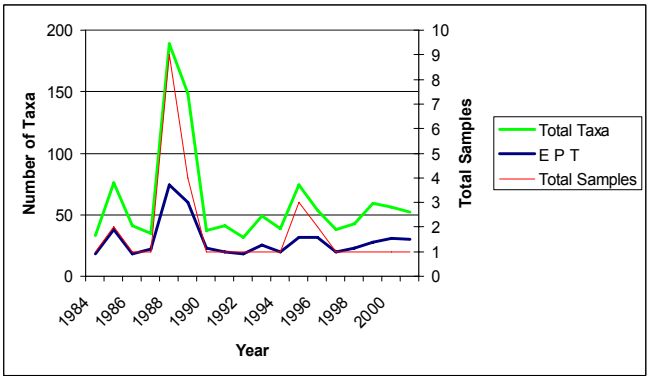


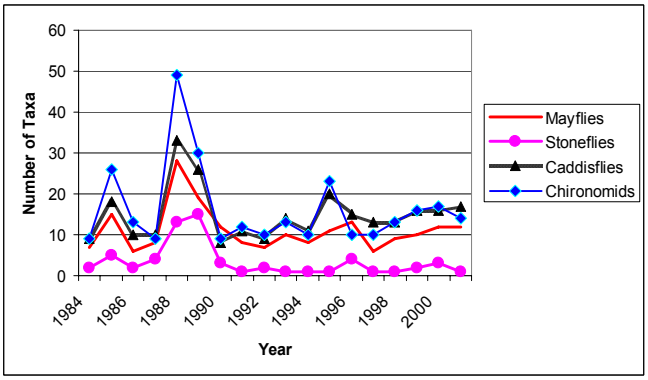
Figure 6.9.1: Number of macro-invertebrate taxa in stream samples collected in July and August with two methods: (A) rock basket, and (B) riffle bags. Data are shown by region (map inset shows the regions).
Number of taxa is the sum of (i) each species + (ii) each genus without any species-level records in that sample + (iii) each family without any genus-level or species-level records in that sample. Each sample represents a unique combination of sampling site, date and collection method. Source data are from MDEP's stream biomonitoring program for the period 1990 – 2003. Plots indicate the following: median = horizontal line within box; 25th and 75th percentiles = bottom and top of box; 5th and 95th percentiles = whiskers; outliers = dots.



(A)



(B)



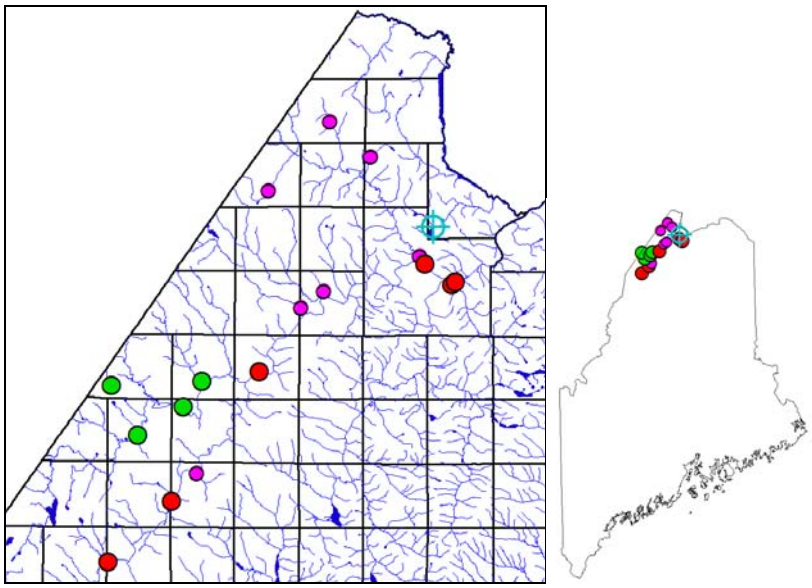
(C)

Figure 6.9.2: Number of various macro-invertebrate taxa in samples collected from the Sheepscot River at North Whitefield (MDEP site # 74; see inset map).
(A) Total number of taxa and number of mayfly, stonefly and caddisfly (EPT) taxa, normalized to the number of samples collected during the year.
(B) As in (A), but with no normalization to sample effort, i.e. total number of taxa collected during the year.
(C) Total number of taxa in four taxonomic groups – not normalized to sample effort.

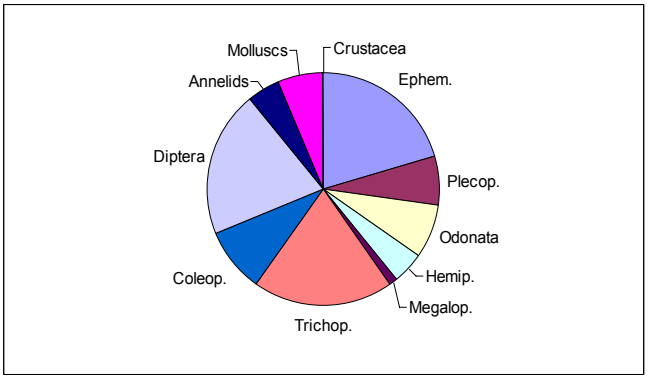
In all panels, data are aggregated across all dates and collection methods. See caption to Figure 6.9.1 for definition of "Number of Taxa".

Figure 6.9.3: Composition of invertebrate samples in the upper St. John River and tributaries.

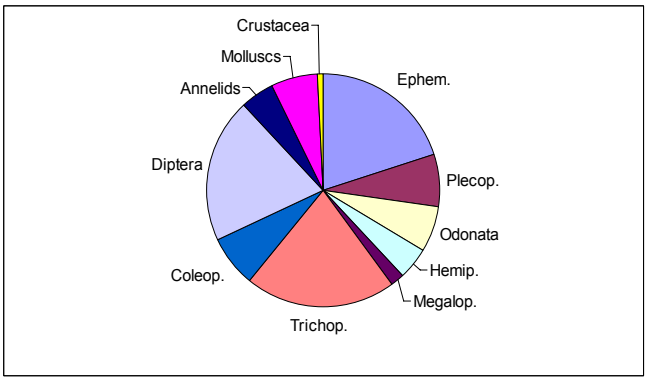
Data are % of total genera recorded at each group of sampling sites. Samples were collected with multiple methods. Sites are shown in map, below.



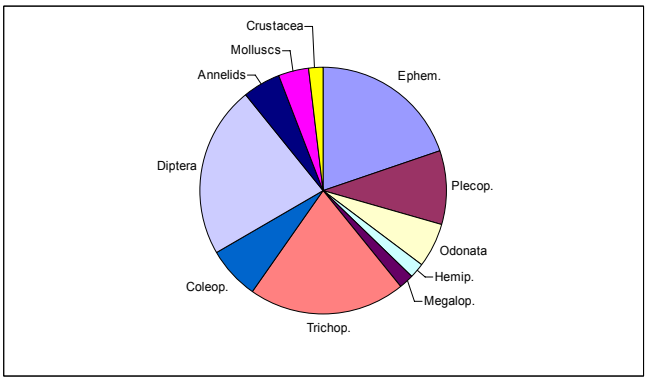
Site Key:
Main stem sites: RED
Big Black River: GREEN
Misc. tributaries: PURPLE
Falls Pond: Cross/Circle



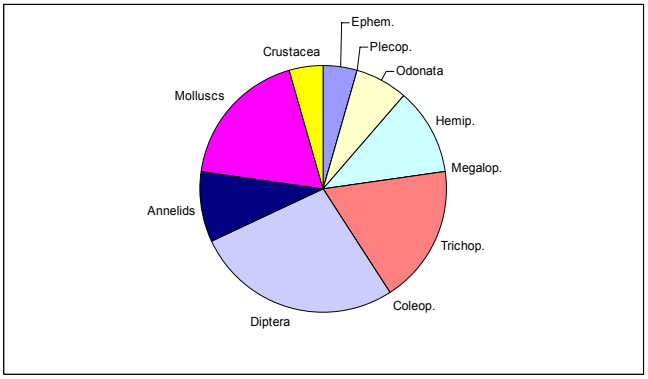
St. John River – main stem



Big Black River



Misc. tributaries



Falls Pond

Figure 6.9.3

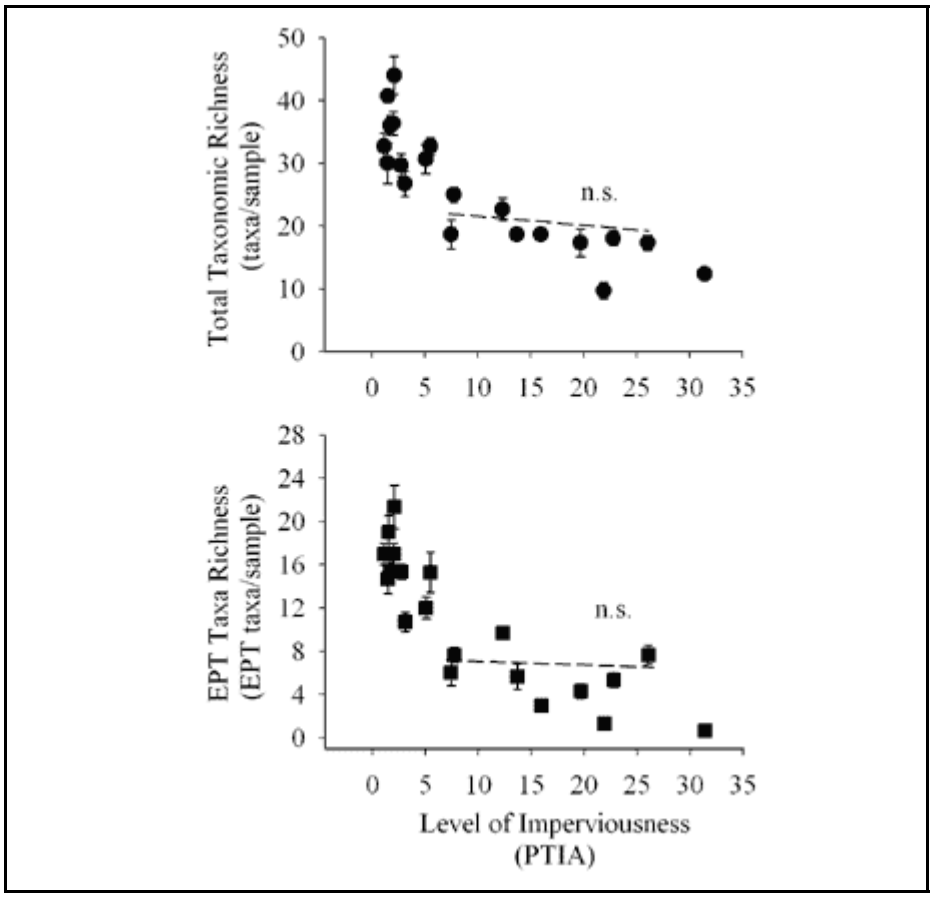
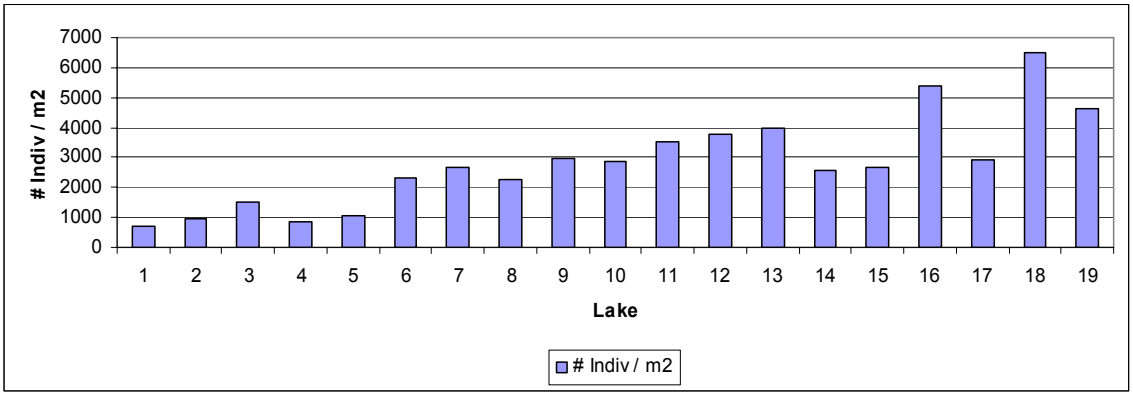
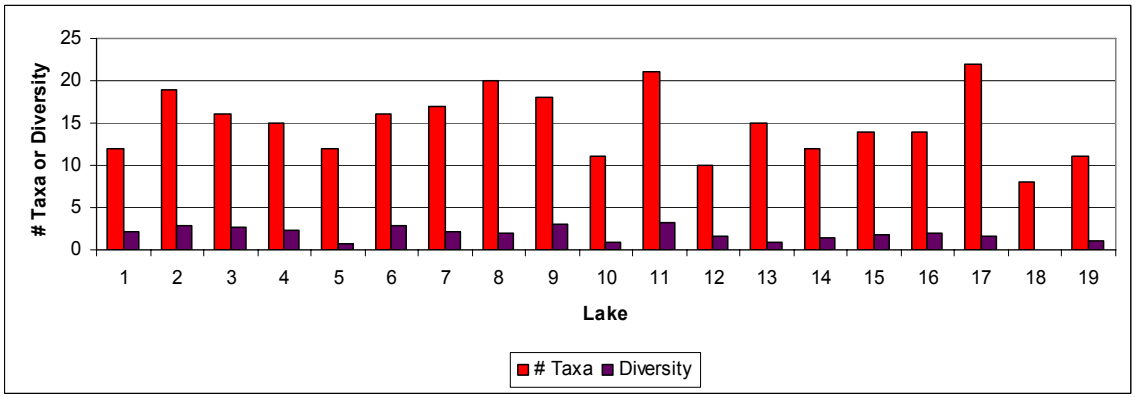


Figure 6.9.4: The influence of increasing urban intensity (as measured by amount of impervious surface) on stream macro-invertebrate richness.

Total richness (upper panel) and Ephemeroptera + Plecoptera + Trichoptera richness (lower panel) of the benthic macroinvertebrate communities of the study streams. (n.s. indicates the lack of a statistically significant relationship between the data points and the level of imperviousness.) Figure from Morse (2001).





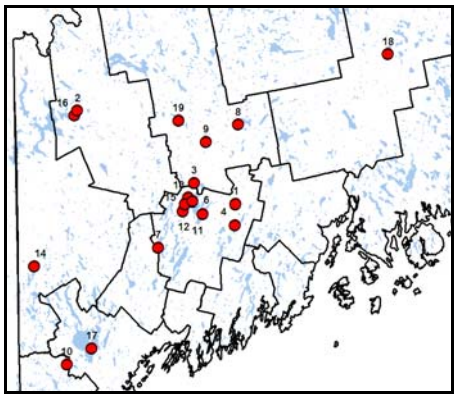


Figure 6.9.5: Benthic invertebrate assemblages in selected Maine lakes. Upper panel shows invertebrate density; lower panel shows number of taxa and Shannon diversity. Note that these taxon totals under-represent true richness because Davis et al. omitted any taxon that contributed <3% of total numbers. Lakes are ordered by increasing trophic rank (least to most productive). Data source: Davis et al. 1978.

Lakes: 1: Pattee P. 2: Haley P. 3: North P. 4: China L. (W. Basin). 5: Long Lake (in Aroostook County; not shown on map). 6: Messalonskee L. 7: Androscoggin L. 8: Great Moose L. (West Basin). 9: Wesserunsett L. 10: Wards P. 11: Great P. (SE Basin). 12: Long Pond (North Basin). 13: Great Pond (NW Basin). 14: Kezar L. 15: Long P. (South Basin). 16: Rangeley L. 17: Sebago L. 18: Cold Stream P. 19: Embden P