NET PRIMARY PRODUCTION AND STANDING BIOMASS IN NORTHERN CONTINENTAL WETLANDS

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ABSTRACT

This report synthesizes published data on aboveground and belowground net primary production (NPP) and biomass for wetlands in continental western Canada and adjacent regions in continental eastern Canada and the United States with similar wetland types and climates. The aim of this report is to identify the range of NPP and biomass among and within wetland types. The synthesis indicates four main points: 1) for aboveground NPP, the degree of variation within a given wetland type can be as large as the variation among most wetland types; 2) mean aboveground NPP ± standard deviation (SD) was 337 ± 142 g m^{-2} yr^{-1} for fens and bogs and 924 ± 463 g m^{-2} yr^{-1} for marshes and swamps; 3) mean total NPP ± SD was estimated at 506 g m^{-2} yr^{-1} for fens and bogs and 1201 g m^{-2} yr^{-1} for marshes and swamps; and 4) mean biomass ± SD was 1198 ± 1556 g m^{-2} for fens and bogs and 2291 ± 2330 g m^{-2} for marshes and swamps.

RÉSUMÉ

Ce rapport résume les données publiées sur la production primaire nette (PPN) et la biomasse aériennes et souterraines des milieux humides de la partie continentale de l'Ouest du Canada ainsi que des régions adjacentes de la partie continentale de l'Est du Canada et des États-Unis qui sont caractérisées par des types de milieux humides et des climats similaires. Il vise à déterminer la gamme de valeurs de PPN et de biomasse entre les divers types de milieux humides et à l'intérieur de ces derniers. Quatre principaux points ressortent: 1) pour la PPN aérienne, le degré de variation à l'intérieur d'un type de milieu humide donné peut être aussi élevé que celui observé entre la plupart des types de milieu humide; 2) la PPN aérienne moyenne ± écart-type (ET) était de 337 ± 142 g $m^{-2}an^{-1}$ pour les tourbières basses et les tourbières hautes et de 924 ± 463 g $m^{-2}an^{-1}$ pour les marais et les marécage; 3) la PPN totale moyenne ± ET a été estimée à 506 g $m^{-2}an^{-1}$ pour les tourbières basses et les tourbières hautes et à 1201 g $m^{-2}an^{-1}$ pour les marais et les marécages; et 4) la biomasse moyenne ± ET était de 1198 ± 1556 g m^{-2} pour les tourbières basses et les tourbières hautes, et de 2291 ± 2330 g m^{-2} pour les marais et les marécages.

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval, nor does the mention of other products necessarily imply endorsement by the Canadian Forest Service.

INTRODUCTION

Determination of the global extent of wetlands is fraught with difficulties, largely because of terminological inconsistencies and incomplete global mapping. Consequently, the ranges for estimates of global wetland area are large (from –61.34% to +173.92% of the mean) (Table 1). Estimates of global wetland area range from 2.80 to 8.56×10^{12} m^2 (Post et al. 1982; Mitsch and Gosselink 1993). Canada is thought to have the greatest area of wetlands in the world—estimated at between 1.27 and 1.70×10^{12} m^2 (13%–17%) of Canada's land area (National Wetlands Working Group 1988; Gorham 1991). Wetlands store about 60% of all organic carbon in Canada (Forestry Canada 1992), representing Canada's most important biological carbon pool. Given that Canadian wetlands account for between 15% and 61% of global wetlands and that they contain > 5.07×10^{17} g of peat (Tarnocai 1984), the net budget of carbon fluxes between Canadian wetlands and the atmosphere has the potential to significantly affect global carbon cycles. A thorough accounting of wetland carbon dynamics is therefore essential to understanding Canada's carbon budget.

Despite their global importance, short-term carbon fluxes (net primary production [NPP]) and pools (biomass) in wetlands have received little attention. This report synthesizes published data on wetland NPP and biomass from continental western Canada and adjacent regions in continental eastern Canada and the United States with similar wetland types and climates to identify the range of productivity and biomass among and within wetland types, and produces some generalizations that can be used to better define NPP and biomass for continental western Canadian wetlands.

Table 1. Estimates of the global extent of peatland and wetlands

Type of wetland	Area ($m^2 \times 10^{12}$)	% difference from mean	Reference
Peatlands	4.220	35.04	Kivinen and Pakarinen 1981
Peatlands	2.380	–23.84	Taylor 1983
Peatlands	3.880–4.080[a]	24.16–30.56	Riley 1992
Peatlands	5.000	60.00	Franzén 1994
Bogs	3.149	0.77	Rodin et al. 1975
Bogs	1.500	–52.00	Armentano and Menges 1986
Bogs	1.208	–61.34	Esser 1984
Bogs	2.974	–4.83	Matthews and Fung 1987
Swamps	3.594	15.00	Rodin et al. 1975
Swamps	2.144	–31.39	Esser 1984
Swamps	2.095	–32.96	Matthews and Fung 1987
Bogs and peatlands	1.500	–52.00	Ajtay 1979, cited in Armentano 1980
Swamp and marsh	2.000	–36.00	Schlesinger 1984
Wetlands	2.800	–10.40	Post et al. 1982
Wetlands and peatlands	2.800	–10.40	Adams et al. 1990
Wetlands	8.560	+173.92	Mitsch and Gosselink 1993
Mean	3.125		

[a] Using 4.08.

METHODS

Wetland Categories

In this report, wetlands are defined as precipitation-fed bogs and groundwater-fed fens, marshes (wetlands without trees or shrub cover, generally but not exclusively on shallow peat [<30–40 cm], and dominated by monocots), and swamps (forested to shrubby wetlands, generally but not exclusively on shallow peat) (Vitt et al. 1996). Fens are further subdivided into poor (*Sphagnum*-dominated), moderately rich, and extremely rich (brown moss dominated) fens, each with characteristic indicator species, acidity, alkalinity, and base cation content (Vitt and Chee 1990). In addition, these categories are further subdivided by the presence or absence of permafrost, trees, and shrubs. Within each wetland category, each species is classified by vegetation layer: tree, shrub, herb (field), and moss (ground).

Data Sources

The sources used in this study are given in the relevant tables. Some of the studies are from eastern Canada and the United States, for settings similar to those found in continental western Canada. Individual species reported are restricted to those that occur within continental western Canada, following the nomenclatue in Moss (1983) for vascular plants and Ireland et al. (1987) for mosses, whereas individual layer data include some species that are not found within continental western Canada.

Estimates of NPP and Biomass

The NPP values were obtained by various methods, including sequential harvests of vegetation (for vascular plants), measurement of extension growth with the cranked-wire method (for *Sphagnum* and brown mosses), or tied threads (for brown mosses), and allometric equations (for trees). Biomass values were also obtained by various methods, including various forms of harvesting (for vascular plants) and allometric equations (for trees). Biomass values for mosses are not included as it is, at present, impossible to distinguish among living and dead peat components.

Most of these studies examined only aboveground NPP and biomass. For the purposes of this paper, NPP and biomass values have been recorded as they were reported, by species and vegetation layer and by wetland type (after Vitt et al. 1996). Where more than one estimate of NPP and biomass were available, for a given location pooled means were calculated by site and location, because some wetland types are regionally overrepresented.

RESULTS

NPP and Biomass Estimates for Canadian Wetlands

Despite the abundance of wetlands in continental Canada, NPP and biomass studies of these systems are scarce. The absence of specific layer data for a number of the wetland types (as indicated by zero entries in Tables 2 and 3) may have significant effects on NPP and biomass estimates.

Tree NPP

There have been few investigations of tree production in northern continental wetlands and only 16 measurements of aboveground NPP for the whole tree layer (independent of species) (Table 4). These values range from 27.0 g m^{-2} yr^{-1} in a nonpermafrost bog (Thormann 1995) to 1011.3 g m^{-2} yr^{-1} in a wooded swamp (Reiners

Table 2. Number of species for which net primary production has been reported in various types of wetland[a]

Wetland type	Tree	Shrub	Herb	Moss
Permafrost bog	1	0	0	1
Nonpermafrost bog	1	7	3	5
Wooded poor fen	0	0	0	3
Wooded moderately rich fen	3	4	5	2
Wooded extremely rich fen	0	0	0	4
Shrubby poor fen	x	6	3	2
Shrubby moderately rich fen	x	5	5	5
Shrubby extremely rich fen	x	0	0	0
Open poor fen	x	x	0	0
Open moderately rich fen	x	x	3	2
Open extremely rich fen	x	x	5	4
Wooded swamp	4	4	27	x
Shrubby swamp	x	6	5	x
Marsh	x	x	20	x

[a] 0 = no reports of net primary production for any species in this type of wetland, x = does not occur in this environment.

Table 3. Number of species for which biomass has been reported in various types of wetland[a]

Wetland type	Tree	Shrub	Herb
Permafrost bog	0	7	0
Nonpermafrost bog	1	0	3
Wooded poor fen	0	0	0
Wooded moderately rich fen	2	4	3
Wooded extremely rich fen	0	0	0
Shrubby poor fen	x	4	3
Shrubby moderately rich fen	x	4	4
Shrubby extremely rich fen	x	0	0
Open poor fen	x	x	0
Open moderately rich fen	x	x	2
Open extremely rich fen	x	x	4
Wooded swamp	9	9	28
Shrubby swamp	x	5	5
Marsh	x	x	27

[a] 0 = no reports of biomass for any species in this type of wetland, x = does not occur in this environment.

Table 4. Estimates of aboveground net primary production (NPP) for individual tree species and whole tree layer

Species or layer	Wetland type	NPP[a] (g m^{-2} yr^{-1}) Aboveground	Total	No. of sites	Reference
Acer rubrum	Wooded swamp	106.9		1	Reiners 1972
	Wooded swamp	7.4		1	Reiners 1972
Larix laricina	Wooded moderately rich fen	37.9		1	Szumigalski and Bayley 1997
	Wooded swamp	35.0		1	Reiners 1972
Picea mariana	Permafrost bog	77.3	108.9	1	Billings 1987
	Nonpermafrost bog (1992a)[b]	54.3		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	27.0		1	Thormann 1995
	Nonpermafrost bog	58.4		1	Reader and Stewart 1972
	Nonpermafrost bog (raised)[b]	100.0		3	Grigal et al. 1985
	Nonpermafrost bog (perched)[b]	310.0		3	Grigal et al. 1985
	Wooded moderately rich fen	5.6		1	Szumigalski 1995
	Wooded swamp	302.5		1	Reader and Stewart 1972
Thuja occidentalis	Wooded moderately rich fen	129.7		1	Reiners 1972
	Wooded swamp	478.5		1	Reiners 1972
	Permafrost bog	77.3	108.9	1	Billings 1987
	Nonpermafrost bog (1992a)[b]	54.3		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	27.0		1	Thormann 1995
	Nonpermafrost bog	72.4		1	Reader and Stewart 1972
	Nonpermafrost bog (raised)[b]	100.0		3	Grigal et al. 1985
	Nonpermafrost bog (perched)[b]	310.0		3	Grigal et al. 1985
	Wooded moderately rich fen	43.5		1	Szumigalski 1995
	Wooded swamp	637.4		1	Reiners 1972
	Wooded swamp	1 011.3		1	Reiners 1972
	Wooded swamp	302.5		1	Reader and Stewart 1972
	Wooded swamp (site A)[b]	540.0		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	459.0		1	Parker and Schneider 1975

[a] All estimates for 1 yr only.

[b] Refers to year and/or site sampled.

1972), with a pooled site mean of 294 g m^{-2} yr^{-1}. Above-ground NPP of four tree species in four wetland types (14 measurements) ranged from 5.6 g m^{-2} yr^{-1} for *Picea mariana* in a wooded moderately rich fen (Szumigalski 1995) to 478.5 g m^{-2} yr^{-1} for *Thuja occidentalis* in a wooded swamp (Reiners 1972) (mean 142 g m^{-2} yr^{-1}). Wooded swamps had much higher yearly NPP than other wetlands, with no overlap within one standard deviation for pooled province and state means of wooded swamp and nonpermafrost bog data (Table 5). Standard deviations could not be calculated for pooled site means for nonpermafrost bogs, because some authors reported pooled means only (Table 5).

Belowground NPP is undoubtedly important, but there is a paucity of studies. In the one available study (Billings 1987), aboveground NPP of *Picea mariana* in a permafrost bog accounted for 71% and belowground NPP for 29% of total tree NPP (Table 4).

Table 5. Pooled means of net production (NPP) data for the tree layer

Reference[a]	NPP reported ($g\ m^{-2}yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}yr^{-1}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}\ yr^{-1}$)	
						Individual	Pooled
Permafrost bogs							
Billings 1987	77.3	77	Peat plateau, Alaska	77	Alaska	77	77
Nonpermafrost bogs							
Szumigalski 1995	54.3						
Thormann 1995	27.0	41	Bleak Lake, Alberta		Alberta	41	
Reader and Stewart 1972	72.4	72	Elma Bog, Manitoba		Manitoba	72	
Grigal et al. 1985	100.0	NA	3 raised bog sites, Minnesota				
	310.0	NA	3 perched bog sites, Minnesota	168	Minnesota	205	106 ± 192
Wooded fens							
Szumigalski 1995	43.5	44	Tawatinaw, Alberta	44	Alberta	44	44
Wooded swamps							
Reader and Stewart 1972	302.5	303	Elma, Manitoba		Manitoba	303	
Reiners 1972	637.4	637	Site 2, Minnesota				
Reiners 1972	1 011.3	1 011	Site 3, Minnesota		Minnesota	824	
Parker and Schneider 1975	540.0	540	Site A, Michigan				
Parker and Schneider 1975	459.0	459	Site B, Michigan	590 ± 265	Michigan	500	542 ± 279

[a] For shrubby fen, open fen, shrubby swamp, and marsh sites, there were no trees.

[b] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Tree Biomass

There were 159 measurements of aboveground biomass for the whole tree layer (independent of species) (Table 6), ranging from 8.0 g m^{-2} in a nonpermafrost bog with 5% tree cover (Grigal et al. 1985) to 15 920.0 g m^{-2} in a wooded swamp with 80% tree cover (Reiners 1972) (mean 3998 g m^{-2}). Aboveground biomass of individual species in the tree layer (101 measurements) ranged from 1.0 g m^{-2} for *Picea mariana* in a wooded swamp (Parker and Schneider 1975) to 8709.4 g m^{-2} for *Thuja occidentalis* in a wooded swamp (Reiners 1972) (mean 1901 g m^{-2}). This range points out the difficulty of using biomass data. Values are difficult to compare because of the different ages and stages of development at different sites. The mean may be more informative than any individual value, but only where a large number of sites have been analyzed. As with NPP, tree biomass within wooded swamps was much greater than in wooded peatlands, although pooled province and state means overlapped within one standard deviation for wooded swamps and nonpermafrost bogs (Table 7). Standard deviations could not be calculated for pooled site means, because some authors reported only pooled means (Table 7).

Shrub NPP

There were 31 measurements of aboveground NPP for the whole shrub layer (independent of species) (Table 8), ranging from 2.7 g m^{-2} yr^{-1} in a wooded swamp (Reiners 1972) to 730.0 g m^{-2} yr^{-1} in a shrubby swamp (Tilton and Bernard 1975) (pooled site mean 157 g m^{-2} yr^{-1}). Aboveground NPP of individual species in the shrub layer (90 measurements) ranged from 1.7 g m^{-2} yr^{-1} for *Betula pumila* in a shrubby, moderately rich fen (Thormann 1995) to 730 g m^{-2} yr^{-1} for *Alnus rugosa* in a shrubby swamp (Tilton and Bernard 1975) (pooled mean 46 g m^{-2} yr^{-1}). Shrubby swamps had the highest shrub NPP, followed by nonpermafrost bogs, wooded fens, shrubby fens, and wooded swamps for both pooled site and pooled province and state means (Table 9). Standard deviations could not be calculated for all wetland types, because for some, only pooled means were reported or there was a lack of samples; however, for sites that pooled means could be calculated for shrubby swamps did not overlap within one standard deviation of other wetland types (Table 9).

Shrub Biomass

There were 243 measurements of aboveground biomass for the whole shrub layer (independent of species) (Table 10), ranging from a pooled mean of 10.0 g m^{-2} for nonpermafrost bogs (Swanson and Grigal 1991) to 11 903.0 g m^{-2} in a shrubby, moderately rich fen (Connolly-McCarthy and Grigal 1985), (mean 437 g m^{-2}). Aboveground biomass of individual species in the shrub layer (101 measurements) ranged from 0.3 g m^{-2} for *Gaultheria procumbens* in a wooded swamp (Reiners 1972) to 7142.0 g m^{-2} for Salix in a shrubby, moderately rich fen (Connolly-McCarthy and Grigal 1985) (mean 302 g m^{-2}). Shrubby swamps had the highest shrub biomass, followed by wooded swamps and fens and bogs (Table 11). The pooled mean site biomass was higher for shrubby fens than for shrubby swamps, whereas the pooled mean biomass values for provinces and states were larger for shrubby swamps than for fens. Standard deviations could not be calculated for any of the pooled site means because some authors reported only pooled means and had inadequate numbers of sites.

Herb NPP

There were 61 measurements of aboveground NPP for the whole herb layer (independent of species) (Table 12), ranging from 3 g m^{-2} yr^{-1} in a nonpermafrost bog (Richardson et al. 1978) to 2297 g m^{-2} yr^{-1} in a marsh (Van der Valk and Davis 1978) (mean 551 g m^{-2} yr^{-1}). Aboveground NPP of individual species in the herb layer (172 measurements) ranged from 0.02 g m^{-2} yr^{-1} for *Anemone quinquefolia* in a wooded swamp (Reiners 1972) and *Lycopus uniflorus* in a wooded swamp (Reiners 1972) to 2858 g m^{-2} yr^{-1} for *Carex atherodes* in a marsh (van der Valk and Davis 1978) (mean 208 g m^{-2} yr^{-1}).

The mean ratio of aboveground to belowground NPP for individual species (65:35) belies the great variability among species (9–69:31–91). Marshes had the greatest NPP, followed by shrubby swamps, open fens, shrubby fens, wooded swamps, wooded fens, and nonpermafrost bogs (Table 13). Pooled site and pooled province and state means overlapped statistically (Table 13), if marshes were excluded (they have a larger NPP than wooded and shrubby peatlands).

Table 6. Estimates of aboveground biomass for individual tree species and whole tree layer

Species or layer	Wetland type	Aboveground biomass (g m^{-2})	No. of sites	Reference
Abies balsamea	Wooded swamp (site A)[a]	68.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	7.0	1	Parker and Schneider 1975
Betula payrifera	Wooded swamp (site B)[a]	201.8	1	Reiners 1972
	Wooded swamp (site C)[a]	3 777.3	1	Reiners 1972
Cornus alternifolia	Wooded swamp (site B)[a]	2.7	1	Reiners 1972
	Wooded swamp (site C)[a]	7.9	1	Reiners 1972
Larix laricina	Wooded moderately rich fen	312.0	1	Szumigalski 1995
	Wooded swamp (site C)[a]	473.8	1	Reiners 1972
	Wooded swamp (site A)[a]	1 081.0	1	Parker and Schneider 1975
Picea mariana	Nonpermafrost bog	367.8	1	Reader and Stewart 1972
	Nonpermafrost bog (raised)[a]	58.5	3	Grigal et al. 1985
	Nonpermafrost bog (1992a)[a]	592.0	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	646.0	1	Thormann 1995
	Nonpermafrost bog (Bh)[a]	7 300.0	26	Swanson and Grigal 1991
	Nonpermafrost bog (Bl)[a]	2 430.0	35	Swanson and Grigal 1991
	Nonpermafrost bog (Bo)[a]	150.0	11	Swanson and Grigal 1991
	Wooded moderately rich fen	39.0	1	Szumigalski 1995
	Wooded swamp (site B)[a]	1.0	1	Parker and Schneider 1975
	Wooded swamp	4 186.0	1	Reader and Stewart 1972
Populus balsamifera	Wooded swamp (site A)[a]	1 028.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	269.0	1	Parker and Schneider 1975
Thuja occidentalis	Wooded swamp (site B)[a]	2 398.9	1	Reiners 1972
	Wooded swamp (site C)[a]	8 709.4	1	Reiners 1972
Ulmus americana	Wooded swamp (site B)[a]	71.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	482.8	1	Reiners 1972
	Wooded swamp (site C)[a]	867.3	1	Reiners 1972
Tree layer	Nonpermafrost bog	367.8	1	Reader and Stewart 1972
	Nonpermafrost bog	592.0	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	646.0	1	Thormann 1995
	Nonpermafrost bog	8.0	3	Grigal et al. 1985
	Nonpermafrost bog	58.5	3	Grigal et al. 1985
	Nonpermafrost bog (Bh)[a]	7 300.0	26	Swanson and Grigal 1991
	Nonpermafrost bog (Bl)[a]	2 430.0	35	Swanson and Grigal 1991
	Nonpermafrost bog (Bo)[a]	150.0	11	Swanson and Grigal 1991
	Wooded fen	2 470.0	34	Swanson and Grigal 1991
	Wooded moderately rich fen	351.0	1	Szumigalski 1995
	Wooded swamp	8 410.0	38	Swanson and Grigal 1991
	Wooded swamp	4 186.0	1	Reader and Stewart 1972
	Wooded swamp (site A)[a]	4 021.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1 080.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	9 698.6	1	Reiners 1972
	Wooded swamp (site C)[a]	15 920.0	1	Reiners 1972

[a] Refers to year and/or site sampled.

Table 7. Pooled means of biomass data for the tree layer

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$) Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	592.0						
Thormann 1995	646.0	619	Bleak Lake, Alberta		Alberta	619	
Reader and Stewart 1972	367.8	368	Elma Bog, Manitoba		Manitoba	368	
Grigal et al. 1985	8.0	NA	3 raised bog sites, Minnesota				
	58.5	NA	3 perched bog sites, Minnesota				
Swanson and Grigal 1991	7 300.0	NA	26 Bh nonpermafrost bog sites, Minnesota				
	2 430.0	NA	35 Bm nonpermafrost bog sites, Minnesota				
	150.0	NA	11 Bo nonpermafrost bog sites, Minnesota	3 471	Minnesota	3 547	1 511 ± 1 767
Wooded fens							
Szumigalski 1995	3 51.0	351	Tawatinaw, Alberta		Alberta	351	
Swanson and Grigal 1991	2 470.0	2 470	35 wooded fen sites, Minnesota	1 411	Minnesota	2 470	1 411
Wooded swamps							
Reader and Stewart 1972	4 186.0	4 186	Elma Bog, Manitoba		Manitoba	5 186	
Parker and Schneider 1975	4 021.0	4 021	Site A, Michigan				
	1 080.0	1 080	Site B, Michigan		Michigan	2 551	
Reiners 1972	9 698.6	9 699	Site 2, Minnesota				
Reiners 1972	15 920.0	15 920	Site 3, Minnesota				
Swanson and Grigal 1991	8 410.0	NA	38 wooded swamp sites, Minnesota	8 244	Minnesota	8 630	5 456 ± 3 049

[a] For permafrost bogs, there were no sites with biomass data. For shrubby fen, open fen, shrubby swamp, and marsh sites, there were no trees.

[b] Only for sites for which such data were available; if only a mean of several sites was reported individual site values were not available or could not be calculated (NA).

Table 8. Estimates of aboveground net primary production (NPP) for individual shrub species and whole shrub layer

Species or layer	Wetland type	Aboveground NPP[a] ($g\ m^{-2} yr^{-1}$)	No. of sites	Reference
Alnus rugosa	Wooded swamp	13.6	1	Reiners 1972
	Wooded swamp	2.7	1	Reiners 1972
	Wooded swamp (site A)[b]	125.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	199.0	1	Parker and Schneider 1975
	Shrubby swamp	730.0	1	Tilton and Bernard 1975
Amelanchier spp.	Wooded swamp	4.0	1	Reiners 1972
Andromeda polifolia	Nonpermafrost bog (1991a)[b]	10.0	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	8.4	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	19.8	1	Thormann 1995
	Wooded moderately rich fen (1991b)[b]	32.9	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	45.0	1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	22.2	1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	14.6	1	Szumigalski 1995
	Shrubby moderately rich fen (1993e)[b]	17.7	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	38.7	1	Thormann 1995
Betula glandulosa	Shrubby poor fen	43.0	1	Bartsch and Moore 1985
	Shrubby moderately rich fen	47.0	1	Bartsch and Moore 1985
	Shrubby moderately rich fen	52.0	1	Bartsch and Moore 1985
Betula pumila	Wooded moderately rich fen (1991b)[b]	27.8	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	39.0	1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	61.4	1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	104.5	1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[b]	5.7	1	Szumigalski 1995
	Shrubby moderately rich fen (1994d)[b]	1.7	1	Thormann 1995
Chamaedaphne calyculata	Nonpermafrost bog (1991a)[b]	4.7	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	4.1	1	Szumigalski 1995
	Nonpermafrost bog	106.1	1	Reader and Stewart 1972
	Nonpermafrost bog	5.5	3	Grigal et al. 1985
	Nonpermafrost bog	52.0	3	Grigal et al. 1985
	Nonpermafrost bog	57.4	1	Reader and Stewart 1972
	Shrubby swamp	227.3	1	Reader and Stewart 1972
Kalmia polifolia	Nonpermafrost bog	30.9	1	Reader and Stewart 1972
	Nonpermafrost bog	13.4	1	Reader and Stewart 1972
Ledum groenlandicum	Nonpermafrost bog (1991a)[b]	48.8	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	71.7	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	65.1	1	Thormann 1995
	Nonpermafrost bog	123.0	1	Reader and Stewart 1972
	Nonpermafrost bog	68.1	1	Reader and Stewart 1972
	Nonpermafrost bog	20.0	3	Grigal et al. 1985
	Nonpermafrost bog	69.5	3	Grigal et al. 1985
	Nonpermafrost bog	123.0	1	Reader and Stewart 1972
	Shrubby poor fen (1992c)[b]	0.7	1	Szumigalski 1995
	Wooded swamp	52.8	1	Reader and Stewart 1972

Table 8 continued

Species or layer	Wetland type	Aboveground NPP[a] ($g\ m^{-2} yr^{-1}$)	No. of sites	Reference
Oxycoccus quadripetalus	Nonpermafrost bog	50.4	1	Reader and Stewart 1972
	Nonpermafrost bog (1991a)[b]	2.7	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	2.1	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	10.9	1	Thormann 1995
	Shrubby rich fen (1993e)[b]	3.6	1	Thormann 1995
	Shrubby rich fen (1994e)[b]	4.4	1	Thormann 1995
Oxycoccus spp.	Wooded moderately rich fen (1991b)[b]	8.6	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	15.6	1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	3.1	1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	5.8	1	Szumigalski 1995
Salix bebbiana	Shrubby swamp	219.1	1	Reader and Stewart 1972
Salix pedicellaris	Wooded moderately rich fen (1991b)[b]	26.9	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	20.3	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	3.6	1	Thormann 1995
	Shrubby poor fen	55.0	1	Bartsch and Moore 1985
	Shrubby poor fen (1991c)[b]	28.3	1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	31.8	1	Szumigalski 1995
	Shrubby moderately rich fen	71.0	1	Bartsch and Moore 1985
	Shrubby moderately rich fen (1991d)[b]	3.6	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[b]	7.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[b]	14.2	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	12.2	1	Thormann 1995
Salix serissima	Shrubby swamp	11.3	1	Reader and Stewart 1972
Salix spp.	Shrubby moderately rich fen (1993e)[b]	11.7	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	8.7	1	Thormann 1995
	Wooded swamp (site A)[b]	14.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	80.0	1	Parker and Schneider 1975
	Shrubby swamp	90.2	1	Jervis 1969
Spiraea spp.	Shrubby swamp	39.4	1	Jervis 1969
Vaccinium vitis-idaea	Nonpermafrost bog (1991a)[b]	10.4	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	10.7	1	Szumigalski 1995
	Nonpermafrost bog	52.7	1	Reader and Stewart 1972
	Nonpermafrost bog (1994a)[b]	21.7	1	Thormann 1995
	Nonpermafrost bog	47.4	1	Reader and Stewart 1972
Viburnum spp.	Shrubby swamp	39.1	1	Jervis 1969
Shrub layer	Nonpermafrost bog (1991a)[b]	76.6	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	97.0	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	117.0	1	Thormann 1995
	Nonpermafrost bog	253.3	1	Reader and Stewart 1972
	Nonpermafrost bog	316.4	1	Reader and Stewart 1972
	Nonpermafrost bog (raised)[b]	200.0	3	Grigal et al. 1985
	Nonpermafrost bog (perched)[b]	43.0	3	Grigal et al. 1985

Table 8 concluded

Species or layer	Wetland type	Aboveground NPP[a] ($g\ m^{-2}yr^{-1}$)	No. of sites	Reference
Shrub layer	Nonpermafrost bog	338.0	1	Richardson et al. 1978
	Wooded moderately rich fen (1991b)[b]	96.2	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	119.9	1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	112.0	1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	157.4	1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[b]	9.3	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[b]	7.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[b]	14.2	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	13.9	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[b]	33.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	51.8	1	Thormann 1995
	Wooded swamp	16.0	1	Reiners 1972
	Wooded swamp	2.7	1	Reiners 1972
	Wooded swamp	64.1	1	Reader and Stewart 1972
	Wooded swamp (site A)[b]	15.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	21.0	1	Parker and Schneider 1975
	Shrubby swamp	211.4	1	Jervis 1969
	Shrubby swamp	497.7	1	Reader and Stewart 1972
	Shrubby swamp	730.0	1	Tilton and Bernard 1975

[a] All estimates for 1 yr only.

[b] Refers to year and/or site sampled.

Table 9. Pooled means of net primary production (NPP) data for the shrub layer

Reference[a]	NPP reported ($g\ m^{-2}yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}yr^{-1}$)	Province or State	Mean NPP for province or state ($g\ m^{-2}yr^{-1}$) Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	76.6						
	97.0						
Thormann 1995	117	97	Bleak Lake, Alberta		Alberta	97	
Reader and Stewart 1972	253.3						
	316.4	285	Elma, Manitoba		Manitoba	285	
Grigal et al. 1985	200	NA	3 raised bog sites, Minnesota				
	43	NA	3 perched bog sites, Minnesota		Minnesota	269	
Richardson et al. 1978	33	338	Open bog, Michigan	161	Michigan	338	247 ± 104
Wooded fens							
Szumigalski 1995	96.2						
	119.9	108	Tawatinaw, Alberta	108	Alberta	108	108
Shrubby fens							
Szumigalski 1995	112.0						
	157.4	135	Bleak Lake, Alberta				
	9.3						
	7.0						
Thormann 1995	14.2						
	13.9	11	Tawatinaw, Alberta				
	33						
	51.8	42	Tawatinaw, Alberta	63 ± 65	Alberta	63	63
Wooded swamps							
Reader and Stewart 1972	64.1	64	Elma Bog, Manitoba		Manitoba	64	
Reiners 1972	16.0	16	Site 2, Minnesota				
	2.7	3	Site 3, Minnesota		Minnesota	10	
Parker and Schnedier 1975	15.0	15	Site A, Michigan				
	21.0	21	Site B, Michigan	24 ± 23	Michigan	18	31 ± 29
Shrubby swamps							
Reader and Stewart 1972	497.7	498	Elma Bog, Manitoba		Manitoba	498	
Jervis 1969	211.4	211	Shrubby swamp, New Jersey		New Jersey	211	
Tilton and Bernard 1975	730.0	730	Alder shrub, New York	480 ± 260	New York	730	480 ± 260

[a] For permafrost bogs, there were no sites with NPP data. For open fen and marsh sites, there were no shrubs.

[b] Only for sites for which such data were available; if only a mean of several sites was reported individual site values were not available or could not be calculated (NA).

Table 10. Estimates of aboveground biomass for individual shrub species and whole shrub layer

Species or layer	Wetland type	Aboveground biomass (g m^{-2})	No. of sites	Reference
Andromeda polifolia	Nonpermafrost bog (1991a)[a]	28.9	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	21.5	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	54.0	1	Thormann 1995
	Wooded moderately rich fen (1991b)[a]	69.1	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	103.0	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	51.3	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	43.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1993e)[a]	31.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	74.0	1	Thormann 1995
Alnus rugosa	Wooded swamp (site A)[a]	1 103.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1 725.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	108.9	1	Reiners 1972
	Wooded swamp (site C)[a]	20.6	1	Reiners 1972
Betula pumila	Wooded moderately rich fen (1991b)[a]	73.4	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	102.0	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	190.5	1	Szumigalski 1995
	Shrubby poor fen (19921c)[a]	268.7	1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[a]	13.2	1	Szumigalski 1995
	Shrubby moderately rich fen (1994d)[a]	5.0	1	Thormann 1995
Betula spp.	Shrubby poor fen (stand 2)[a]	174.0	1	Connolly-McCarthy and Grigal 1985
	Shruuby poor fen (stand 11)[a]	569.0	1	Connolly-McCarthy and Grigal 1985
Chamaedaphne calyculata	Nonpermafrost bog	140.5	1	Reader and Stewart 1972
	Nonpermafrost bog	151.0	1	Reader and Stewart 1972
	Nonpermafrost bog (perched)[a]	21.0	3	Grigal et al. 1985
	Nonpermafrost bog (raised)[a]	201.0	3	Grigal et al. 1985
	Shrubby swamp	452.1	1	Reader and Stewart 1972
Cornus stolonifera	Wooded swamp (site A)[a]	25.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	90.0	1	Parker and Schneider 1975
Gaultheria procumbens	Wooded swamp (site B)[a]	0.3	1	Reiners 1972
Ilex verticillata	Wooded swamp (site A)[a]	17.0	1	Parker and Schneider 1975
Kalmia polifolia	Nonpermafrost bog	27.6	1	Reader and Stewart 1972
	Nonpermafrost bog	44.0	1	Reader and Stewart 1972
Ledum groenlandicum	Nonpermafrost bog (perched)[a]	108.0	3	Grigal et al. 1985
	Nonpermafrost bog (raised)[a]	392.0	3	Grigal et al. 1985
	Nonpermafrost bog (1991a)[a]	150.3	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	187.8	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	179.0	1	Thormann 1995
	Nonpermafrost bog	128.4	1	Reader and Stewart 1972
	Nonpermafrost bog	237.0	1	Reader and Stewart 1972
	Wooded swamp	134.5	1	Reader and Stewart 1972
Oxycoccus quadripetalus	Nonpermafrost bog	35.5	1	Reader and Stewart 1972
	Nonpermafrost bog (1991a)[a]	6.3	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	3.3	1	Szumigalski 1995

Table 10 continued

Species or layer	Wetland type	Aboveground biomass (g m^{-2})	No. of sites	Reference
Oxycoccus quadripetalus	Nonpermafrost bog (1994a)[a]	17.0	1	Thormann 1995
	Wooded moderately rich fen (1991b)[a]	17.4	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	25.6	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	5.9	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	10.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1993e)[a]	7.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	8.0	1	Thormann 1995
Prunus virginiana	Wooded swamp (site A)[a]	1.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1.0	1	Parker and Schneider 1975
Salix bebbiana	Shrubby swamp	998.2	1	Reader and Stewart 1972
Salix serissima	Shrubby swamp	66.9	1	Reader and Stewart 1972
Salix spp.	Nonpermafrost bog (1994a)[a]	6.0	1	Thormann 1995
	Wooded moderately rich fen (1991b)[a]	72.6	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	40.2	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	61.1	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	58.5	1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[a]	8.1	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[a]	17.5	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	29.0	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	21.0	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	30.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	21.0	1	Thormann 1995
	Shrubby moderately rich fen (stand 1)[a]	422.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 1)[a]	422.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 5)[a]	402.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 9)[a]	299.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 17)[a]	715.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 20)[a]	701.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 22)[a]	7 142.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 23)[a]	849.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 29)[a]	1 615.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 30)[a]	330.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 31)[a]	538.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 33)[a]	603.0	1	Connolly-McCarthy and Grigal 1985
	Wooded swamp (site A)[a]	14.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	80.0	1	Parker and Schneider 1975
	Shrubby swamp	90.2	1	Jervis 1969
	Shrubby swamp (stand 15)[a]	1 664.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 19)[a]	1 273.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 21)[a]	1 510.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 25)[a]	1 083.0	1	Connolly-McCarthy and Grigal 1985
Vaccinium angustifolium	Wooded swamp (site B)[a]	1.2	1	Reiners 1972

Table 10 continued

Species or layer	Wetland type	Aboveground biomass (g m^{-2})	No. of sites	Reference
Vaccinium vitis-idaea	Nonpermafrost bog	53.4	1	Reader and Stewart 1972
	Nonpermafrost bog	56.3	1	Reader and Stewart 1972
	Nonpermafrost bog (1991a)[a]	23.2	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	22.4	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	39.0	1	Thormann 1995
Viburnum trilobum	Swamp	3.0	1	Parker and Schneider 1975
Viburnum spp.	Shrubby swamp	39.1	1	Jervis 1969
Shrub layer	Nonpermafrost bog	461.4	1	Reader and Stewart 1972
	Nonpermafrost bog	423.3	1	Reader and Stewart 1972
	Nonpermafrost bog (1991a)[a]	222.7	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	248.3	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	304.0	1	Thormann 1995
	Nonpermfrost bog (perched)[a]	129.0	3	Grigal et al. 1985
	Nonpermafrost bog (raised)[a]	592.0	3	Grigal et al. 1985
	Nonpermafrost bog (Bh)[a]	80.0	26	Swanson and Grigal 1991
	Nonpermafrost bog (Bl)[a]	10.0	35	Swanson and Grigal 1991
	Nonpermafrost bog (Bo)[a]	10.0	11	Swanson and Grigal 1991
	Wooded moderately rich fen (1991b)[a]	232.5	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	270.8	1	Szumigalski 1995
	Wooded fen	380.0	34	Swanson and Grigal 1991
	Shrubby fen	470.0	20	Swanson and Grigal 1991
	Shrubby poor fen (1991c)[a]	284.2	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	373.2	1	Szumigalski 1995
	Shrubby poor fen (stand 2)[a]	193.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby poor fen (stand 3)[a]	1 511.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby poor fen (stand 4)[a]	615.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby poor fen (stand 6)[a]	1 615.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby poor fen (stand 10)[a]	174.0	1	Connolly-McCarthy and Grigal 1985
	Shruuby poor fen (stand 11)[a]	569.0	1	Connolly-McCarthy and Grigal 1985
	Shruuby poor fen (stand 13)[a]	810.0	1	Connolly-McCarthy and Grigal 1985
	Shruuby poor fen (stand 14)[a]	123.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby poor fen (stand 26)[a]	929.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (1991d)[a]	21.3	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[a]	17.5	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	29.0	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	26.0	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	68.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	103.0	1	Thormann 1995
	Shrubby moderately rich fen (stand 1)[a]	2 108.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 5)[a]	576.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 8)[a]	867.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 9)[a]	2 439.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 12)[a]	2 467.0	1	Connolly-McCarthy and Grigal 1985

Table 10 concluded

Species or layer	Wetland type	Aboveground biomass (g m^{-2})	No. of stes	Reference
Shrub layer	Shrubby moderately rich fen (stand 17)[a]	1 432.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 18)[a]	681.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 20)[a]	877.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 22)[a]	11 903.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 23)[a]	1 215.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 27)[a]	509.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 28)[a]	2 534.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 29)[a]	1 797.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 30)[a]	1 101.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 31)[a]	674.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 32)[a]	2 744.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 33)[a]	2 011.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby moderately rich fen (stand 33)[a]	3 727.0	1	Connolly-McCarthy and Grigal 1985
	Wooded swamp	134.5	1	Reader and Stewart 1972
	Wooded swamp (site A)[a]	1 163.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1 896.0	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	110.4	1	Reiners 1972
	Wooded swamp (site C)[a]	20.9	1	Reiners 1972
	Wooded swamp	300.0	38	Swanson and Grigal 1991
	Shrubby swamp	1 517.0	1	Reader and Stewart 1972
	Shrubby swamp	380.0	18	Swanson and Grigal 1991
	Shrubby swamp (stand 7)[a]	332.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 15)[a]	1 852.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 16)[a]	207.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 19)[a]	1 273.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 21)[a]	1 681.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 24)[a]	1 376.0	1	Connolly-McCarthy and Grigal 1985
	Shrubby swamp (stand 25)[a]	1 083.0	1	Connolly-McCarthy and Grigal 1985

[a] Refers to year and/or site sampled.

Table 11. Pooled means of biomass data for the shrub layer

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$)	
						Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	222.7						
	248.3						
Thormann 1995	304	258	Bleak Lake, Alberta		Alberta	258	
Reader and Stewart 1972	461.4						
	423.3	442	Elma Bog, Manitoba		Manitoba	442	
Grigal et al. 1985	129	NA	3 raised bog sites, Minnesota				
	592	NA	3 perched bog sites, Minnesota				
Swanson and Grigal 1991	80	NA	26 Bh nonpermafrost bog sites, Minnesota				
	10	NA	35 Bm nonpermafrost bog sites, Minnesota				
	10	NA	11 Bo nonpermafrost bog sites, Minnesota	67	Minnesota	60	253 ± 191
Wooded fens							
Szumigalski 1995	232.5						
	270.8	252	Tawatinaw, Alberta		Alberta	252	
Swanson and Grigal 1991	380	NA	34 wooded fen sites, Minnesota	376	Minnesota	380	316
Shrubby Fens							
Szumigalski 1995	284.2						
	3 73.2	329	Bleak Lake, Alberta				
	21.3						
	17.5						
Thormann 1995	29						
	26	24	Tawatinaw, Alberta				
	68						
	103	86	Tawatinaw, Alberta		Alberta	146	
Swanson and Grigal 1991	470	NA	20 shrubby fen sites, Minnesota				

Table 11 continued

Reference[a]	Biomass reported (g m^{-2})	Individual site biomass[b] (g m^{-2})	Site location	Pooled site mean (g m^{-2})	Province or state	Mean bomass for province or state (g m^{-2})	
						Individual	Pooled
Connolly-McCarthy and Grigal 1985	193	193	Poor fen stand 2, Minnesota				
	1 511	1 511	Poor fen stand 3, Minnesota				
	615	615	Poor fen stand 4, Minnesota				
	1 615	1 615	Poor fen stand 6, Minnesota				
	174	174	Poor fen stand 10, Minnesota				
	569	569	Poor fen stand 11, Minnesota				
	810	810	Poor fen stand 13, Minnesota				
	123	123	Poor fen stand 14, Minnesota				
	929	929	Poor fen stand 26, Minnesota				
	2 108	2 108	Rich fen stand 1, Minnesota				
	576	576	Rich fen stand 5, Minnesota				
	867	867	Rich fen stand 8, Minnesota				
	2 439	2 439	Rich fen stand 9, Minnesota				
	2 467	2 467	Rich fen stand 12, Minnesota				
	1 432	1 432	Rich fen stand 17, Minnesota				
	681	681	Rich fen stand 18, Minnesota				
	877	877	Rich fen stand 20, Minnesota				
	1 903	1 903	Rich fen stand 22, Minnesota				
	1 215	1 215	Rich fen stand 23, Minnesota				
	509	509	Rich fen stand 27, Minnesota				
	2 534	2 534	Rich fen stand 28, Minnesota				
	1 797	1 797	Rich fen stand 29, Minnesota				
	1 101	1 101	Rich fen stand 30, Minnesota				
	674	674	Rich fen stand 31, Minnesota				
	2 744	2 744	Rich fen stand 32, Minnesota				
	2 011	2 011	Rich fen stand 33, Minnesota				
	3 727	3 727	Rich fen stand 34, Minnesota	921	Minnesota	970	558

Table 11 concluded

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$) Individual	Pooled
Wooded swamps							
Reader and Stewart 1972	1 34.5	1 34.5	Elma Bog, Manitoba		Manitoba	135	
Parker and Schneider 1975	1 163	1 163	Site A, Michigan				
	1 896	1 896	Site B, Michigan		Michigan	1530	
Reiners 1972	110.38	100	Site 2, Minnesota				
	20.9	21	Site 3, Minnesota				
Swanson and Grigal 1991	300	NA	38 wooded swamp sites, Minnesota	342	Minnesota	288	651 ± 765
Shrubby swamps							
Reader and Stewart 1972	1 517	1 517	Elma, Manitoba		Manitoba	1517	
Swanson and Grigal 1991	300	NA	18 shrubby swamp sites, Minnesota				
Connolly-McCarthy and Grigal 1985	332	332	Shrubby swamp Stand 7, Minnesota				
	1 852	1 852	Shrubby swamp Stand 15, Minnesota				
	207	207	Shrubby swamp Stand 16, Minnesota				
	1 273	1 273	Shrubby swamp Stand 19, Minnesota				
	1 681	1 681	Shrubby swamp Stand 21, Minnesota				
	1 376	1 376	Shrubby swamp Stand 24, Minnesota				
	1 083	1 083	Shrubby swamp Stand 25, Minnesota	566	Minnesota	528	1 023

[a] For permafrost bogs, there were no sites with biomass data. For open fen and marsh sites, there were no shrubs.

[b] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Table 12. Estimates of aboveground net primary production (NPP) for individual herb species and whole herb layer

Species or layer	Wetland type	NPP[a] ($g\ m^{-2}yr^{-1}$) Aboveground	Total	No. of sites	Reference
Anemone quinquefolia	Wooded swamp	0.02		1	Reiners 1972
Aralia nudicaulis	Wooded swamp	0.24		1	Reiners 1972
	Wooded swamp	0.94		1	Reiners 1972
Aster lateriflorus	Wooded swamp (site A)[b]	2.30		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	1.20		1	Parker and Schneider 1975
Aster umbellatus	Wooded swamp (site A)[b]	1.70		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	0.70		1	Parker and Schneider 1975
Athyrium filix-femina	Wooded swamp	8.32		1	Reiners 1972
	Wooded swamp	8.18		1	Reiners 1972
Calamagrostis canadensis	Wooded swamp (site A)[b]	5.80		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	0.90		1	Parker and Schneider 1975
	Shrubby swamp	48.3		1	Reader and Stewart 1972
	Marsh	869.7		1	Auclair 1977
	Marsh	30.17		1	Jervis 1969
	Marsh (1993a)	153.9		1	Thormann 1995
	Marsh (1994a)	189.2		1	Thormann 1995
Caltha palustris	Wooded swamp (site A)[b]	2.8		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	1.8		1	Parker and Schneider 1975
Carex aquatilis	Open moderately rich fen	340		1	Gorham and Somers 1973
	Open extremely rich fen	164		1	Bartsch and Moore 1985
	Marsh	1 043.9		1	Auclair 1977
Carex atherodes	Marsh	2 858		1	Van der Valk and Davis 1978
Carex chordorrhiza	Shrubby moderately rich fen	233		1	Bartsch and Moore 1985
Carex diandra	Marsh	500.5		1	Auclair 1977
Carex lacustris	Open moderately rich fen	965	1 173	1	Bernard and Solsky 1977
	Marsh	1 580	1 741	1	Bernard and MacDonald 1976
	Marsh	1 181		1	Klopatek and Stearns 1978
	Marsh	709.8		1	Auclair 1977
Carex lanuginosa	Marsh	574.6		1	Auclair 1977
Carex leptalea	Wooded swamp	0.03		1	Reiners 1972
	Wooded swamp (site A)[b]	0.6		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	0.5		1	Parker and Schneider 1975
Carex limosa	Shrubby poor fen	27		1	Bartsch and Moore 1985
Carex rostrata	Shrubby moderately rich fen	90		1	Bartsch and Moore 1985
	Open moderately rich fen	515		1	Gorham and Somers 1973
	Open moderately rich fen	823		1	Bernard and Gorham 1978
	Shrubby swamp	116		1	Reader and Stewart 1972
	Marsh	738	918	1	Bernard 1974
Carex stipata	Wooded swamp	0.5		1	Parker and Schneider 1975
	Wooded swamp	1.5		1	Parker and Schneider 1975

Table 12 continued

Species or layer	Wetland type	NPP[a] (g $m^{-2}yr^{-1}$) Aboveground	Total	No. of sites	Reference
Carex stricta	Marsh	903.5		1	Auclair 1977
	Marsh	703.1		1	Jervis 1969
Carex vesicaria	Wooded swamp (site A)[b]	4.8		1	Parker and Schneider 1975
Carex spp.	Wooded moderately rich fen (1991b)[b]	26.7		1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	26.0		1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	44.4		1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	28.8		1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[b]	201.8		1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[b]	121.4		1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[b]	78.5		1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	294.8		1	Thormann 1995
	Shrubby moderately rich fen (1993e)[b]	94.4		1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	126.9		1	Thormann 1995
	Shrubby swamp	582.94		1	Jervis 1969
	Marsh (1993f)[b]	337.4		1	Thormann 1995
	Marsh (1994f)[b]	474.6		1	Thromann 1995
	Marsh (1993a)[b]	236.9		1	Thormann 1995
	Marsh (1994a)[b]	97.5		1	Thormann 1995
	Marsh (1993b)[b]	531.7		1	Thormann 1995
	Marsh (1994b)[b]	877.7		1	Thormann 1995
Cinna latifolia	Wooded swamp (site A)[b]	0.5		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	2.3		1	Parker and Schneider 1975
Circaea alpina	Wooded swamp	0.07		1	Reiners 1972
	Wooded swamp	0.09		1	Reiners 1972
Cornus canadensis	Wooded swamp	0.06		1	Reiners 1972
Dryopteris spinulosa	Wooded swamp	0.45		1	Reiners 1972
	Wooded swamp	1.2		1	Reiners 1972
	Wooded swamp (site A)[b]	2.4		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	2.9		1	Parker and Schneider 1975
Equisetum arvense	Wooded swamp (site A)[b]	4.1		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	0.5		1	Parker and Schneider 1975
Equisetum fluviatile	Shrubby moderately rich fen (1993e)[b]	0.6		1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	3.7		1	Thormann 1995
Eriophorum vaginatum	Nonpermafrost bog (1991a)[b]	2.5		1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	3.7		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	3.6		1	Thormann 1995
Eupatorium maculatum	Wooded swamp (site A)[b]	2.5		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	6.6		1	Parker and Schneider 1975
Fragaria virginiana	Wooded swamp	0.23		1	Reiners 1972
Galium trifidum	Marsh (1993a)[b]	0.3		1	Thormann 1995
	Marsh (1994a)[b]	1		1	Thormann 1995
	Marsh (1993b)[b]	3.4		1	Thormann 1995
	Wooded swamp	0.01		1	Reiners 1972
	Wooded swamp	0.02		1	Reiners 1972

Table 12 continued

Species or layer	Wetland type	NPP[a] ($g\ m^{-2}yr^{-1}$) Aboveground	Total	No. of stes	Reference
Glyceria striata	Wooded swamp (site A)[b]	30		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	44.7		1	Parker and Schneider 1975
Impatiens capensis	Wooded swamp (site A)[b]	3.4		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	15.3		1	Parker and Schneider 1975
	Wooded swamp	0.78		1	Reiners 1972
	Wooded swamp	0.08		1	Reiners 1972
Juncus spp.	Open extremely rich fen (1991)[b]	1.9		1	Szumigalski 1995
	Open extremely rich fen (1992)[b]	1.8		1	Szumigalski 1995
Lemna spp.	Shrubby swamp	46.7		1	Jervis 1969
	Marsh	33.0		1	Jervis 1969
	Marsh	35.5		1	Jervis 1969
	Marsh	192.1		1	Jervis 1969
Lycopus uniflorus	Wooded swamp	0.02		1	Reiners 1972
	Wooded swamp	0.14		1	Reiners 1972
Maianthemum canadense	Wooded swamp	0.14		1	Reiners 1972
	Wooded swamp	0.04		1	Reiners 1972
Mentha arvensis	Marsh (1994a)[b]	0.4		1	Thormann 1995
Menyanthes trifoliata	Wooded moderately rich fen (1991b)[b]	41.7		1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	16.8		1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	6.5		1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	4.4		1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[b]	12.8		1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	19.5		1	Thormann 1995
Mitella nuda	Wooded swamp	0.17		1	Reiners 1972
	Wooded swamp	0.82		1	Reiners 1972
Muhlenbergia glomerata	Open extremely rich fen (1991)[b]	15.5		1	Szumigalski 1995
	Open extremely rich fen (1992)[b]	1.9		1	Szumigalski 1995
Oryzopsis asperifolia	Wooded moderately rich fen	15.2		1	Reiners 1972
Phalaris arundinacea	Marsh	1 353	2 028	1	Klopatek and Stearns 1978
Poa palustris	Wooded swamp	0.1		1	Reiners 1972
	Wooded swamp	0.09		1	Reiners 1972
	Wooded swamp	0.03		1	Reiners 1972
	Wooded swamp	0.05		1	Reiners 1972
Polygonum spp.	Shrubby swamp	34.3		1	Jervis 1969
	Marsh	110.43		1	Jervis 1969
	Marsh	21.2		1	Jervis 1969
	Marsh	21.85		1	Jervis 1969
Potentilla palustris	Shrubby moderately rich fen (1993d)[b]	7.2		1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	13.6		1	Thormann 1995
	Shrubby moderately rich fen (1993e)[b]	1.7		1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	2.9		1	Thormann 1995
	Marsh (1994f)	1.9		1	Thormann 1995
Pteridium aquilinum	Wooded swamp	1.7		1	Reiners 1972

Table 12 continued

Species or layer	Wetland type	NPP[a] ($g\ m^{-2}yr^{-1}$) Aboveground	Total	No. of sites	Reference
Rubus chamaemorus	Nonpermafrost bog (1991a)[b]	1.7		1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	1.4		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	20.2		1	Thormann 1995
Rubus pubescens	Wooded swamp	0.6		1	Reiners 1972
	Wooded swamp	0.9		1	Reiners 1972
	Wooded swamp	2.8		1	Parker and Schneider 1975
	Wooded swamp	2.4		1	Parker and Schneider 1975
Scirpus cyperinus	Open extremely rich fen (1991)[b]	54.4		1	Szumigalski 1995
	Open extremely rich fen (1992)[b]	51.2		1	Szumigalski 1995
Scirpus fluviatilis	Marsh	1 116	1 533	1	Klopatek and Stearns 1978
	Marsh	943		1	van der Valk and Davis 1978
Scirpus validus	Marsh	713		1	van der Valk and Davis 1978
Scirpus spp.	Marsh	119.1		1	Jervis 1969
Smilacina trifolia	Nonpermafrost bog (1991a)[b]	4.3		1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	9.4		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	6.1		1	Thormann 1995
	Wooded moderately rich fen (1991b)[b]	7.9		1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[b]	7.1		1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	2.0		1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	17.3		1	Szumigalski 1995
Sparganium eurycarpum	Marsh	1 066.0		1	van der Valk and Davis 1978
Sparganium spp.	Marsh	239.6		1	Jervis 1969
	Marsh	20.77		1	Jervis 1969
Trientalis borealis	Wooded moderately rich fen	0.01		1	Reiners 1972
	Wooded swamp	0.08		1	Reiners 1972
Triglochin maritima	Marsh (1993f)[b]	3.6		1	Thormann 1995
	Marsh (1994f)[b]	1.4		1	Thormann 1995
Triglochin spp.	Open extremely rich fen (1991)[b]	19.8		1	Szumigalski 1995
	Open extremely rich fen (1992)[b]	24.0		1	Szumigalski 1995
Typha latifolia	Shrubby swamp	43.7		1	Jervis 1969
	Marsh	404.0	1 316	1	McNaughton 1966
	Marsh	416.0	972	1	McNaughton 1966
	Marsh	1 643	3 200	1	Klopatek and Stearns 1978
	Marsh	83.25		1	Jervis 1969
	Marsh	1 565.63		1	Jervis 1969
	Marsh	933.4		1	Auclair 1977
	Marsh (1993b)[b]	46.1		1	Thormann 1995
	Marsh (1994b)[b]	54.9		1	Thormann 1995
	Marsh (stand 4)[b]	144		1	Bray et al. 1959
	Marsh (stand 12)[b]	168		1	Bray et al. 1959
Typha spp.	Marsh	1 360		1	Bray 1962
Urtica dioica	Marsh (1994a)[b]	1.8		1	Thormann 1995

Table 12 continued

Species or layer	Wetland type	NPP[a] (g $m^{-2}yr^{-1}$) Aboveground	Total	No. of sites	Reference
Herb layer	Nonpermafrost bog (1991a)[b]	8.5		1	Szumigalski 1995
	Nonpermafrost bog (1992a)[b]	14.5		1	Szumigalski 1995
	Nonpermafrost bog (1994a)[b]	34		1	Thormann 1995
	Nonpermafrost bog, raised	14		3	Grigal et al. 1985
	Nonpermafrost bog, perched	22		3	Grigal et al. 1985
	Nonpermafrost bog	3		1	Richardson et al. 1978
	Wooded moderately rich fen (1991a)[b]	76.3		1	Szumigalski 1995
	Wooded moderately rich fen (1992a)[b]	52.3		1	Szumigalski 1995
	Shrubby poor fen (1991c)[b]	55.3		1	Szumigalski 1995
	Shrubby poor fen (1992c)[b]	51.6		1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[b]	203.3		1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[b]	122.3		1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[b]	80.6		1	Thormann 1995
	Shrubby moderately rich fen (1994d)[b]	302		1	Thormann 1995
	Shrubby moderately rich fen (1993e)[b]	121.7		1	Thormann 1995
	Shrubby moderately rich fen (1994e)[b]	165.7		1	Thormann 1995
	Open poor fen	111.7		1	Billings 1987
	Open moderately rich fen	965	1 173	1	Bernard and Solsky 1977
	Open moderately rich fen	823		1	Bernard and Gorham 1978
	Open extremely rich fen (1991)[b]	96.9		1	Szumigalski 1995
	Open extremely rich fen (1992)[b]	81.4		1	Szumigalski 1995
	Wooded swamp	86		1	Parker and Schneider 1975
	Wooded swamp	96		1	Parker and Schneider 1975
	Wooded swamp	46.5		1	Reiners 1972
	Wooded swamp	17.8		1	Reiners 1972
	Wooded swamp (site A)[b]	85.5		1	Parker and Schneider 1975
	Wooded swamp (site B)[b]	96.2		1	Parker and Schneider 1975
	Shrubby swamp	1 487.59		1	Jervis 1969
	Shrubby swamp	452.7		1	Reader and Stewart 1972
	Shrubby swamp	241		1	Tilton and Bernard 1975
	Marsh	1 580	1 741	1	Bernard and MacDonald 1976
	Marsh (1993f)[b]	338.4		1	Thormann 1995
	Marsh (1994f)[b]	480.3		1	Thormann 1995
	Marsh (1993a)[b]	394.1		1	Thormann 1995
	Marsh (1994a)[b]	296.7		1	Thormann 1995
	Marsh (1993b)[b]	581.7		1	Thormann 1995
	Marsh (1994b)[b]	932.6		1	Thormann 1995
	Marsh	1 547		1	Jervis 1969
	Marsh	1 905		1	Jervis 1969
	Marsh	1 492		1	Jervis 1969
	Marsh	1 643	3 200	1	Klopatek and Stearns 1978
	Marsh	1 585	2 877	1	Klopatek and Stearns 1978
	Marsh	1 116	1 533	1	Klopatek and Stearns 1978

Table 12 concluded

Species or layer	Wetland type	NPP[a] ($g\ m^{-2}yr^{-1}$) Aboveground	Total	No. of sites	Reference
Herb layer	Marsh	1 181		1	Klopatek and Stearns 1978
	Marsh	1 353	2 028	1	Klopatek and Stearns 1978
	Marsh	820		1	Auclair et al. 1976a
	Marsh	914		1	Auclair et al. 1976b
	Marsh	1 680		1	Bray et al. 1959
	Marsh	1 360		1	Bray 1963
	Marsh	1 066		1	van der Valk and Davis 1978
	Marsh	2 297		1	van der Valk and Davis 1978
	Marsh	404.0	1 316	1	McNaughton 1966
	Marsh	416.0	972	1	McNaughton 1966
	Marsh (stand 4)[b]	144		1	Bray et al. 1959
	Marsh(stand 12)[b]	168		1	Bray et al. 1959
	Marsh (year 1)[b]	940.0		1	Neill 1993
	Marsh(year 2)[b]	969.0		1	Neill 1993

[a] All estimates for 1 yr only.

[b] Refers to year and/or site sampled.

Table 13. Pooled means of net primary production (NPP) data for the herb layer

Reference[a]	NPP reported ($g\ m^{-2}yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}yr^{-1}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}yr^{-1}$) Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	8.5						
	14.5						
Thormann 1995	34.0	19	Bleak Lake, Alberta		Alberta	19	
Grigal et al. 1985	14.0	NA	3 raised bog sites, Minnesota				
	22.0	NA	3 perched bog sites, Minnesota		Minnesota	18	
Richardson et al. 1978	3.0	3	Open bog, Michigan	16	Michigan	3	13
Wooded fens							
Szumigalski 1995	76.3						
	52.3	64	Tawatinaw, Alberta	64	Alberta	64	64
Shrubby fens							
Szumigalski 1995	55.3						
	51.6	54	Bleak Lake, Alberta				
	203.3						
	122.3						
Thormann 1995	80.6						
	302.0	177	Tawatinaw, Alberta				
	121.7						
	165.7	144	Tawatinaw, Alberta	12 5 ± 64	Alberta	125	125
Open fens							
Billings 1987	111.7	112	Collapse scar, Alaska		Alaska	112	
Szumigalski 1995	96.9		Calahoo, Alberta				
	81.4	89	Calahoo, Alberta		Alberta	89	
Bernard and Solsky 1977	965.0	965	Open fen, New York				
Bernard and Gorham 1978	823.0	823	Open fen, New York	497 ± 462	New York	894	365 ± 458
Wooded swamps							
Parker and Schneider 1975	86.0	86	Site A, Michigan				
	96.0	96	Site B, Michigan		Michigan	91	
Reiners 1972	46.5	47	Site 2, Minnesota				
	17.8	18	Site 3, Minnesota	62 ± 36	Minnesota	33	62

Table 13 continued

Reference[a]	NPP reported ($g\ m^{-2}yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}yr^{-1}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}yr^{-1}$) Individual	Pooled
Shrubby swamps							
Reader and Stewart 1972	452.7	453	Elma Bog, Manitoba		Manitoba	453	
Jervis 1969	1 487.6	1 488	Shrubby swamp, New Jersey		New Jersy	1 488	
Tilton and Bernard 1975	241.0	241	Alder shrub, New York	727 ± 667	New York	241	727 ± 667
Marshes							
Thormann 1995	338.4						
	480.3	409	Riverine Marsh, Alberta				
	394.1						
	296.7	345	Lacustrine Marsh, Alberta				
	581.7						
	932.6	757	Site 4, Alberta		Alberta	504	
Neill 1993	940.0		Delta Marsh, Manitoba				
	969.0	955	Delta Marsh, Manitoba		Manitoba	955	
Auclair et al. 1976a	820.0	820	*Carex* marsh, Quebec				
Auclair et al. 1976b	914.0	914	*Scirpus* marsh, Quebec		Quebec	867	
McNaughton 1966	404.0	404	*Typha* marsh, North Dakota		North Dakota	404	
Bray et al. 1959	1 680.0	1 680	Marsh, Minnesota				
	144.0	144	Marsh stand 4, Minnesota				
	168.0	168	Marsh stand 12, Minnesota				
Bray 1962	1 360.0	1 360	*Typha* marsh, Minnesota		Minnesota	557	
Klopatek and Stearns 1978	1 643.0	1 643	*Typha* marsh, Wisconsin				
	1 585.0	1 585	*Typha–Sparganium* marsh, Wisconsin				
	1 116.0	1 116	*Scirpus* marsh, Wisconsin				
	1 181.0	1 181	*Carex* marsh, Wisconsin				
	1 353.0	1 353	*Phalaris* marsh, Wisconsin		Wisconsin	1 376	
McNaughton 1966	416.0	416	*Typha* marsh, Nebraska		Nebraska	416	
van der Valk andDavis 1978	1 066.0	1 066	Prairie pothole, Iowa				
	2 297.0	2 297	Prairie pothole, Iowa		Iowa	1 682	
Bernard and MacDonald 1976	1 580.0	1 580	Marsh, New York		New York	15 580	
Jervis 1969	1 547.0	1 547	*Zizania* marsh, New Jersey				
	1 905.0	1 905	*Typha* marsh, New Jersey				
Jervis 1969	1 492.0	1 492	*Carex stricta* marsh, New Jersey	1 092 ± 592	New Jersey	1 648	999 ± 529

[a] For permafrost bogs there were no sites with NPP data.

[b] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Herb Biomass

There were 240 measurements of aboveground biomass for the whole herb layer (independent of species) (Table 14), ranging from 8.5 g m^{-2} in a nonpermafrost bog (Szumigalski 1995) to 1738.00 g m^{-2} in a marsh (Jervis 1969) (mean 240 g m^{-2}). Aboveground biomass of individual species in the herb layer (488 measurements) ranged from 0.01 g m^{-2} for *Galium triflorum* in a wooded swamp (Reiners 1972) to 1566.00 g m^{-2} for *Typha* in a marsh (Jervis 1969) (mean 355 g m^{-2}). Pooled site and pooled province or state means for marshes were greater than for any other wetland type, followed by shrubby swamps, open fens, shrubby fens, wooded fens, wooded swamps, and nonpermafrost bogs (Table 15). Pooled site and pooled province and state means for marshes did not overlap the pooled means for other wetland types by one standard deviation, except for the pooled province and state mean for open fens (Table 15). Unfortunately, very few standard deviations could be calculated for the pooled means of each wetland type because of insufficient sample size and the reporting of only pooled means by some authors.

Moss NPP

There were 143 measurements of NPP for the whole moss layer (independent of species) (Table 16), ranging from 17.0 g m^{-2} yr^{-1} in a nonpermafrost bog (Reader and Stewart 1972) to a pooled mean of 380.0 g m^{-2} yr^{-1} in a nonpermafrost bog (Grigal et al. 1985) (mean 143 g m^{-2} yr^{-1}). Aboveground NPP of individual species in the moss layer (106 measurements) ranged from 5.4 g m^{-2} yr^{-1} for *Aulacomnium palustre* in a nonpermafrost bog (Reader and Stewart 1972) to 404.7 g m^{-2} yr^{-1}, also for *Aulacomnium palustre*, in a shrubby, moderately rich fen (Thormann and Bayley 1997a) (mean 128 g m^{-2} yr^{-1}).

Some studies of moss production have considered microtopography as well as species and site types, which creates additional categories for comparison. The most productive was a *Sphagnum* hollow in a nonpermafrost bog, which reached a pooled mean of 520.0 g m^{-2} yr^{-1} (Grigal 1985) ; the least productive was a mud-bottom in a wooded extremely rich fen, which had a pooled mean of 40.0 g m^{-2} yr^{-1} (Vitt 1990) (overall mean 145 g m^{-2} yr^{-1}) (Table 16). Because of insufficient site numbers and reporting of pooled means by some authors, standard deviations could be calculated only for pooled site means for shrubby fens. When pooled site means were considered, nonpermafrost bogs had the greatest moss NPP, followed by open, shrubby, and wooded fens, and permafrost bogs. When pooled province and state means were considered, open fens had more moss NPP than nonpermafrost bogs (Table 17). All wetland types supporting mosses had some overlap in yearly NPP values, which suggests that any trends represented by the pooled means for the moss layer may be misleading.

Total NPP

There were 61 measurements of total NPP for all layers (independent of species) (Table 18), ranging from 121.6 g m^{-2} yr^{-1} in a shrubby, moderately rich fen (Thormann 1995) to 2297.0 g m^{-2} yr^{-1} in a marsh (van der Valk and Davis 1978) (mean 626 g m^{-2} yr^{-1}). Pooled site and province or state means suggest that swamps and marshes have more NPP than peatlands (Table 18). The pooled site mean for nonpermafrost bogs was dominated by more southerly sites, which have higher NPP. The pooled province and state mean for nonpermafrost bogs was much lower, within the range of the NPP values for other fens and bogs.

Total Biomass

There were 269 measurements of total aboveground biomass for all layers (independent of species and not including the moss layer), ranging from 92.7 g m^{-2} in an open, extremely rich fen (Szumigalski 1995) to 15 995.0 g m^{-2} in a swamp (Reiners 1972) (mean 3245 g m^{-2}) (Table 19). Pooled province and state means suggest that wooded and shrubby swamps as well as nonpermafrost and wooded fens and bogs had the greatest amount of biomass, followed by marshes, shrubby fens, and open fens.

Table 14. Herb aboveground biomass for individual species and herb layer

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Alisma plantago-aquatica	Marsh (2)[a]	444.00	1	van der Valk and Davis 1978
	Marsh (15)[a]	52.00	1	van der Valk and Davis 1978
Anemone quinquefolia	Wooded swamp (site B)[a]	0.10	1	Reiners 1972
Aralia nudicaulis	Wooded swamp (site B)[a]	0.66	1	Reiners 1972
	Wooded swamp (siteC)[a]	2.65	1	Reiners 1972
Aster puniceus	Wooded swamp (site A)[a]	1.20	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	2.30	1	Parker and Schneider 1975
Aster umbellatus	Wooded swamp (site A)[a]	1.70	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	0.70	1	Parker and Schneider 1975
Athyrium filix-femina	Wooded swamp (site B)[a]	26.60	1	Reiners 1972
	Wooded swamp (siteC)[a]	28.40	1	Reiners 1972
Bidens cernua	Marsh	598.00	1	van der Valk and Davis 1978
Calamagrostis canadensis	Wooded swamp (site A)[a]	5.80	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	0.90	1	Parker and Schneider 1975
	Shrubby swamp	23.20	1	Reader and Stewart 1972
	Marsh	807.00	1	Auclair 1977
	Marsh (1993a)[a]	153.90	1	Thormann 1995
	Marsh (1994a)[a]	189.20	1	Thormann 1995
Caltha palustris	Wooded swamp (site A)[a]	2.80	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1.80	1	Parker and Schneider 1975
Carex aquatilis	Open moderately rich fen	380.00	1	Gorham and Somers 1973
	Marsh	706.00	1	Auclair 1977
Carex diandra	Marsh	936.00	1	Auclair 1977
Carex lacustris	Marsh	1 037.00	1	Bernard and MacDonald 1976
	Marsh	1 145.00	1	Bernard and Solsky 1975
	Marsh	940.30	1	Klopatek and Stearns 1978
	Marsh	449.00	1	Auclair 1977
	Wooded swamp (site B)[a]	1.50	1	Parker and Schneider 1975
Carex lanuginosa	Marsh	1 283.00	1	Gorham and Bernard 1978
	Marsh	843.00	1	Auclair 1977
Carex leptalea	Wooded swamp (site C)[a]	0.04	1	Reiners 1972
	Wooded swamp (site A)[a]	0.60	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	0.50	1	Parker and Schneider 1975
Carex rostrata	Open moderately rich fen	640.00	1	Gorham and Somers 1973
	Shrubby swamp	43.50	1	Reader and Stewart 1972
	Marsh	852.00	1	Bernard 1974
Carex stricta	Wooded swamp (site A)[a]	0.50	1	Parker and Schneider 1975
	Marsh	737.00	1	Auclair 1977
Carex vesicaria	Wooded swamp (site A)[a]	4.80	1	Parker and Schneider 1975

Table 14 continued

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Carex spp.	Wooded moderately rich fen (1992b)[a]	26.70	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	26.00	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	44.40	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	28.80	1	Szumigalski 1995
	Shrubby moderately rich fen (1991d)[a]	201.80	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[a]	121.40	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	78.50	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	294.80	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	94.40	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	126.90	1	Thormann 1995
	Shrubby swamp	582.94	1	Jervis 1969
	Marsh	677.10	1	Jervis 1969
	Marsh	545.00	1	van Dyke 1972; cited in van der Valk and Davis 1978
	Marsh (1975)[a]	840.00	1	van der Valk and Davis 1978
	Marsh (1976)[a]	523.00	1	van der Valk and Davis 1978
	Marsh	530.00	1	van der Valk and Davis 1978
	Marsh (1993f)[a]	337.40	1	Thormann 1995
	Marsh (1994f)[a]	474.60	1	Thromann 1995
	Marsh (1993a)[a]	236.90	1	Thormann 1995
	Marsh (1994a)[a]	97.50	1	Thormann 1995
	Marsh (1993b)[a]	531.70	1	Thormann 1995
	Marsh (1994b)[a]	877.70	1	Thormann 1995
Cinna latifolia	Wooded swamp (site A)[a]	0.50	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	2.30	1	Parker and Schneider 1975
Circaea alpina	Wooded swamp (site B)[a]	0.09	1	Reiners 1972
	Wooded swamp (site C)[a]	0.10	1	Reiners 1972
Cornus canadensis	Wooded swamp (site C)[a]	0.13	1	Reiners 1972
Dryopteris spinulosa	Wooded swamp (site A)[a]	2.40	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	2.90	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1.24	1	Reiners 1972
	Wooded swamp (site C)[a]	3.03	1	Reiners 1972
Eleocharis palustris	Marsh (8)[a]	447.00	1	Van der Valk and Bliss 1971
	Marsh (15)[a]	208.00	1	Van der Valk and Bliss 1971
Equisetum arvense	Wooded swamp (site A)[a]	4.10	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	0.50	1	Parker and Schneider 1975
Equisetum fluviatile	Shrubby moderately rich fen (1993e)[a]	0.60	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	3.70	1	Thormann 1995
	Marsh (5)[a]	707.00	1	van der Valk and Bliss 1971
	Marsh (8)[a]	491.00	1	van der Valk and Bliss 1971
	Marsh (12)[a]	430.00	1	van der Valk and Bliss 1971

Table 14 continued

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Eriophorum vaginatum	Nonpermafrost bog (1991a)[a]	2.50	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	3.70	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	3.60	1	Thormann 1995
Eupatorium maculatum	Wooded swamp (site A)[a]	2.50	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	6.60	1	Parker and Schneider 1975
Galium trifidum	Marsh (1993a)[a]	0.30	1	Thormann 1995
	Marsh (1994a)[a]	1.00	1	Thormann 1995
	Marsh (1993b)[a]	3.40	1	Thormann 1995
	Wooded swamp (site B)[a]	0.01	1	Reiners 1972
	Wooded swamp (site C)[a]	0.02	1	Reiners 1972
Glyceria striata	Wooded swamp (site A)[a]	30.00	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	44.70	1	Parker and Schneider 1975
Impatiens capensis	Wooded swamp (site B)[a]	0.80	1	Reiners 1972
	Wooded swamp (site C)[a]	0.10	1	Reiners 1972
	Wooded swamp (site A)[a]	3.40	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	15.30	1	Parker and Schneider 1975
Juncus spp.	Open extremely rich fen (1991)[a]	1.90	1	Szumigalski 1995
	Open extremely rich fen (1992)[a]	1.80	1	Szumigalski 1995
Lemnaceae	Shrubby swamp	46.65	1	Jervis 1969
	Marsh	192.05	1	Jervis 1969
	Marsh	33.03	1	Jervis 1969
	Marsh	53.35	1	Jervis 1969
Lycopus uniflorus	Wooded swamp (site B)[a]	0.02	1	Reiners 1972
	Wooded swamp (site C)[a]	0.16	1	Reiners 1972
Maianthemum canadense	Wooded swamp (site B)[a]	0.40	1	Reiners 1972
	Wooded swamp (site C)[a]	0.12	1	Reiners 1972
Mentha arvensis	Marsh (1994a)[a]	0.40	1	Thormann 1995
Menyanthes trifoliata	Wooded moderately rich fen (1991b)[a]	41.70	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	16.80	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	6.50	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	4.40	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	12.80	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	19.50	1	Thormann 1995
Mitella nuda	Wooded swamp (site B)[a]	0.29	1	Reiners 1972
	Wooded swamp (site C)[a]	1.30	1	Reiners 1972
Muhlenbergia glomerata	Open extremely rich fen (1991)[a]	15.50	1	Szumigalski 1995
	Open extremely rich fen (1992)[a]	1.90	1	Szumigalski 1995
Oryzopsis asperifolia	Wooded swamp (site B)[a]	0.71	1	Reiners 1972
Phalaris arundinacea	Marsh	1 352.70	1	Klopatek and Stearns 1978
Phragmites communis	Marsh	1 110.00	1	van Dyke 1972, cited in van der Valk and Davis 1978

Table 14 continued

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Phragmites communis	Marsh	777.00	1	van der Valk and Davis 1976
Poa palustris	Wooded swamp (site B)[a]	0.12	1	Reiners 1972
	Wooded swamp (site C)[a]	0.13	1	Reiners 1972
	Wooded swamp (site B)[a]	0.06	1	Reiners 1972
	Wooded swamp (site C)[a]	0.09	1	Reiners 1972
Polygonum spp.	Shrubby swamp	1 280.00	1	Jervis 1969
	Marsh	21.90	1	Jervis 1969
	Marsh	21.20	1	Jervis 1969
	Marsh	110.43	1	Jervis 1969
Potentilla palustris	Shrubby moderately rich fen (1993d)[a]	7.20	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	13.60	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	1.70	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	2.90	1	Thormann 1995
	Marsh (1994f)[a]	1.90	1	Thormann 1995
Pteridium aquilinum	Wooded swamp (site B)[a]	2.30	1	Reiners 1972
Rubus chamaemorus	Nonpermafrost bog (1991a)[a]	1.70	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	1.40	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	20.20	1	Thormann 1995
Rubus pubescens	Wooded swamp (site A)[a]	2.80	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	2.40	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	1.11	1	Reiners 1972
	Wooded swamp (site C)[a]	1.64	1	Reiners 1972
Sagittaria latifolia	Marsh	460.00	1	van der Valk and Davis 1976, cited in van der Valk and Davis 1978
Scirpus acutus	Marsh	951.00	1	van Dyke 1972, cited in van der Valk and Davis 1978
	Marsh	751.00	1	van der Valk and Davis 1978
Scirpus caespitosus	Open extremely rich fen 1992	54.40	1	Szumigalski 1995
Scirpus cespitosus	Open extremely rich fen 1991	51.20	1	Szumigalski 1995
Scirpus fluviatilis	Marsh	984.00	1	Klopatek and Stearns 1978
	Marsh	450.00	1	van Dyke, 1972, cited in van der Valk and Davis 1978
	Marsh (1975)[a]	465.00	1	van der Valk and Davis 1978
	Marsh (1976)[a]	483.00	1	van der Valk and Davis 1978
Scirpus validus	Marsh	361.00	267	Lieffers and Shay 1982
	Marsh (1975)[a]	243.00	1	van der Valk and Davis 1978
	Marsh (1976)[a]	360.00	1	van der Valk and Davis 1978
Scirpus spp.	Marsh	119.10	1	Jervis 1969
Scolochloa festucacea	Marsh (1989)[a]	937.00	1	Neill 1993
	Marsh (1990)[a]	969.00	1	Neill 1993

Table 14 continued

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Smilacina trifolia	Nonpermafrost bog (1991a)[a]	4.30	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	9.40	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	6.10	1	Thormann 1995
	Wooded moderately rich fen (1991b)[a]	7.90	1	Szumigalski 1995
	Wooded moderately rich ren (1992b)[a]	7.10	1	Szumigalski 1995
	Shrubby poor fen (1991c)[a]	2.00	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	17.30	1	Szumigalski 1995
Sparganium eurycarpum	Marsh	770.00	1	van Dyke 1972, cited in van der Valk and Davis 1978
	Marsh (1975)[a]	489.00	1	van der Valk and Davis 1978
	Marsh (1976)[a]	474.00	1	van der Valk and Davis 1978
Sparganium spp.	Marsh	239.60	1	Jervis 1969
	Marsh	20.77	1	Jervis 1969
Trientalis borealis	Wooded swamp (site B)[a]	0.02	1	Reiners 1972
	Wooded swamp (site C)[a]	0.13	1	Reiners 1972
Triglochin maritima	Marsh (1993f)[a]	3.60	1	Thormann 1995
	Marsh (1994f)[a]	1.40	1	Thormann 1995
Triglochin spp.	Open extremely rich fen (1991)[a]	19.80	1	Szumigalski 1995
	Open extremely rich fen (1992)[a]	24.00	1	Szumigalski 1995
Typha latifolia	Marsh	1 527.00	1	Penfound 1956
	Marsh	1 494.00	1	Klopatek and Stearns 1978
	Marsh (stand 4)[a]	144.00	1	Bray 1959
	Marsh (stand 12)[a]	168.00	1	Bray 1959
	Marsh	951.00	30	Boyd and Hess 1970
	Marsh (PND)[a]	404.00	1	McNaughton 1966
	Marsh (WSD)[a]	378.00	1	McNaughton 1966
	Marsh (CON)[a]	416.00	1	McNaughton 1966
	Marsh (OOK)[a]	730.00	1	McNaughton 1966
	Marsh (10)[a]	322.00	1	van der Valk and Bliss 1971
	Marsh (1993b)[a]	46.10	1	Thormann 1995
	Marsh (1994b)[a]	54.90	1	Thormann 1995
Typha spp.	Marsh	83.25	1	Jervis 1969
	Marsh	1 566.00	1	Jervis 1969
	Marsh	1 360.00	3	Bray 1962
Urtica dioica	Marsh (1994a)[a]	1.80	1	Thormann 1995
Herb layer	Nonpermafrost bog (1991a)[a]	8.50	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	14.50	1	Szumigalski 1995
	Nonpermafrost bog (1994a)[a]	34.00	1	Thormann 1995
	Nonpermafrost bog (Bh)[a]	30.00	26	Swanson and Grigal 1991
	Nonpermafrost bog (Bl)[a]	80.00	35	Swanson and Grigal 1991
	Nonpermafrost bog (Bo)[a]	130.00	11	Swanson and Grigal 1991
	Wooded moderately rich fen (1991b)[a]	78.10	1	Szumigalski 1995

Table 14 continued

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Herb layer	Wooded moderately rich fen (1992b)[a]	52.30	1	Szumigalski 1995
	Wooded fen	90.00	34	Swanson and Grigal 1991
	Shrubby poor fen (1991c)[a]	55.30	1	Szumigalski 1995
	Shrubby poor fen (1992c)[a]	51.60	1	Szumigalski 1995
	Shubby moderately rich fen (1991d)[a]	203.30	1	Szumigalski 1995
	Shubby moderately rich fen (1992d)[a]	122.30	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	80.60	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	302.00	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	121.70	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	165.70	1	Thormann 1995
	Open extremely rich fen (1991)[a]	96.90	1	Szumigalski 1995
	Open extremely rich fen (1992)[a]	81.40	1	Szumigalski 1995
	Shrubby fen	130.00	20	Swanson and Grigal 1991
	Open moderately rich fen	640.00	1	Gorham and Somers 1973
	Open moderately rich fen	380.00	1	Gorham and Somers 1973
	Open fen	270.00	46	Swanson and Grigal 1991
	Wooded swamp (site B)[a]	186.61	1	Reiners 1972
	Wooded swamp (site C)[a]	54.22	1	Reiners 1972
	Wooded swamp (site A)[a]	85.50	1	Parker and Schneider 1975
	Wooded swamp (site B)[a]	96.20	1	Parker and Schneider 1975
	Wooded swamp	60.00	38	Swanson and Grigal 1991
	Shrubby swamp	65.70	1	Reader and Stewart 1972
	Shrubby swamp	1 280.00	1	Jervis 1969
	Shrubby swamp	130.00	18	Swanson and Grigal 1991
	Marsh	807.00	1	Auclair 1976b
	Marsh	845.00	1	Auclair 1976a
	Marsh	1 145.00	1	Bernard and Solsky 1977
	Marsh	1 037.00		Bernard and MacDonald 1976
	Marsh (1973A meadow)[a]	792.00	1	van der Valk and Davis 1978
	Marsh (1975a meadow)[a]	776.00	1	van der Valk and Davis 1978
	Marsh (1973B meadow[a]	687.00	1	van der Valk and Davis 1978
	Marsh (1975b meadow)[a]	541.00	1	van der Valk and Davis 1978
	Marsh (1973A emergent)[a]	529.00	1	van der Valk and Davis 1978
	Marsh (1975a emergent)[a]	541.00	1	van der Valk and Davis 1978
	Marsh (1973B emergent)[a]	515.00	1	van der Valk and Davis 1978
	Marsh (1975b emergent)[a]	511.00	1	van der Valk and Davis 1978
	Marsh (1989)[a]	940.00	1	Neill 1993
	Marsh (1990)[a]	969.00	1	Neill 1993
	Marsh	1 352.70	1	Klopatek and Stearns 1978
	Marsh	1 494.00	1	Klopatek and Stearns 1978
	Marsh	984.00	1	Klopatek and Stearns 1978
	Marsh	940.30	1	Klopatek and Stearns 1978

Table 14 concluded

Species or layer	Wetland type	Aboveground biomass ($g\ m^{-2}$)	No. of sites	References
Herb layer	Marsh	1 213.00	1	Jervis 1969
	Marsh	1 738.00	1	Jervis 1969
	Marsh	1 269.00	1	Jervis 1969
	Marsh (Stand 4)[a]	144.00	1	Bray 1959
	Marsh (Stand 12)[a]	168.00	1	Bray 1959
	Marsh (1993f)[a]	338.40	1	Thormann 1995
	Marsh (1994f)[a]	480.30	1	Thormann 1995
	Marsh (1993a)[a]	394.10	1	Thormann 1995
	Marsh (1994a)[a]	296.70	1	Thormann 1995
	Marsh (1993b)[a]	581.70	1	Thormann 1995
	Marsh (1994b)[a]	932.60	1	Thormann 1995

[a] Refers to year and/or site sampled.

Table 15. Pooled means of biomass data for the herb layer

Reference[a]	Biomass reported (g m^{-2})	Individual site biomass[b] (g m^{-2})	Site location	Pooled site mean (g m^{-2})	Province or state	Mean biomass for province or state (g m^{-2}) Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	8.50						
	14.50						
Thormann 1995	34.00	19	Bleak Lake, Alberta		Alberta	19	
Swanson and Grigal 1991	30.00	NA	26 Bh nonpermafrost bog sites, Minnesota				
	80.00	NA	35 Bm nonpermafrost bog sites, Minnesota				
	130.00	NA	11 Bo nonpermafrost bog sites, Minnesota	69	Minnesota	70	45
Wooded fens							
Szumigalski 1995	78.10						
	52.30	65	Tawatinaw, Alberta		Alberta	65	
Swanson and Grigal 1991	90.00	NA	34 wooded fen sites, Minnesota	89	Minnesota	90	78
Shrubby fens							
Szumigalski 1995	55.30						
	51.60	54	Bleak Lake, Alberta				
	203.30						
	122.30						
Thormann 1995	80.60						
	302.00	177	Tawatinaw, Alberta				
	121.70						
	165.70	144	Tawatinaw, Alberta		Alberta	125	
Swanson and Grigal 1991	130.00	NA	20 shrubby fen sites, Minnesota	129	Minnesota	130	128

Table 15 continued

Reference[a]	Biomass reported (g m^{-2})	Individual site biomass[b] (g m^{-2})	Site location	Pooled site mean (g m^{-2})	Province or state	Mean biomass for province or state (g m^{-2}) Individual	Pooled
Open fens							
Szumigalski 1995	96.90						
	81.40	89	Calahoo, Alberta				
Gorham and Somers 1973	640.00	640	Open fen, Alberta				
	380.00	380	Open fen, Alberta		Alberta	370	
Swanson and Grigal 1991	270.00	NA	46 open fens, Minnesota	276	Minnesota	270	320
Wooded swamps							
Parker and Schneider 1975	85.50	86	Site A, Michigan				
	96.20	96	Site B, Michigan		Michigan	91	
Reiners 1972	186.61	187	Site 2, Minnesota				
	54.22	54	Site 3, Minnesota				
Swanson and Grigal 1991	60.00	NA	38 wooded swamps, Minnesota	64	Minnesota	63	77
Shrubby swamps							
Reader and Stewart 1972	65.70	66	Elma, Manitoba		Manitoba	66	
Jervis 1969	1 280.00	1 280	Shrubby swamp, New Jersey		New Jersey	1 280	
Swanson and Grigal 1991	130.00	NA	18 shrubby swamp sites, Minnesota	184	Minnesota	130	492 ± 683
Marshes							
Thormann 1995	338.40						
	480.30	409	Riverine Marsh, Alberta				
	394.10						
	296.70	345	Lacustrine Marsh, Alberta				
	581.70						
	932.60	757	Site 4, Alberta		Alberta	485	

Table 15 concluded

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$) Individual	Pooled
Neill 1993	940.00						
	969.00	955	Delta Marsh, Manitoba		Manitoba	955	
Auclair et al. 1976b	807.00	807	*Scirpus* Marsh, Quebec				
Auclair et al. 1976a	845.00	845	*Carex* Marsh, Quebec		Quebec	826	
Bray et al. 1959	144.00	144	Marsh stand 4, Minnesota				
	168.00	168	Marsh stand 12, Minnesota		Minnesota	156	
Klopatek and Stearns 1978	1 352.70	1 353	*Typha* marsh, Wisconsin				
	1 494.00	1 494	*Scirpus* marsh, Wisconsin				
	984.00	984	*Carex* marsh, Wisconsin				
	940.30	940	*Phalaris* marsh, Wisconsin		Wisconsin	1 193	
van der Valk and Davis 1978	792.00		Marsh 1973A meadow marsh, Iowa				
	776.00	784	Marsh 1975A meadow marsh, Iowa				
	687.00		Marsh 1973B meadow marsh, Iowa				
	541.00	614	Marsh 1975B meadow marsh, Iowa				
	529.00		Marsh 1973A emergent marsh, Iowa				
	541.00	535	Marsh 1975A emergent marsh, Iowa				
	515.00		Marsh 1973B emergent marsh, Iowa				
	511.00	513	Marsh 1975B emergent marsh, Iowa		Iowa	612	
Bernard and Solsky 1977	1 145.00	1 145	*Carex lacustris* Marsh, New York				
Bernard and MacDonald 1976	1 037.00	1 037	*Carex lacustris* Marsh, New York		New York	1 091	
Jervis 1969	1 213.00	1 213	*Zizania* marsh, New Jersey				
	1 738.00	1 738	*Typha* marsh, New Jersey				
	1 269.00	1 269	*Carex stricta* marsh, New Jersey	860 ± 428	New Jersey	1 407	840.6 ± 382.2

[a] For permafrost bogs, there were no sites with biomass data.

[b] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Table 16. Estimates of total net primary production (NPP) for individual species of moss and whole moss layer

Species or layer	Wetland type	Total NPP ($g\ m^{-2}\ yr^{-1}$)	No. of sites	Reference
Aulacomnium palustre	Nonpermafrost bog	5.4	1	Reader and Stewart 1972
	Shrubby moderately rich fen (1993)[a]	136.2	1	Thormann and Bayley 1997a
	Shrubby moderately rich fen (1994)[a]	404.7	1	Thormann and Bayley 1997a
	Shrubby swamp	35.9	1	Reader and Stewart 1972
Campylium stellatum	Wooded extremely rich fen (1983)[a]	58.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	52.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	36.0	3	Vitt 1990
	Open extremely rich fen (1983)[a]	88.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	67.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	78.0	2	Vitt 1990
Drepanocladus aduncus	Shrubby moderately rich fen (1991d)[a]	47.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1992d)[a]	38.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1993d)[a]	26.8	1	Thormann and Bayley 1997a
	Shrubby moderately rich fen (1994d)[a]	120.8	1	Thormann and Bayley 1997a
Drepanocladus revolvens	Wooded extremely rich fen (1983)[a]	109.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	91.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	47.0	3	Vitt 1990
	Open extremely rich fen (1983)[a]	105.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	102.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	101.0	2	Vitt 1990
Hylocomium splendens	Wooded moderately rich fen	79.0	1	Busby et al. 1978
Hypnum pratense	Shrubby swamp	31.2	1	Reader and Stewart 1972
Pleurozium schreberi	Wooded swamp	107.7	1	Reader and Stewart 1972
Polytrichum juniperinum	Nonpermafrost bog	35.0	1	Reader and Stewart 1972
Scorpidium scorpioides	Wooded extremely rich fen (1983)[a]	108.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	97.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	40.0	3	Vitt 1990
	Open extremely rich fen (1983)[a]	108.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	156.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	170.0	2	Vitt 1990
Sphagnum angustifolium	Nonpermafrost bog (1984)[a]	186.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1985)[a]	169.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1986)[a]	157.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1987)[a]	99.0	1	Rochefort et al. 1990
	Wooded poor fen (1984)[a]	191.0	1	Rochefort et al. 1990
	Wooded poor fen (1985)[a]	198.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	100.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	97.0	1	Rochefort et al. 1990
	Shrubby poor fen (1991b)[a]	166.0	1	Szumigalski 1995
	Shrubby poor fen (1992b)[a]	95.0	1	Szumigalski 1995
	Shrubby moderately rich fen (1984 site A)[a]	127.4	1	Moore 1989a
	Shrubby moderately rich fen (1985 site A)[a]	29.2	1	Moore 1989a
	Shrubby moderately rich fen	19.2	1	Bartsch and Moore 1985
	Shrubby moderately rich fen	57.9	1	Bartsch and Moore 1985

Table 16 continued

Species or layer	Wetland type	Total NPP ($g\ m^{-2}\ yr^{-1}$)	No. of sites	Reference
Sphagnum capillifolium	Open moderately rich fen (1984 site E)[a]	78.7	1	Moore 1989a
	Open moderately rich fen (1985 site E)[a]	69.8	1	Moore 1989a
Sphagnum fuscum	Nonpermafrost bog (1991a)[a]	189.0	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	119.0	1	Szumigalski 1995
	Nonpermafrost bog (1993a)[a]	155.9	1	Thormann and Bayley 1997a
	Nonpermafrost bog (1994a)[a]	267.8	1	Thormann and Bayley 1997a
	Nonpermafrost bog	7.8	1	Reader and Stewart 1972
	Nonpermafrost bog	7.1	1	Reader and Stewart 1972
	Nonpermafrost bog (1984)[a]	69.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1985)[a]	91.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1986)[a]	116.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1987)[a]	119.0	1	Rochefort et al. 1990
	Wooded poor fen (1984)[a]	240.0	1	Rochefort et al. 1990
	Wooded poor fen (1985)[a]	303.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	175.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	156.0	1	Rochefort et al. 1990
	Wooded poor fen (1984 site D)[a]	75.3	1	Moore 1989a
	Wooded poor fen (1985S site D)[a]	83.5	1	Moore 1989a
Sphagnum magellanicum	Nonpermafrost bog (1984)[a]	230.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1985)[a]	186.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1986)[a]	73.0	1	Rochefort et al. 1990
	Nonpermafrost bog (1987)[a]	52.0	1	Rochefort et al. 1990
	Wooded poor fen (1984)[a]	246.0	1	Rochefort et al. 1990
	Wooded poor fen (1985)[a]	103.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	59.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	52.0	1	Rochefort et al. 1990
Sphagnum riparium	Shrubby moderately rich fen	8.6	1	Bartsch and Moore 1985
Sphagnum teres	Shrubby poor fen (1991b)[a]	143.0	1	Szumigalski 1995
	Shrubby poor fen (1992b)[a]	101.0	1	Szumigalski 1995
Sphagnum warnstorfii	Open moderately rich fen (1984 site B)[a]	142.1	1	Moore 1989a
	Open moderately rich fen (1985 site B)[a]	107.6	1	Moore 1989a
	Shrubby moderately rich fen (1993)[a]	33.2	1	Thormann and Bayley 1997a
	Shrubby moderately rich fen (1994)[a]	275.3	1	Thormann and Bayley 1997a
Sphagnum spp.	Nonpermafrost bog	390.0	1	Elling and Knighton 1984
	Permafrost bog	20.3	1	Billings 1987
	Open poor fen	194.9	1	Billings 1987
Tomenthypnum nitens	Wooded extremely rich fen (1983)[a]	55.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	58.0	3	Vitt 1990
	Wooded extremely rich fen (1984)[a]	64.0	3	Vitt 1990
	Wooded moderately rich fen	190.0	1	Busby et al. 1978
	Wooded moderately rich fen (1991b)[a]	170.0	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	115.0	1	Szumigalski 1995
	Wooded moderately rich fen	190.0	1	Busby et al. 1978
	Open extremely rich fen (1991)[a]	204.0	1	Szumigalski 1995

Table 16 continued

Species or layer	Wetland type	Total NPP ($g\ m^{-2}\ yr^{-1}$)	No. of sites	Reference
Tomenthypnum nitens	Open extremely rich fen (1992)[a]	95.0	1	Szumigalski 1995
	Open extremely rich fen (1983)[a]	104.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	130.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	131.0	2	Vitt 1990
Mud-bottom	Open extremely rich fen (1983)[a]	157.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	156.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	170.0	2	Vitt 1990
	Wooded extremely rich fen (1983)[a]	108.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	97.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	40.0	2	Vitt 1990
Carpet	Open extremely rich fen (1983)[a]	105.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	102.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	101.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	170.0	2	Vitt 1990
	Wooded extremely rich fen (1983)[a]	109.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	91.0	2	Vitt 1990
Lawn	Wooded extremely rich fen (1984)[a]	47.0	2	Vitt 1990
	Open moderately rich fen (1984 site C)[a]	90.1	1	Moore 1989a
	Open moderately rich fen (1985 site C)[a]	36.0	1	Moore 1989a
	Open extremely rich fen (1983)[a]	88.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	67.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	78.0	2	Vitt 1990
	Wooded extremely rich fen (1983)[a]	58.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	52.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	36.0	2	Vitt 1990
Hollow	Wooded poor fen (1985)[a]	198.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	100.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	97.0	1	Rochefort et al. 1990
	Nonpermafrost bog	520.0	3	Grigal 1985
	Nonpermafrost bog	370.0	3	Grigal 1985
Mid-hummock	Wooded poor fen (1985)[a]	103.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	59.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	52.0	1	Rochefort et al. 1990
Hummock	Nonpermafrost bog	320.0	3	Grigal 1985
	Nonpermafrost bog	300.0	3	Grigal 1985
	Wooded poor fen (1985)[a]	303.0	1	Rochefort et al. 1990
	Wooded poor fen (1986)[a]	175.0	1	Rochefort et al. 1990
	Wooded poor fen (1987)[a]	156.0	1	Rochefort et al. 1990
	Shrubby moderately rich fen	72.8	1	Bartsch and Moore 1885
	Wooded extremely rich fen (1983)[a]	55.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	58.0	2	Vitt 1990
	Wooded extremely rich fen (1984)[a]	64.0	2	Vitt 1990
	Open extremely rich fen (1983)[a]	104.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	130.0	2	Vitt 1990
	Open extremely rich fen (1984)[a]	131.0	2	Vitt 1990

Table 16 concluded

Species or layer	Wetland type	Total NPP ($g\ m^{-2}\ yr^{-1}$)	No. of sites	Reference
Moss layer	Permafrost bog	24.3	1	Billings 1987
	Nonpermafrost bog	55.4	1	Reader and Stewart 1972
	Nonpermafrost bog	17.0	1	Reader and Stewart 1972
	Nonpermafrost bog (1991a)[a]	189.0	1	Szumigalski 1995
	Nonpermafrost bog (1992a)[a]	119.0	1	Szumigalski 1995
	Nonpermafrost bog (1993a)[a]	155.9	1	Thormann 1995
	Nonpermafrost bog (1994a)[a]	267.8	1	Thormann 1995
	Nonpermafrost bog (raised)	320.0	3	Grigal et al. 1985
	Nonpermafrost bog (perched)	380.0	3	Grigal et al. 1985
	Wooded moderately rich fen (1991b)[a]	170.0	1	Szumigalski 1995
	Wooded moderately rich fen (1992b)[a]	115.0	1	Szumigalski 1995
	Wooded extremely rich fen (1985)[a]	93.0	3	Vitt 1990
	Wooded extremely rich fen (1986)[a]	83.0	3	Vitt 1990
	Wooded extremely rich fen (1987)[a]	47.0	3	Vitt 1990
	Shrubby poor fen (1991c)[a]	156.1	1	Szumigalski and Bayley 1997
	Shrubby poor fen (1992c)[a]	97.6	1	Szumigalski and Bayley 1997
	Shrubby moderately rich fen (1991d)[a]	47.0	1	Szumigalski and Bayley 1997
	Shrubby moderately rich fen (1992d)[a]	38.0	1	Szumigalski and Bayley 1997
	Shrubby moderately rich fen (1993d)[a]	26.8	1	Thormann 1995
	Shrubby moderately rich fen (1994d)[a]	120.8	1	Thormann 1995
	Shrubby moderately rich fen (1993e)[a]	52.0	1	Thormann 1995
	Shrubby moderately rich fen (1994e)[a]	287.0	1	Thormann 1995
	Open poor fen	194.9	1	Billings 1987
	Open extremely rich fen (1985)[a]	125.0	2	Vitt 1990
	Open extremely rich fen (1986)[a]	126.0	2	Vitt 1990
	Open extremely rich fen (1987)[a]	131.0	2	Vitt 1990
	Open extremely rich fen (1991)[a]	204.0	1	Szumigalski and Bayley 1997
	Open extremely rich fen (1992)[a]	95.0	1	Szumigalski and Bayley 1997
	Wooded swamp	116.3	1	Reader and Stewart 1972
	Shrubby swamp	75.8	1	Reader and Stewart 1972

[a] Refers to year and/or site sampled.

Table 17. Pooled means of net primary production (NPP) data for the moss layer

Reference[a]	NPP reported ($g\ m^{-2}\ yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}\ yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}\ yr^{-1}$)	
						Individual	Pooled
Permafrost bogs							
Billings 1987	24.3	24	Peat plateau, Alaska	24	Alaska	24	24
Nonpermafrost bogs							
Reader and Stewart 1972	55.4						
	17.0	36	Elma, Manitoba		Manitoba	36	
Szumigalski 1995	189.0						
	119.0						
Thormann 1995	155.9						
	267.8	183	Tawatinaw, Alberta		Alberta	183	
Grigal et al. 1985	320.0	NA	3 raised bog sites, Minnesota				
	380.0	NA	3 perched bog sites, Minnesota	290	Minnesota	350	190 ± 157
Wooded Fens							
Szumigalski 1995	170.0						
	115.0	143	Tawatinaw, Alberta				
Vitt 1990	93.0	NA	3 sites in boreal Alberta				
	83.0	NA	3 sites in boreal Alberta				
	47.0	NA	3 sites in boreal Alberta	81	Alberta	81	81

Table 17 concluded

Reference[a]	NPP reported ($g\ m^{-2}\ yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}\ yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}\ yr^{-1}$)	
						Individual	Pooled
Shrubby fens							
Szumigalski and Bayley 1997	156.1						
	97.6	127	Bleak Lake, Alberta				
	47.0						
	38.0						
Thormann 1995	26.8						
	120.8	58	Tawatinaw, Alberta				
	52.0						
	287.0	170	Tawatinaw, Alberta	118 ± 57	Alberta	118	118
Open fens							
Billings 1987	194.9	195	Collapse scar, Alaska		Alaska	195	
Vitt 1990	125.0	NA	2 sites in montane Alberta				
	126.0	NA	2 sites in montane Alberta				
	131.0	NA	2 sites in montane Alberta				
Szumigalski and Bayley 1997	204.0						
	95.0	150	Calahoo, Alberta	139	Alberta	131	163

[a] For wooded swamp and shrubby swamp sites, there were no mosses.

[b] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Table 18. Pooled means of net primary production (NPP) data for all layers

Reference[a]	NPP reported ($g\ m^{-2}\ yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}\ yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2} yr^{-1}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}\ yr^{-1}$)	
						Individual	Pooled
Permafrost bogs							
Billings 1987	175.8	176	Peat plateau, Alaska	176		176	176
Nonpermafrost bogs							
Szumigalski 1995	158.3						
	284.8						
Thormann 1995	445.8	296	Bleak Lake, Alberta		Alberta	296	
Reader and Stewart 1972	343.0						
	371.8	357	Elma Bog, Manitoba		Manitoba	357	
Grigal et al. 1985	634.0	NA	3 raised bog sites, Minnesota				
	755.0	NA	3 perched bog sites, Minnesota	603	Minnesota	695	449 ± 215
Wooded fens							
Szumigalski 1995	386.0						
	330.7	358	Tawatinaw, Alberta	358	Alberta	358	358
Shrubby fens							
Szumigalski and Bayley 1997	323.4						
	306.6	315	Bleak Lake, Alberta				
	259.6						
	167.3						
Thormann 1995	121.6						
	436.7	246	Tawatinaw, Alberta				
	206.7						
	504.5	356	Tawatinaw, Alberta		Alberta	306	
Bartsch and Moore 1985, cited in Moore and Knowles 1987	190.0	190	Shrubby poor fen, Quebec				
	250.0	250	Shrubby moderately rich fen, Quebec	271 ± 65	Quebec	220	263

Table 18 continued

Reference[a]	NPP reported (g m^{-2} yr^{-1})	Individual site NPP[b] (g m^{-2} yr^{-1})	Site location	Pooled site mean (g m^{-2})	Province or state	Mean NPP for province or state (g m^{-2} yr^{-1}) Individual	Pooled
Open fens							
Billings 1987	306.6	307	Collapse scar, Alaska		Alaska	307	
Szumigalski and Bayley 1997	310.2						
	182.6	246	Calahoo, Alberta		Alberta	246	
Bartsch and Moore 1985 cited in Moore and Knowles 1987	250.0	250	Open extremely rich fen, Quebec	268 ± 34	Quebec	250	268 ± 34
Wooded swamps							
Reader and Stewart 1972	482.8	483	Elma, Manitoba		Manitoba	483	
Parker and Schneider 1975	641.0	641	Site A, Michigan				
	576.0	576	Site B, Michigan		Michigan	609	
Reiners 1972	710.0	710	Site 2, Minnesota				
	1 030.0	1 030	Site 3, Minnesota	688 ± 209	Minnesota	870	654 ± 197
Shrubby swamps							
Reader and Stewart 1972	1 026.2	1 026	Elma, Manitoba		Manitoba	1 026	
Tilton and Bernard 1975	972.0	972	New York		New York	972	
Jervis 1969	1 699.0	1 699	Shrubby swamp, New Jersey	1 232 ± 405	New Jersey	1 699	1232 ± 405
Marshes							
Thormann 1995	338.4						
	480.3	409	Riverine Marsh, Alberta				
	394.1						
	296.7	345	Lacustrine Marsh, Alberta				
	581.7						
	932.6	757	Site 4, Alberta		Alberta	504	

Table 18 concluded

Reference[a]	NPP reported ($g\ m^{-2}\ yr^{-1}$)	Individual site NPP[b] ($g\ m^{-2}\ yr^{-1}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean NPP for province or state ($g\ m^{-2}\ yr^{-1}$) Individual	Pooled
Neill 1993	940.0		Delta Marsh, Manitoba				
	969.0	955	Delta Marsh, Manitoba		Manitoba	955	
Auclair et al. 1976b	820.0	820	*Carex* marsh, Quebec				
Auclair et al. 1976a	914.0	914	*Scirpus* marsh, Quebec		Quebec	867	
McNaughton 1966	404.0	404	*Typha* marsh, North Dakota		North Dakota	404	
Bray et al. 1959	1 680.0	1 680	Marsh, Minnesota				
	144.0	144	Marsh stand 4, Minnesota				
	168.0	168	Marsh stand 12, Minnesota				
Bray 1962	1 360.0	1 360	*Typha* marsh, Minnesota		Minnesota	838	
Klopatek and Stearns 1978	1 643.0	1 643	*Typha* marsh, Wisconsin				
	1 585.0	1 585	*Typha–Sparganium* marsh, Wisconsin				
	1 116.0	1 116	*Scirpus* marsh, Wisconsin				
	1 181.0	1 181	*Carex* marsh, Wisconsin				
	1 353.0	1 353	*Phalaris* marsh, Wisconsin		Wisconsin	1 376	
McNaughton 1966	416.0	416	*Typha* marsh, Nebraska		Nebraska	416	
van der Valk and Davis 1978	1 066.0	1 066	Prairie pothole, Iowa				
	2 297.0	2 297	Prairie pothole, Iowa		Iowa	1 682	
Jervis 1969	1 547.0	1 547	*Zizania* marsh, New Jersey				
	1 905.0	1 905	*Typha* marsh, New Jersey				
	1 492.0	1 492	*Carex stricta* marsh, New Jersey	1 071 ± 596	New Jersey	1 648	1 034 ± 456

[a] Only for sites for which such data were available; if only a mean of several sites was reported, individual site values were not available or could not be calculated (NA).

Table 19. Pooled means of total biomass data for all layers

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$) Individual	Pooled
Nonpermafrost bogs							
Szumigalski 1995	823.2						
	854.8						
Thormann 1995	984.0	887	Bleak Lake, Alberta		Alberta	887	
Reader and Stewart 1972	901.3						
	423.3	662	Elma Bog, Manitoba		Manitoba	662	
Grigal et al. 1985	134.0	NA	3 raised bog sites, Minnesota				
	651.0	NA	3 perched bog sites, Minnesota				
Swanson and Grigal 1991	7 440.0	NA	26 Bh nonpermafrost bog sites, Minnesota				
	2 650.0	NA	35 Bm nonpermafrost bog sites, Minnesota		Minnesota		
	400.0	NA	11 Bo nonpermafrost bog sites, Minnesota	3 681		3 755	1 768 ± 1 408
Wooded fens							
Szumigalski 1995	887.3						
	613.3	750	Bleak Lake, Alberta		Alberta	750	
Swanson and Grigal 1991	2 970.0	NA	34 wooded fen sites, Minnesota	2 907	Minnesota	2970	1 860
Shrubby fens							
Szumigalski 1995	364.1						
	424.8	395	Bleak Lake, Alberta				
	224.6						
	139.8						
Thormann 1995	110.0						
	328.0	201	Tawatinaw, Alberta				
	190.0						
	269.0	230	Tawatinaw, Alberta		Alberta	275	
Moore 1989b	190.0	190	Shrubby fen, Quebec		Quebec	190	
Swanson and Grigal 1991	650.0	NA	20 shrubby fen sites, Minnesota	584	Minnesota	650	372 ± 245

Table 19 continued

Reference[a]	Biomass reported (g m^{-2})	Individual site biomass[b] (g m^{-2})	Site location	Pooled site mean (g m^{-2})	Province or state	Mean biomass for province or state (g m^{-2}) Individual	Pooled
Open fens							
Szumigalski 1995	105.0						
	92.7	99	Calahoo, Alberta		Alberta	99	
Swanson and Grigal 1991	490.0	NA	46 open fen sites, Minnesota	482	Minnesota	490	295
Wooded swamp							
Reader and Stewart 1972	4 455.0	4 455	Elma Bog, Manitoba		Manitoba	4 455	
Parker and Schneider 1975	5 300.0	5 300	Site A, Michigan				
	3 100.0	3 100	Site B, Michigan		Michigan	4 200	
Reiners 1972	9 995.4	9 995	Site 2, Minnesota				
	15 995.0	15 995	Site 3, Minnesota				
Swanson and Grigal 1991	8 780.0	NA	38 wooded swamp sites, Minnesota	8 662	Minnesota	8 991	5 882 ± 2 201
Shrubby swamps							
Reader and Stewart 1972	2 418.9	2 419	Elma Bog, Manitoba		Manitoba	2 419	
Tilton and Bernard 1975	2 752.0	2 752	Alder swamp, New York		New York	2 752	
Jervis 1969	1 280.0	1 280	Shrubby swamp, New Jersey		New Jersey	1 280	
Swanson and Grigal 1991	3 480.0	NA	18 shrubby swamp sites, Minnesota	3 290	Minnesota	3 480	2 483 ± 916
Marshes							
Thormann 1995	338.4						
	480.3	401	Riverine marsh, Alberta				
	394.1						
	296.7	345	Lacustrine marsh, Alberta		Alberta		
	581.7						
	932.6	757	Site 4, Alberta			503	

Table 19 concluded

Reference[a]	Biomass reported ($g\ m^{-2}$)	Individual site biomass[b] ($g\ m^{-2}$)	Site location	Pooled site mean ($g\ m^{-2}$)	Province or state	Mean biomass for province or state ($g\ m^{-2}$)	
						Individual	Pooled
Neill 1993	940.0						
	969.0	955	Delta marsh, Manitoba		Manitoba	955	
Auclair et al. 1976b	807.0	807	*Scirpus* marsh, Quebec		Quebec		
Auclair et al. 1976a	845.0	845	*Carex* marsh, Quebec			826	
Bray et al. 1959	144.0	144	Marsh stand 4, Minnesota		Minnesota	156	
	168.0	168	Marsh stand 12, Minnesota				
Klopatek and Stearns 1978	1 352.7	1 353	*Typha* marsh, Wisconsin				
	1 494.0	1 494	*Scirpus* marsh, Wisconsin				
	984.0	984	*Carex* marsh, Wisconsin		Wisconsin	1 193	
	940.3	940	*Phalaris* marsh, Wisconsin				
van der Valk and Davis 1978	792.0		Marsh 1973A meadow marsh, Iowa				
	776.0	784	Marsh 1975a meadow marsh, Iowa				
	687.0		Marsh 1973B meadow marsh, Iowa				
	541.0	614	Marsh 1975b meadow marsh, Iowa		Iowa		
	529.0		Marsh 1973A emergent marsh, Iowa				
	541.0	535	Marsh 1975a emergent marsh, Iowa				
	515.0		Marsh 1973B emergent marsh, Iowa			612	
	511.0	513	Marsh 1975b emergent marsh, Iowa				
Bernard and Solsky 1977	1 145.0	1 145	*Carex lacustris* marsh, New York		New York	1 091	
Bernard and MacDonald 1976	1 037.0	1 037	*Carex lacustris* marsh, New York				
Jervis 1969	1 213.0	1 213	*Zizania* marsh, New Jersey				
	1 738.0	1 738	*Typha* marsh, New Jersey		New Jersey	1 407	843 ± 380
	1 269.0	1269	*Carex stricta* marsh, New Jersey	857 ± 428			

[a] For permafrost bogs, there were no sites with biomass data.

[b] Only for sites for which such data were available; if only a mean of seeral sites was reported, individual sites values were not available or could not be calculated (NA).

DISCUSSION

Given the diversity of wetland types, species, and microtopographic settings, there is a scarcity of research relating total wetland NPP to environmental factors (Reader 1978; Richardson 1978; Gorham 1982). Links among NPP of wetlands and water levels (Forrest and Smith 1975; Moore 1989b; Szumigalski and Bayley 1997; Thormann and Bayley 1997a, 1997b, 1997c; Thormann et al. 1998), climate (Gorham 1974; Damman 1979; Wieder and Lang 1983; Droste 1984; Wieder et al. 1989; Rochefort et al. 1990; Szumigalski and Bayley 1997; Thormann and Bayley 1997a, 1997b), and nutrient availability (Reader 1978; Brinson et al. 1981; Bartsch and Moore 1985; Grigal et al. 1985; Backéus 1990; Li and Vitt 1997; Szumigalski and Bayley 1997; Thormann and Bayley 1997a, 1997b, 1997c) have been reported; however, reporting of these variables has not been consistent. This synthesis indicates that the degree of variation within wetland types can be as large as that among most wetland types, although marshes and swamps tend to have a higher NPP than fens and bogs for all layers, excluding the moss layer that is restricted to fens and bogs, according to the Vitt et al. (1996) wetland classification. Vitt (1994) argued that available nutrients do not differ appreciably along the rich fen–bog gradient but that fens and bogs do differ significantly from marshes and swamps in terms of available nutrients. The pattern established for NPP in this synthesis supports this conclusion. In addition, more southerly sites of similar wetland types have higher rates of NPP, as others have shown.

Although there is an overall production gradient consistent with the idea that potential primary production of a wetland is in general a function of its "openness" to hydrological fluxes (Moore and Bellamy 1974), the gradient is statistically significant only at the coarse scale of fens and bogs versus swamps and marshes (although for the herb and moss layers, this general trend appeared to hold true). On the basis of the data reviewed in this synthesis and until more data are collected, a simple twofold separation based on the aboveground NPP of fens and bogs (337 ± 142 g m^{-2} yr^{-1}; mean of all fen and bog sites pooled by wetland type and location) and marshes and swamps (924 ± 463 g m^{-2} yr^{-1}; mean of all swamp and marsh sites pooled by wetland type and location) would be a reasonable first approximation of aboveground NPP in continental western Canada (Table 20). This general conclusion agrees with those reached by Thormann (1995) and Thormann and Bayley (1997a, 1997b) for sites restricted to a small part of continental western Canada.

In a study of belowground NPP of vascular plants in an open, nonpermafrost bog in Sweden, 38%–59% of the total NPP was in the fine roots alone (coarse roots were not considered) (Backéus 1990). Backéus (1990) also concluded that during dry years, belowground NPP increased as roots penetrated significantly deeper peat layers. There is little information available on belowground NPP in continental Canada. In most studies, only data for aboveground NPP were collected because belowground NPP is difficult to measure. The available studies indicate that belowground NPP constitutes anywhere from 25% to 90% of the total NPP (Forrest 1971; Taylor 1983; Wallén 1986, 1987, 1992). The only study in continental Canada that considered aboveground, belowground, and total NPP of all vegetation layers showed great variability in aboveground NPP (which ranged from 20% to 72% of total NPP) and belowground NPP (which ranged from 28% to 80% of total NPP) (Reader and Stewart 1972). Belowground NPP of fens and bogs (28% to 80%; Reader and Stewart 1972) is greater than that of marshes (14% to 46%; Bernard 1974; Klopatek 1975; Auclair et al. 1976a; Bernard and MacDonald 1976; Bernard and Solsky 1977; Klopatek and Stearns 1978).

On the basis of the means of these ranges of belowground NPP, it seems reasonable to estimate that the belowground NPP of fens and bogs is about 50% (169 g m^{-2} yr^{-1}) and that of marshes and swamps is 30% (277 g m^{-2} yr^{-1}) of the aboveground NPP.

Biomass values follow a similar pattern. Marshes and swamps generally have a greater amount of biomass than fens and bogs. Because some authors reported only pooled means, many standard deviations could not be calculated, and the statistical validity of patterns cannot be established. On the basis of this synthesis, a subdivision of swamps and marshes from fens and bogs seems reasonable. The site mean for fens and bogs (1198 ± 1556 g m^{-2}) is much lower than that for marshes and swamps (2291 ± 2330 g m^{-2}) (Table 21).

Table 20. Summary of aboveground pooled state and province means for net primary production

Wetland type	Net primary production (g m^{-2} yr^{-1})				
	Tree	Shrub	Herb	Moss	Total
Peatland					
Permafrost bog	77	No data	No data	24	176
Nonpermafrost bog	106 ± 192	247 ± 104	13	190 ± 157	449 ± 215
Wooded fen	44	108	34	81	358
Shrubby fen	x	63	125	118	263
Open fen	x	x	365 ± 458	163	268 ± 34
Bogs and fens	88 ± 68	210 ± 136	166 ± 298	139 ± 106	337 ± 142
Non-peat-accumulating					
Wooded swamp	542 ± 279	31 ± 29	62	x	654 ± 197
Shrubby swamp	x	480 ± 260	727 ± 667	x	1 232 ± 405
Marsh	x	x	999 ± 529	x	1 034 ± 156
Swamps and marshes	542 ± 279	255 ± 296	820 ± 592	x	924 ± 463

x = does not occur in this environment.

Table 21. Summary of Pooled State and Province Means for Biomass

Wetland type	Biomass (g m^{-2})				
	Tree	Shrub	Herb	Moss	Total
Peatland					
Permafrost bog	No data	No data	No data	x	No data
Nonpermafrost bog	1 511 ± 1 767	253 ± 191	45	x	1 768 ± 1 408
Wooded fen	1 411	316	78	x	1 860
Shrubby fen	x	558	128	x	372 ± 245
Open fen	x	x	320	x	295
Bogs and fens	1 471 ± 1 458	358 ± 299	142 ± 118	x	1 198 ± 1 556
Non-peat-accumulating					
Wooded swamp	5 456 ± 3 049	351 ± 765	77	x	5 882 ± 2 201
Shrubby swamp	x	1 023	492 ± 683	x	2 483 ± 916
Marsh	x	x	841 ± 382	x	843 ± 380
Swamps and marshes	5 456 ± 3 049	800 ± 676	650 ± 523	x	2 291 ± 2 330

x = does not occur in this environment.

CONCLUSIONS

This paper has synthesized published NPP and biomass measurements from continental western Canadian wetlands and from sites in continental eastern Canada and the United States that have wetland types similar in composition and climate to those found in western continental Canada. The major limitations to the data set are

1) the low number of available studies;
2) the lack of standard laboratory measurements for the NPP and biomass of individual species, which resulted in the need to combine data for the vegetation layers;
3) the almost complete lack of data for belowground NPP and biomass; and
4) the paucity of detailed environmental data (i.e., climate, water table) that could be related to NPP and biomass studies.

Despite this need for further data, we conclude that mean total NPP for continental western Canada is 506 g m^{-2} yr^{-1} (337 [aboveground NPP] + 169 [belowground NPP] g m^{-2} yr^{-1}) for fens and bogs and 1201 g m^{-2} yr^{-1} (924 [aboveground NPP] + 277 [belowground NPP] g m^{-2} yr^{-1}) for marshes and swamps.

The value of total NPP for fens and bogs obtained in this analysis is similar to those obtained by Mitsch and Gosselink (1993) for northern bogs (560 g m^{-2} yr^{-1}); however, the total NPP for marshes and swamps differs, swamps having smaller NPP and inland marshes having larger NPP than in the study by Mitsch and Gosselink (1993), where swamps had an NPP of 870 g m^{-2} yr^{-1} and marshes had 1980 g m^{-2} yr^{-1}. The estimated biomass values are 1198 ± 1556 g m^{-2} for fens and bogs and 2291 ± 2330 g m^{-2} for marshes and swamps (Table 21). As for NPP, fens and bogs had about half the biomass of marshes and swamps.

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