10-1989

Spruce Budworm in Maine: The End of the Outbreak: Biological Conditions in 1986, 1987, and 1988, and a Look at the Future

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DEPARTMENT OF CONSERVATION
MAINE

Insect & Disease Management Div.
Technical Report No. 28
October 1989

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SPRUCE BUDWORM IN MAINE:
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ACKNOWLEDGMENTS

The author wishes to thank David Struble and Richard Dearborn for their review of this report. He also wishes to thank Michael Devine, Richard Dearborn, and Daniel Pratt for providing data and materials necessary for the preparation of the text.

He wishes to thank the excellent group of technicians who gathered the data and prepared figures for this report. Finally, he wishes to thank the clerical staff at the Old Town Forestry Headquarters for their help.

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SPRUCE BUDWORM IN MAINE: THE END OF THE OUTBREAK; BIOLOGICAL CONDITIONS IN 1986, 1987, AND 1988, AND A LOOK AT THE FUTURE

I. INTRODUCTION

This report presents spruce budworm survey and evaluation data gathered by the Insect and Disease Management Staff (I&DM), of the Maine Forest Service (MFS), formally the Budworm Survey and Assessment Unit. Budworm surveys have been conducted annually by the I&DM staff to determine budworm population levels and host tree conditions.

Past reports of budworm conditions have covered a single year, but this issue reports conditions for 1986, 1987 and 1988. These years can be characterized by declines in infestation size and intensity to a point where budworm larvae are now very scarce in most of Maine's spruce-fir forest. Several survey techniques used throughout the outbreak have been modified or completely eliminated in response to the declining infestation. These modified survey methods and results will be discussed.

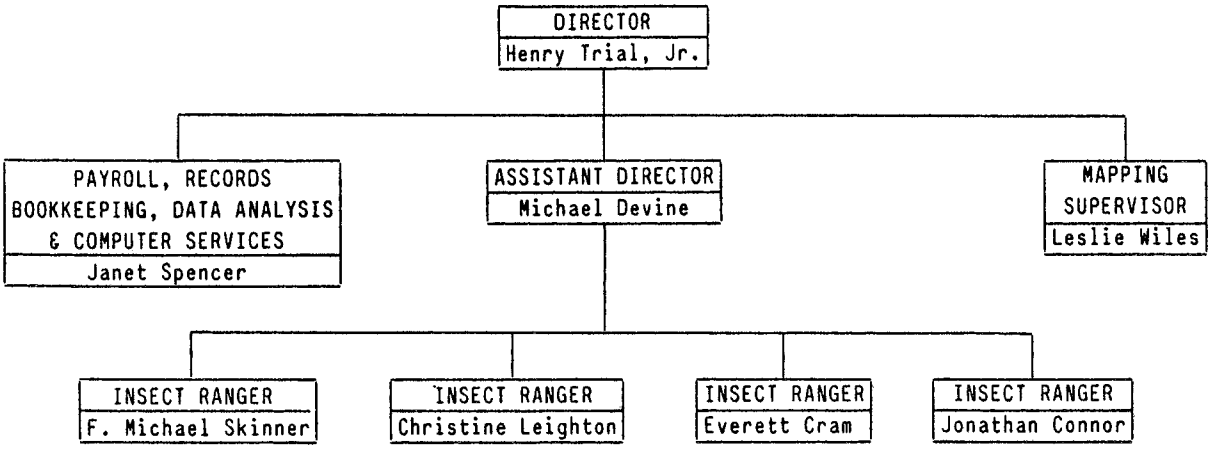
A. Personnel Organization

The sharp decline in the budworm infestation dictated many changes in the size and organization of the MFS budworm staff. In January of 1986 the budworm dedicated revenue fund supported 7 full time positions (Figure 1). This unit was responsible for all survey activities, any spray project activities, mapping, and taxation. By January of 1987 all but 2 of these 7 positions (the Director and Assistant Director) had been eliminated from the dedicated account. Three of the individuals in budworm positions were absorbed into other accounts in the I&DM. Two positions were eliminated. Early in 1987 plans were finalized to completely eliminate the budworm dedicated account as a separate unit and make all budworm activities functions of the I&DM division. In August, one of the remaining budworm staff transferred to an I&DM position; the final position transferred to I&DM in September of 1987. All 1987 and 1988 budworm field work was conducted by I&DM staff. Administrative functions related to budworm were done in I&DM after September, 1987.

The current I&DM organization is shown in Figure 2. Budworm related activities are now handled by the Field Director and Field Staff.

Figure 1.

SPRUCE BUDWORM SURVEY & ASSESSMENT UNIT ORGANIZATIONAL CHART
January 1, 1986



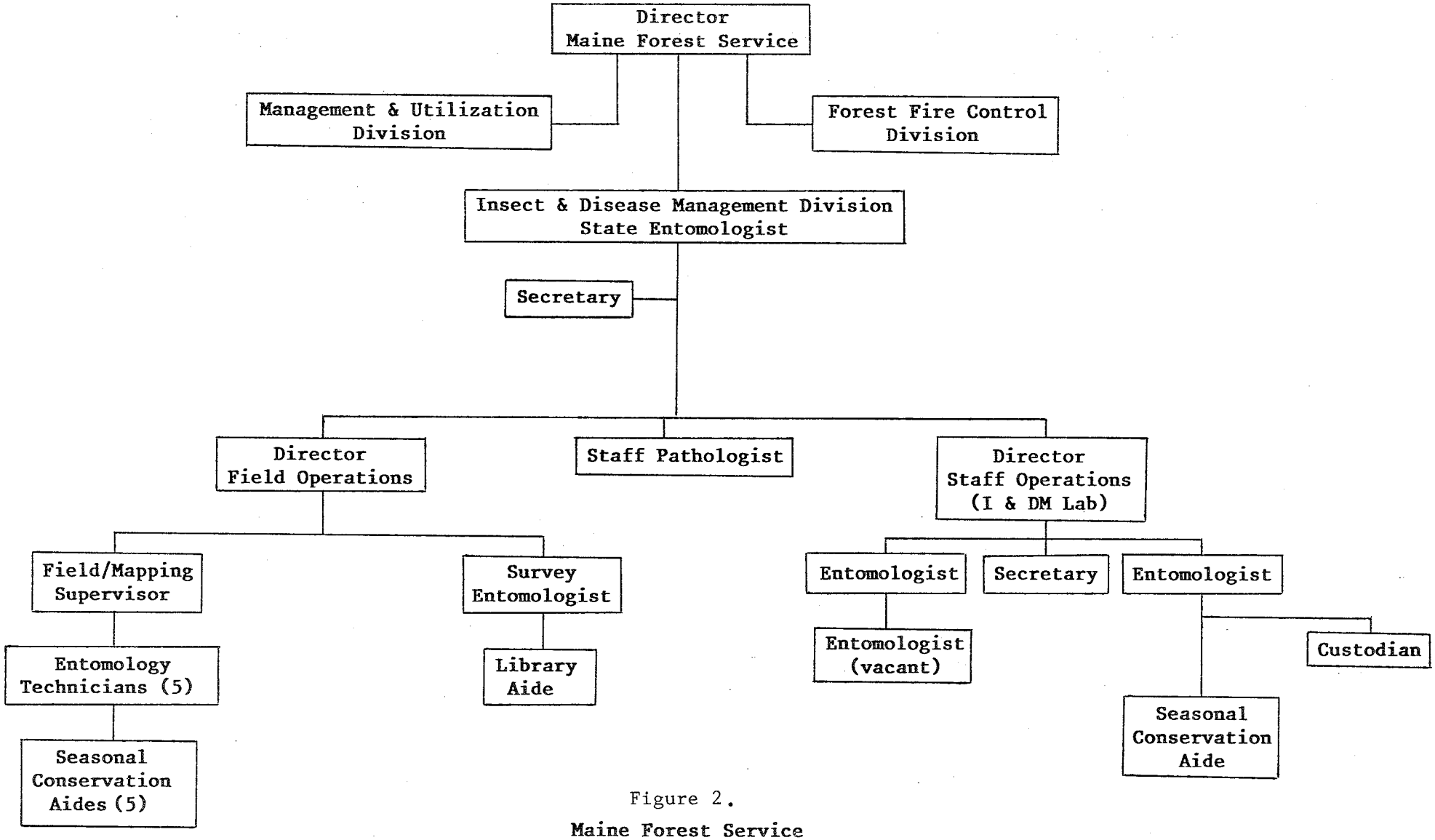


Figure 2.

Maine Forest Service
MAINE DEPARTMENT OF CONSERVATION
Insect & Disease Management Division
Organizational Chart
March 1989

B. Administrative Activities

Three major activities related to administration of the budworm program required considerable effort in the period 1986 through 1988. These activities were clean-up and securing spray tank farms, including; disposal of associated wastes, the sale of spray equipment, and eventual discontinuation of the budworm tax system.

Because the MFS did not expect to spray from any of its airport facilities in the immediate future, a complete clean-up of these sites was initiated. Partial clean-ups had been conducted periodically to dispose of residual spray material. Work began on clean-up of a former spray tank farm site in Millinocket in the summer of 1986. This project was completed in the fall of 1987. In the spring of 1987, spray wastes from the Presque Isle airport were removed for incineration. Also in 1987, spray storage tanks in Presque Isle were cleaned and residues removed for incineration. The tank farm in Presque Isle will be secured in early 1989, which will complete the clean-up activities. The total cost of tank farm clean-up and spray waste disposal will exceed $250,000.00. This apparently large sum actually represents a fraction of a cent per acre sprayed during the outbreak.

Spray equipment accumulated during the 70's and 80's was sold from 1986 to 1988. Much of the equipment was considered obsolete for current spray technology. Also, the MFS believed that the equipment would be of little value by the time it would be needed again unless a costly maintenance program was undertaken. Nearly all the equipment was sold by September, 1987 for approximately $60,000.00.

Finally, considerable effort was expended in updating budworm tax records in 1986. A large portion of the program acreage was removed from the protection district in 1986. This acreage had entered the program in 1981 and the 5-year term expired in 1986. Landowners did not resubmit lands for another 5 years in 1986, due largely to the lack of budworm and predicted declines. Tax records had to be adjusted to reflect acreage reduction for collection of 1987 taxes. The final program taxes were collected in the fall of 1987 and all residual funds in the dedicated account should be expended on the Presque Isle tank farm clean-up by July and August of 1989.

II. BIOLOGICAL CONDITIONS IN 1986, 1987, AND 1988

During the recent decline in the Maine budworm infestation, the I&DM staff has attempted to make observations of budworm health and survival, host conditions,

and budworm parasitism. However, budworm populations became so low in many areas the observations had to be discontinued.

A. Budworm Health and Development in 1986, 1987, and 1988

Larval emergence in 1986 was about a week earlier than the 10-year average in much of Maine, but relatively cool weather quickly retarded development. Weather throughout the development period generally lacked extremes that would adversely affect budworm survival. Host buds developed rapidly in 1986 and provided an ample food supply for larvae.

The most notable aspect of budworm development in 1986 was sudden, widespread loss of late instar larvae. Losses affected a high percentage of larvae and occurred between the 5th and late 6th instar. These losses were noted in areas with low and high populations and could not be explained by weather events or unusual parasitism. Losses were detected by comparing 4th and 6th instar population counts, however, the actual dying larvae were not collected. Similar losses had been noted in scattered areas in 1984 and 1985, but the 1986 event was seen in most of the infested areas.

Larval survival in 1986 was low in all but southeastern Maine. Survival rates averaged less than 15% compared to rates over 30% in many areas in 1985. Rates in the southeast ranged from 25 to 40%.

In 1987 larvae were difficult or impossible to find in nearly all of northern and central Maine. In portions of the southeast where larvae were common, larvae emerged 10 to 12 days earlier than average. Development conditions were favorable throughout the larval period and pupation occurred about a week earlier than normal. Late instar losses, were noted in portions of the southeast in 1987. Survival for a limited number of check areas was 28%.

No health or survival data was collected in 1988.

The cause of the late larval decline is not known, but there may be an association with levels of microsporidian disease. Microsporidian levels were highest in areas where reductions in budworm populations were first noted and lowest where populations persisted (Dimond, 1987, and Personal Communication). Microsporidian levels were not measured on dying larvae in Maine. However, in Nova Scotia a similar but stronger association has been made between microsporidian levels and budworm decline in 1987 and 1988 (Smith, Personal Communication, 1988). In Nova Scotia, disease levels were measured in areas of decline, and were found to be extreme both in percent of individuals infected and infection levels found within the individual larvae.

B. Pre-Treatment Host Conditions in 1986 to 1988

The early spring condition of fir and spruce in infested areas has been evaluated each year. In the past, this evaluation has been noted separately for each of 6 zones established and described by the budworm survey unit. In the period 1986-1988 most zones, except the southeast coastal had similar conditions and they are discussed together.

In the 5 northern and western zones, very little budworm feeding occurred in any of the 3 years. Therefore, spruce and fir in these zones have 3 or more years of foliage accumulated and are showing considerable recovery. Areas most heavily damaged by past feeding have not regained a normal foliage compliment as yet, but are improving annually.

Moderate to heavy damage continued in portions of the southeast coastal zone during this period. In general, localized damage continued in the central and southern portions of the zone, while the northern portion of the zone improved each year. Some areas in this zone which were sprayed in the 80's are in better condition than unsprayed areas. Some former spray blocks deteriorated in 1986, due to 1986 damage, but by 1987 and 1988 all previously sprayed areas were virtually free of budworm. Where the budworm remains active in the southeast, trees are in fair or poor condition, and some mortality is occurring. Residual infestations in the coastal zone are of recent origin; within the past 4 years. Many of the host trees in the infested areas are young and the defoliation has not been especially intense. Most of these trees should survive if population declines within the next year or two.

C. Parasite Survey

Parasitism of spruce budworm has been monitored annually at a number of study plots distributed over the spruce-fir region of Maine. The number of plots varied somewhat in earlier years, but was fixed at 12 permanent locations in 1978 (Figure 3) to provide consistent data for evaluating year-to-year trends of parasite populations. Plots were located outside treated areas and were relocated only as host availability necessitated. Prior to 1985 most plots provided suitable samples, but in 1985 three plots were discontinued due to low budworm populations. By 1986, only 3 of the 12 original plots, (Bradley, Edmunds, and Princeton) yielded enough budworm for a complete parasite survey. Early larval collections were made at some of the other regular points but collections of later larval stages were not made due to low populations. Larval numbers were so low, even at these 3 locations, that reliable parasitism estimates could not be made. Further reductions in budworm population in 1987 and 1988 resulted in cancellation of the formal survey.

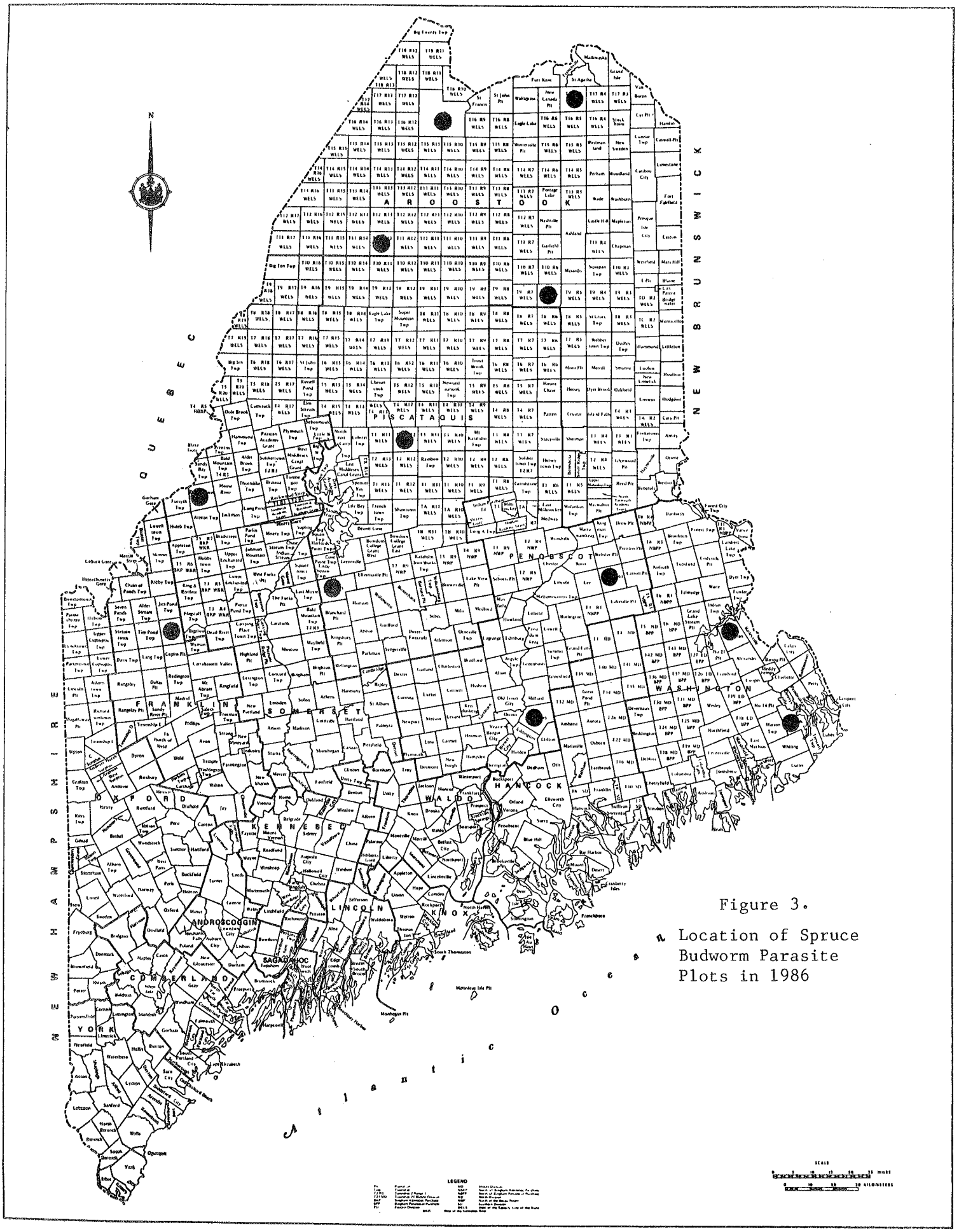


Figure 3.

Location of Spruce Budworm Parasite Plots in 1986

An attempt was made to determine parasitism rates from faunistic checks in 1987 but sufficient numbers of larvae were not found. No tables of parasitism results will be included in this report.

Disection of early larval collection in 1986 from the Dickey Brook (T17R5) site yield unusually high numbers of Synetaeris tenuifemur from the small number of larvae collected. A second collection was made at the site to confirm this unusual finding but the second collection did not yield any more of this parasite.

III. CONTROL ACTIVITIES

There were no state, federal, or private operational spruce budworm control projects during the period 1986-1988. The only budworm spray activity that occurred was an experimental trial of split application and new formulations of Bt (Bacillus thuringiensis) conducted jointly by the Maine Forest Service, the University of Maine, Abbott Laboratories, Zoecon Corp., and Champion International Corp.. A complete report of this trial, "An Aerial Field Trial Evaluating Split Applications and New Formulations of Bacillus thuringiensis Against the Spruce Budworm (Choristoneura fumiferana) In Maine-1986". Technical Report No. 26, 1988 is available from the Maine Forest Service.

IV. FOREST CONDITIONS - 1986 to 1988 AND A LOOK AT THE FUTURE

This section contains results from defoliation surveys, light trap surveys of moth activity, and population prediction surveys. Hazard evaluations are also included. The future of the Maine spruce budworm infestation is also discussed.

A. Current Defoliation Surveys - Aerial and Ground

Aerial defoliation surveys were conducted in July of each year to map current budworm defoliation. The survey was done during the budworm pupal stage when most of the brownish budworm-clipped dead needles still adhered to the webbing and twigs.

Trained observers surveyed the infested area from a Cessna 185 aircraft. The areas of defoliation were sketched on maps in the following categories: none (0), light (1-30), and moderate to severe (30+%).

Defoliation surveys in recent years were hampered by poor flying conditions, rain and wind which removed webbing and clipped brown needles (browning), and by less intense feeding. These conditions made accurate aerial mapping difficult and resulted in an increased dependence on ground

surveys, to supplement and verify aerial data. Ground surveys proved to be important additions to the 1986, 1987, and 1988 evaluations of defoliation.

The 1986, 1987, and 1988 aerial surveys were greatly reduced compared to past efforts because extensive portions of the State had no measurable infestation. Much of the 1986 survey was done from greater altitude than usual because damage was so scarce. In 1986, most visible "browning" was found in southern Washington and in Hancock county (Figure 4). Although defoliation intensity varied in 1986, significant portions of the southeast experienced heavy or severe damage. Four other small areas of defoliation were mapped in northern and western Maine, but these areas were difficult to spot from the air. Ground checks of these areas revealed an unusual defoliation pattern where tops had little or no damage, but mid and lower crowns were heavily damaged. The green tops over the damage made "browning" much less vivid from the air. Overall, damage in 1986 was less intense than in 1985.

The 1987 aerial survey showed even less damage than the 1986 survey, and all of the defoliation mapped was in the southeast (Figure 5). Also, 1987 damage was so spotty that it was mapped as "areas containing moderate to severe defoliation" rather than mapping each tiny area. The general intensity of defoliation was reduced in 1987 compared to 1986, but small areas of severe defoliation were found.

In 1988, light and moderate to severe defoliation was again restricted to the southeast (Figure 6). Damage was extremely spotty throughout the defoliated area.

The size of the moderate to severe defoliation area declined sharply in each year from 1985 to 1988. Defoliation in 1985 had been measured at 1.2 million acres. In 1986, defoliated acreage dropped to 600,000 acres and after the 1987 and 1988 seasons was measured at 210,000 acres and 55,000 acres respectively.

B. Light Trap Survey Summary

A total of 20 light traps situated in forested areas throughout the state (Figure 7) were operated in 1986, 1987, and 1988 during the spruce budworm moth flight period. Total moths trapped dropped through the period from a level which was already low in 1985. Seasonal catch during the period was 1365 moths in 1986, 464 in 1987, and 209 in 1988. Total catch in 1988 was the lowest since 1967 (Table 1, Figure 8). This decline parallels other population measurements.

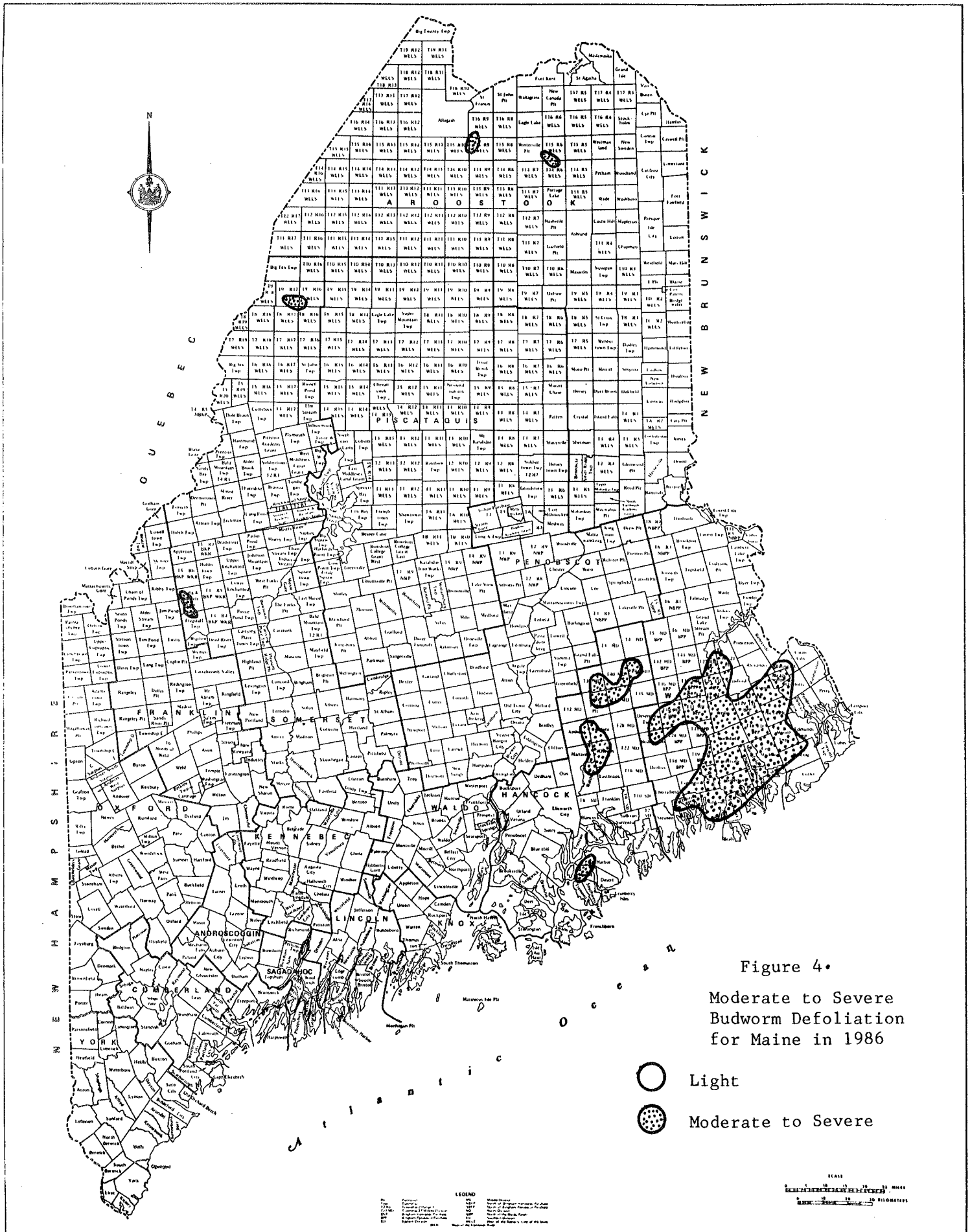


Figure 4.

Moderate to Severe Budworm Defoliation for Maine in 1986

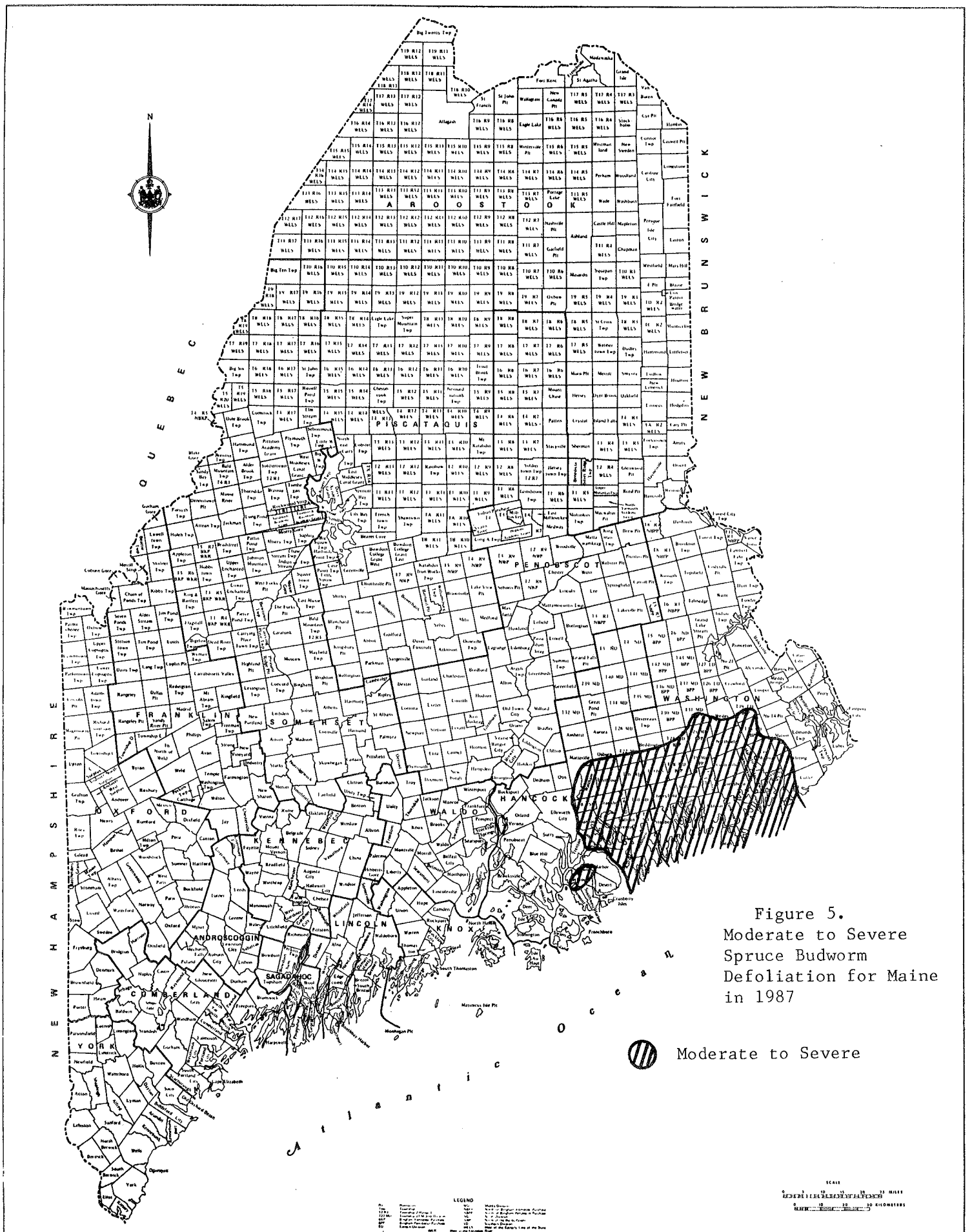
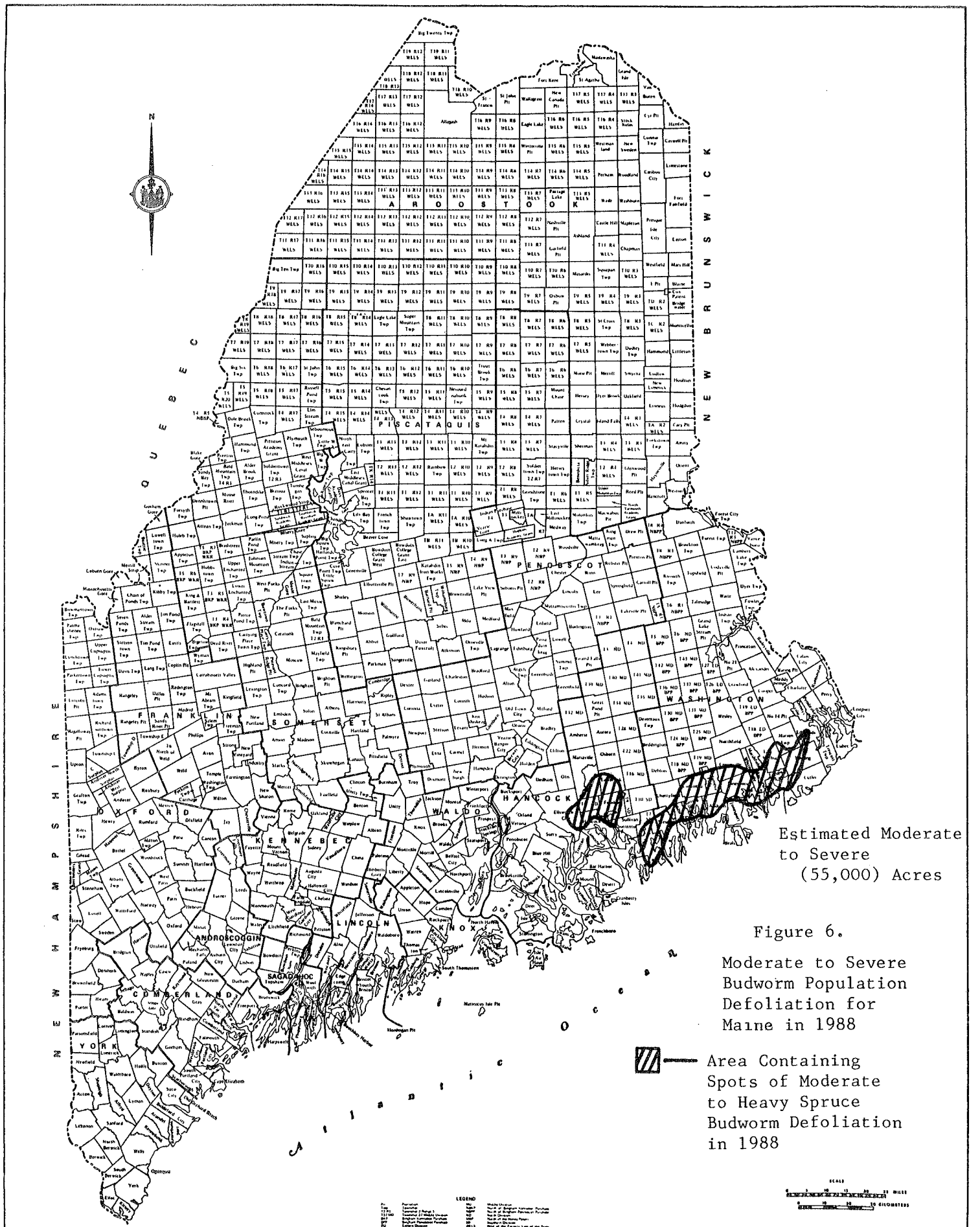


Figure 5. Moderate to Severe Spruce Budworm Defoliation for Maine in 1987

Moderate to Severe



Estimated Moderate to Severe (55,000) Acres

Figure 6.

Moderate to Severe Budworm Population Defoliation for Maine in 1988

Area Containing Spots of Moderate to Heavy Spruce Budworm Defoliation in 1988

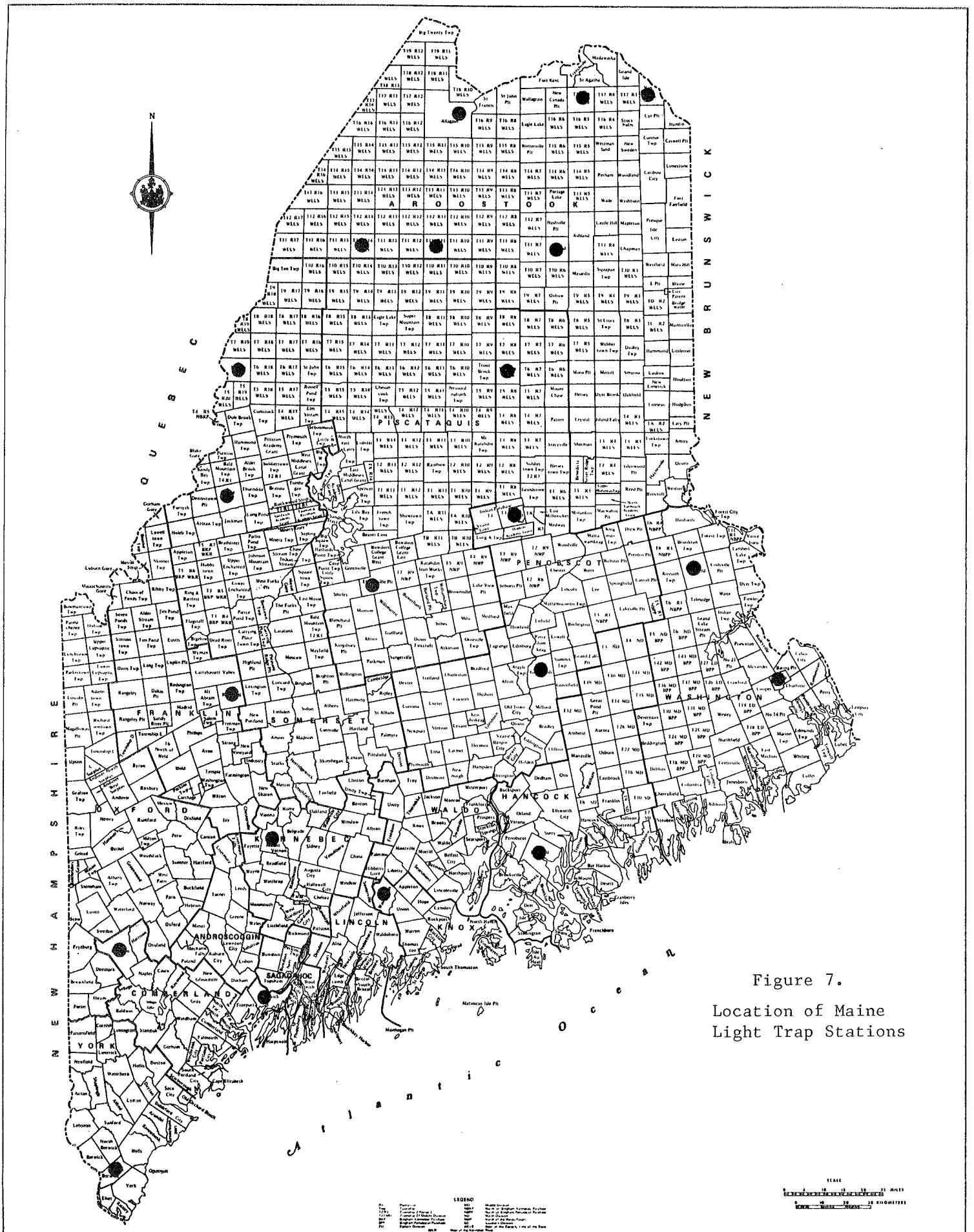


Figure 7.

Location of Maine Light Trap Stations

TABLE 1.

SPRUCE BUDWORM SEASONAL LIGHT TRAP SUMMARIES

YEAR	TOTAL # MOTHS	# TRAPS	AVERAGE # MOTHS/TRAP
1988	209	20	10.4
1987	464	20	23.2
1986	1,365	20	68.0
1985	13,233	20	661.0
1984	17,983	20	895.0
1983	144,673	18	8,037.0
1982	49,200	20	2,460.0
1981	39,724	20	1,986.0
1980	100,537	19	5,291.0
1979	95,811	16	5,988.0
1978	220,264	17	12,957.0
1977	24,212	15	1,614.0
1976	22,308	16	1,394.0
1975	149,874	23	6,516.0
1974	158,784	24	6,616.0
1973	39,069	24	1,628.0
1972	15,959	24	665.0
1971	20,653	25	826.0
1970	1,076	24	45.0
1969	5,415	27	201.0
1968	948	24	39.5
1967	120	26	4.6
1966	51	24	2.0
1965	83	24	3.5
1964	159	25	6.0
1963	133	24	5.5
1962	258	23	11.2
1961	763	17	44.9

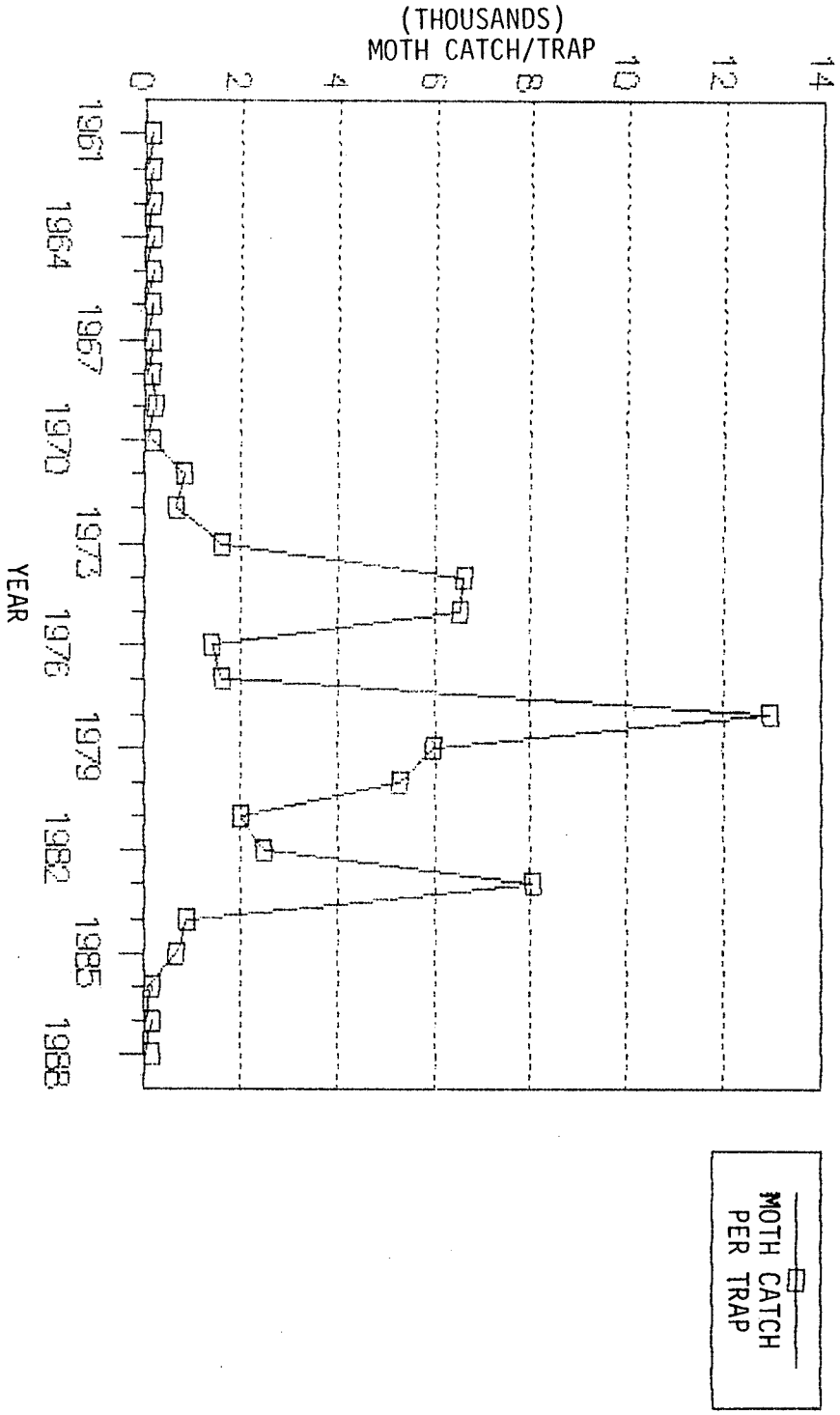


FIGURE 8: LIGHT TRAP MOTH CATCH PER TRAP IN MAINE-1961-1988

Changes in moth catch distribution (Table 2) also reflect regional population declines. In 1985, 18 of 20 traps yielded moths. This proportion was reduced to 15 of 20 in 86, and 9 of 20 in both 87 and 88. In 1988, all moths were caught in southern or eastern Maine traps and 86% of all moths came from one southeastern trap (Meddybemps).

A small moth flight may have occurred in St. Francis (Allagash) in 1986. No moth flights were evident in 1987, for the first time since 1970. Daily moth catch by trap for the years 1986, 1987 and 1988 is shown in Tables 3, 4 and 5
The period of peak moth activity was slightly later than normal in 1986 and 1988.

C. F.I.S. Field Collection Survey

The general field tree beating and picking survey did not yield either spruce budworm larvae or pupae in the period 1986 through 1988. This is the first time since the 1940's that budworm were not found during this survey.

D. Population Prediction Survey

This section examines methods and results for the 1986 through 1988 population prediction surveys. Declining budworm populations dictated changes in prediction survey methods and intensity. Survey changes included reductions in sample density thus reducing field and laboratory time. Another significant change, beginning in 1987, was the switch from the traditional L-II survey to a moth trapping method using pheromones for the general survey.

1986 Results

L-II Survey The 1986 L-II survey was similar to recent surveys in coverage and methodology. However, sample intensity was reduced significantly because summer insect observations and the defoliation survey showed very low population levels in most of the State. Also, the 1985 L-II survey had found very low larval numbers everywhere except the southeast. A total of 364 sample locations were evaluated in 1986 compared to 504 locations in 1985. As in 1985, each sample location contained sub-sites, but in 1986 locations had 1 or 2 sub-sites compared to 2 to 5 in 1985. The reduction in the number of sub-sites greatly reduced the total number of branches evaluated during the survey and therefore reduced costs. Points were spread over the entire budworm protection district (5-year lands), but density was lower and few non 5-year areas were sampled. Other aspects of the field and lab methods were the same as those employed in 1985.

Field and laboratory work in 1986 was done entirely by MFS personnel. Due to the reduced sample load there was no

Table 2.

Light Trap Collections
Annual Comparisons by Species
(Seasonal Totals)

Location	*Choristoneura fumiferana*						*Dioryctria reniculelloides*						*Archips resaceana*					
	Year						Year						Year					
	83	84	85	86	87	88	83	84	85	86	87	88	83	84	85	86	87	88
Allagash	71730	5433	2865	286	58	0	95	15	36	8	2	0	773	757	380	37	0	38
Ashland	0	1	1	12	0	0	0	0	0	0	0	0	4	3	1	-	0	1
Blue Hill	371	19	2	0	0	7	3	7	1	0	0	3	10	7	8	0	0	5
Brunswick	2306	151	21	14	1	1	226	62	3	1	0	0	188	272	522	30	0	168
Clayton Lake	5282	216	536	24	19	0	7	302	17	0	1	0	165	66	56	0	0	18
Elliotsville	15205	68	70	0	0	0	60	49	2	0	0	0	72	90	73	3	0	1
Greenbush	3946	1985	4058	23	9	19	102	85	26	0	0	0	159	71	106	3	0	11
Guerette		595	251	44	44	0		108	10	1	0	0		269	130	25	1	11
Kingfield	3425	67	19	1	0	0	34	6	0	0	0	0	66	39	63	8	0	17
Matagamon	1448	43	0	0	0	0	216	13	0	0	0	2	785	352	4	35	0	91
Meddybemps	21492	7492	7081	808	317	180	170	95	103	14	5	0	2443	794	265	71	0	60
Millinocket	346	16	1	1	0	0	20	3	0	0	0	0	115	103	111	0	0	13
Moose River	2192	92	12	6	7	0	25	32	0	0	0	0	265	5	5	1	0	1
Mt. Vernon	216	17	0	0	0	0	10	2	0	0	0	0	72	134	83	0	0	54
Musquacook	121	26	23	4	2	0	86	5	2	0	0	0	261	160	170	0	0	8
North Bridgton	3156	41	2	0	0	0	36	7	0	3	0	0	362	227	375	42	0	41
South Berwick		8	1	11	0	1		5	0	0	0	0		124	151	0	0	41
Ste. Aurelie	4926	508	100	5	0	0	112	36	4	0	0	0	1791	127	87	0	0	0
Topsfield	8197	1197	1182	120	7	1	19	81	4	0	0	0	195	230	28	1	0	10
Washington	314	8	8	6	0	0	4	0	0	0	0	0	14	4	10	0	0	19
Total Moths	144673	17983	13233	1365	464	209	1225	1313	175	27	3	5	7740	3834	2628	260	1	608
Total Traps	18	20	20	20	20	20	18	20	20	20	20	20	18	20	20	20	20	20

Note: See accompanying map for relative locations of the traps in 1988

Table 3 .
Summary of the Number of Spruce Budworm Moths Collected at Light Traps in 1986

Light Trap Station	June Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals
Ashland																											3	9					12
Blue Hill																																	0
Brunswick																							3	4	7								14
Clayton Lake									4			1						1	2		1				2	1	2	10					24
Elliotsville																																	0
Greenbush	3	7		8	3		1			1																							23
Kingfield																											1						1
(Matagamon) (T6 R8)																																	0
Meddybemps		1		4	4	2	25		24	79	49	40	58	63	1			75		6	17	54	27	10	71	72	59	41		8	4	14	808
Millinocket	1																																1
Moose River																					1					4				1			6
Mt. Vernon																																	0
Musquacook Gate (T11 R11)																									1		1	2					4
North Bridgton																																	0
South Berwick																								7	2	2							11
St. Aurelie (Big 6)																										1		3	1				5
St. Francis (Allagash)		1				1								3				3	2		7		1		6	11	31	220					286
Topsfield									2		1		2	50	24			2							1	3	20	15					120
Van Buren												3			1			7	3	5	2		2		1	3	5	12					44
Washington						1			1																	3	1						6
Totals	4	9		12	7	4	26		31	80	50	44	60	116	26			88	13	22	65	27	16	82	92	87	105	279		6	14		1,365

Table 4.

Summary of the Number of Spruce Budworm Moths Collected at Light Traps in 1987

Light Trap Station	June Total	July 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals
Ashland																																	0
Blue Hill																																	0
Brunswick								1																									1
Clayton Lake		2							8	2	1	6																					19
Elliotsville																																	0
Greenbush	2			2	2	2	1																										9
Kingfield																																	0
(Matagomon) (T6 R8)																																	0
Meddybemps	23	10	16	2	2	5	22	5	6	13	10	41	46	30	7	11	14	11		33	2	4		3	1								317
Millinocket																																	0
Moose River										1						3	1								2								7
Mt. Vernon																																	0
Musquacook Gate (T11 R11)															1								1										2
North Bridgton																																	0
South Berwick																																	0
St. Aurelie (Big 6)																																	0
St. Francis (Allagash)	2				2	2	3	4	4	8	19		1		11	2																	58
Topsfield	3											1		1				1							1								7
Van Buren			1				5	10	5	7	1	2	5	8																			44
Washington																																	0
Totals	30	12	17	4	6	9	31	20	23	31	31	50	52	39	19	16	15	12		33	2	4	1	3	4								464

Table 5.
Summary of the Number of Spruce Budworm Moths Collected at Light Traps in 1988

	June	July																					
Light Trap Station	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Totals
Ashland																							0
Blue Hill	1				3			1	1								1						7
Brunswick														1									1
Clayton Lake																							0
Elliotsville																							0
Greenbush									1	17	1												19
Kingfield																							0
(Matagomon)(T6 R8)																							0
Meddybemps						26	27	12	7	17	13	19	5	12	5	5	6	11	7	4	3	1	180
Millinocket																							0
Moose River																							0
Mt. Vernon																							0
Musquacook Gate(T11 R11)																							0
North Bridgton																							0
South Berwick									1														1
St. Aurelie(Big 6)																							0
St. Francis(Allagash)																							0
Topsfield									1														1
T17 R5(Guerette)																							0
Washington																							0
Totals	1				3	26	27	13	11	34	14	19	5	13	5	5	7	11	7	4	3	1	209

need to supplement the normal staff with project employees. Field collections were made in 3 weeks using four - 2-person collecting crews. Laboratory evaluation was done by 2 to 5 person crews in October, November, and December.

Analysis of 1986 L-II results revealed that overwintering spruce budworm populations were even lower than expected. From 364 locations, only 15 were not in the low category. Of these 15, 11 were moderate, 3 were high, and only 1 was extreme. All of the 15 were located in southeastern Maine (Figure 9). Another significant aspect of the data was that of the 349 low points, 247 did not yield any larvae. Population level by zone is presented in Figure 9 through 14. Past reports have included a discussion of the zone maps individually, but in 1986, 5 of the zones contained exclusively low counts and need no further discussion. Only the southeast coastal zone had population points in the moderate to extreme range. Most of these higher counts were located in the northcentral portion of the zone from T22 MD and T28 MD on the west to Northfield and T19 ED on the east. The highest counts were found in the Beddington/Devereaux area. This portion of the zone has had heavy defoliation for several years. Populations in much of the eastern portion of the zone dropped sharply in 1986 from previously high levels.

Pheromone Survey Much development work has been conducted on the use of pheromone traps to catch moths as an alternative survey technique to the L-II method. Pheromone traps are thought to be more sensitive for detecting low level populations than the L-II method. In 1986, a test of the pheromone method was conducted in Maine. This test consisted of 10 areas, each with 10 pheromone trap locations. Each location consisted of 3 pheromone traps. Trap catch was later compared to L-II counts.

Moth catches from these trap locations were used to supplement the L-II survey. In general, the pheromone catches were consistent with L-II results. All catches except locations in the southeast were very low or zeroes (Figure 15). A complete analysis of the 1986 pheromone test will be reported in a separate report dealing with pheromone research in Maine.

Prediction Based on L-II and pheromone data 250,000 acres of moderate to severe defoliation were predicted for 1987, which was the smallest defoliated area since 1966 (Figure 16).

1987 Results

L-II Survey The 1987 L-II survey was very limited. Due to a total lack of defoliation everywhere except the southeast in 1987, the only L-II points collected in 1987 were in the southeast. A total of 24 single locations were

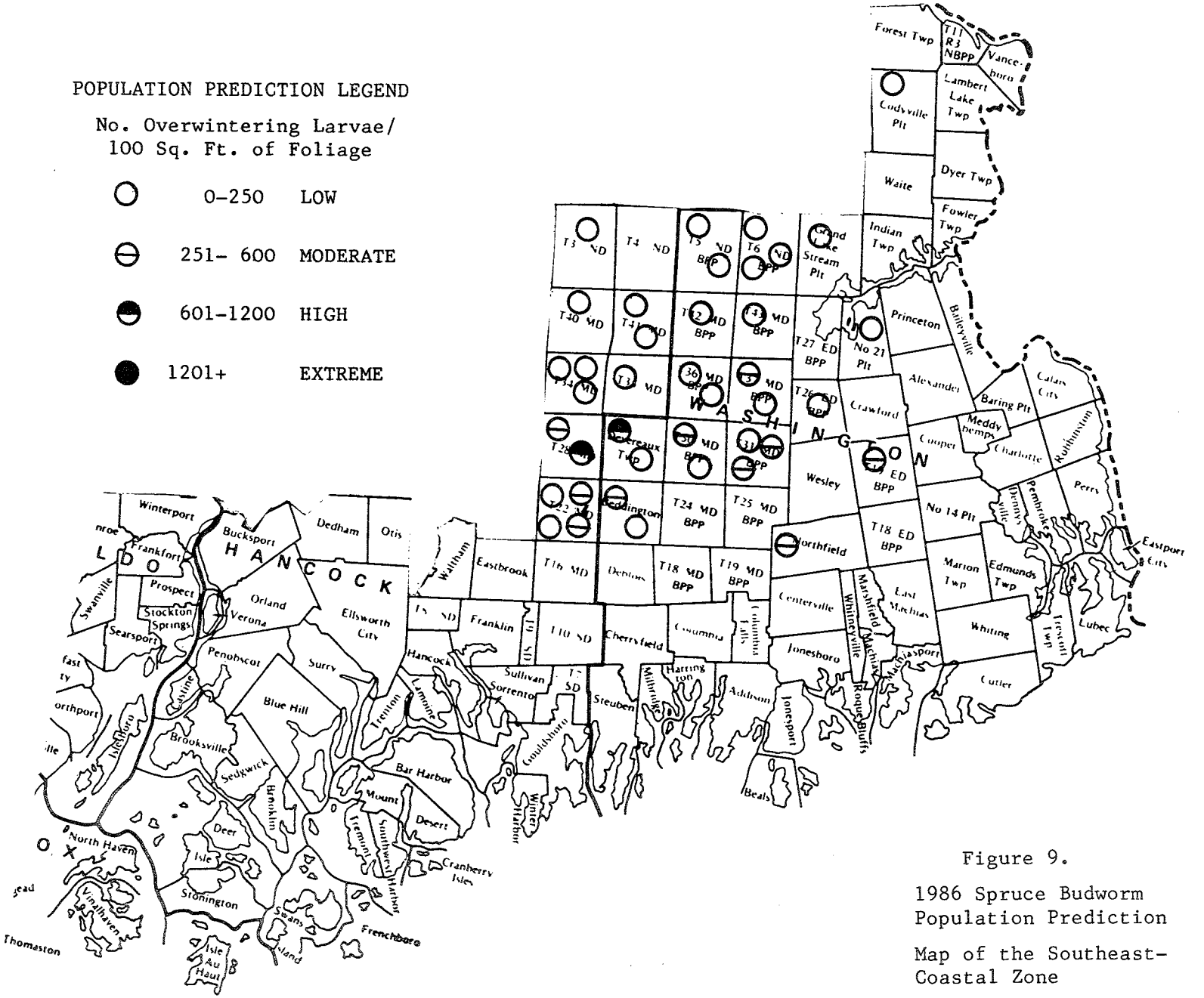


Figure 9.

1986 Spruce Budworm Population Prediction

Map of the Southeast-Coastal Zone

POPULATION PREDICTION LEGEND

No. Overwintering Larvae/
100 Sq. Ft. of Foliage

○	0–250	LOW
⊖	251– 600	MODERATE
◒	601–1200	HIGH
●	1201+	EXTREME

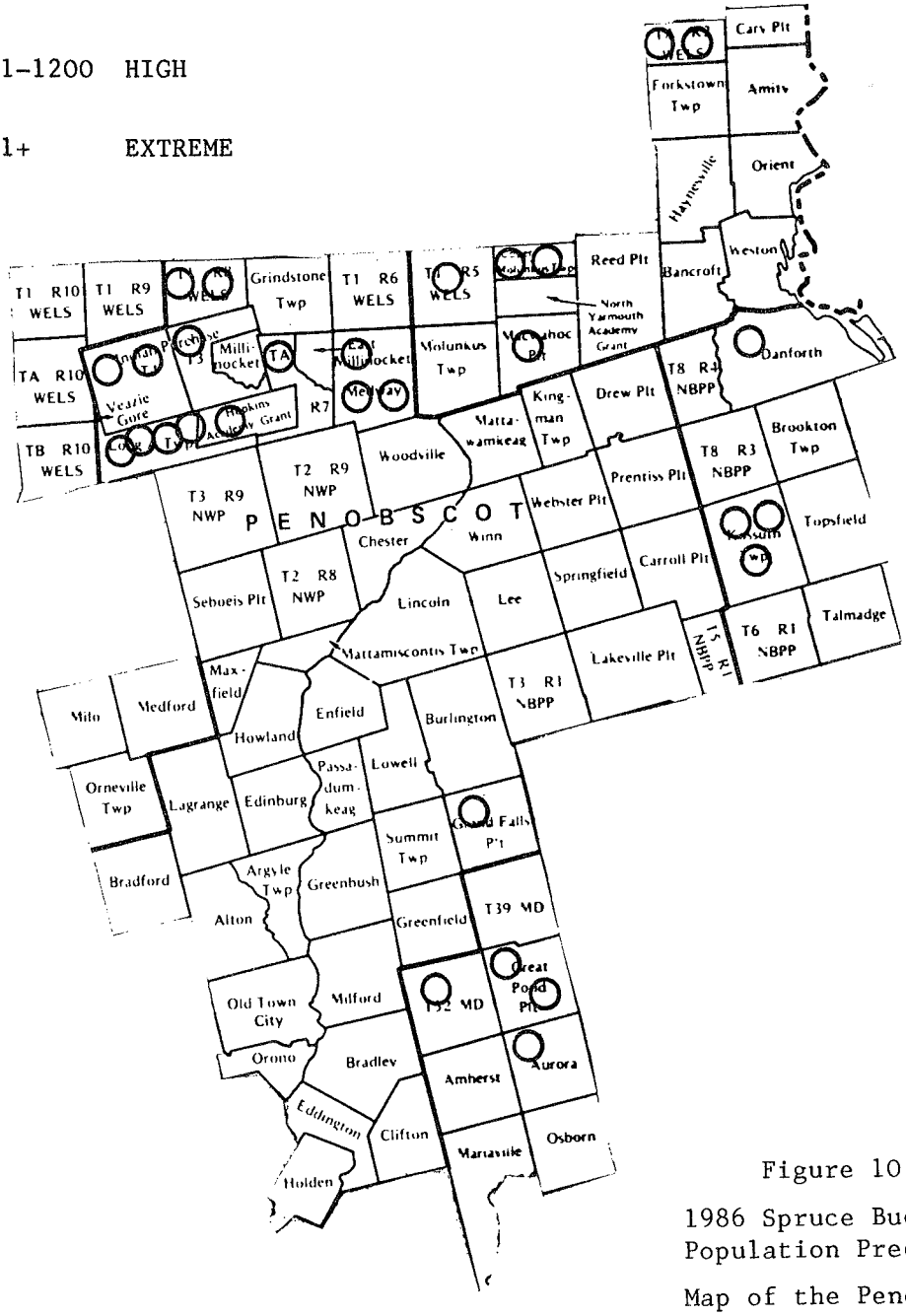


Figure 10.

1986 Spruce Budworm Population Prediction

Map of the Penobscot-Mattawamkeag Zone

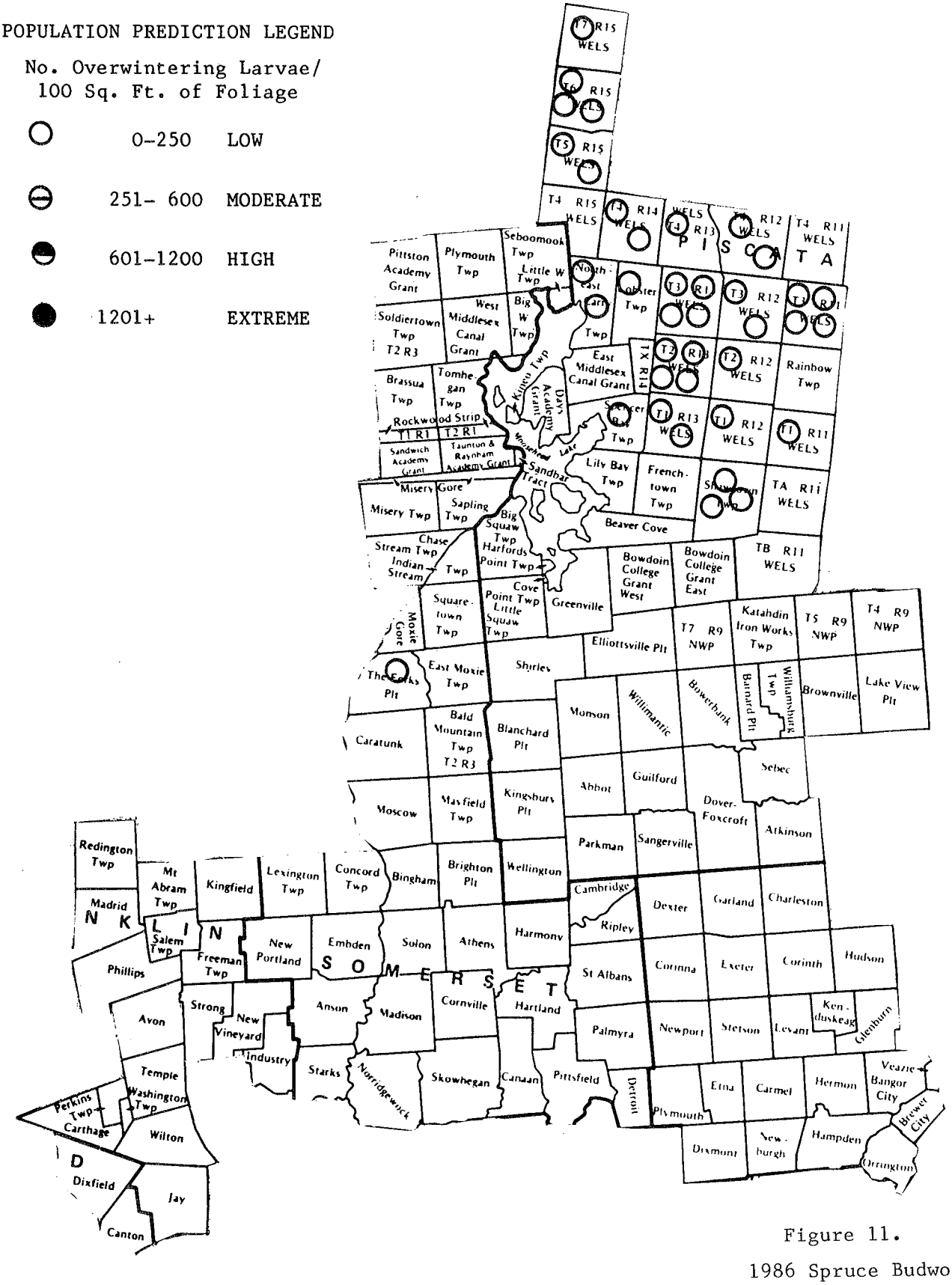


Figure 11.

1986 Spruce Budworm Population Prediction

Map of the Moosehead Zone

POPULATION PREDICTION LEGEND

No. Overwintering Larvae/
100 Sq. Ft. of Foliage

○	0-250	LOW
⊖	251- 600	MODERATE
⊖	601-1200	HIGH
●	1201+	EXTREME

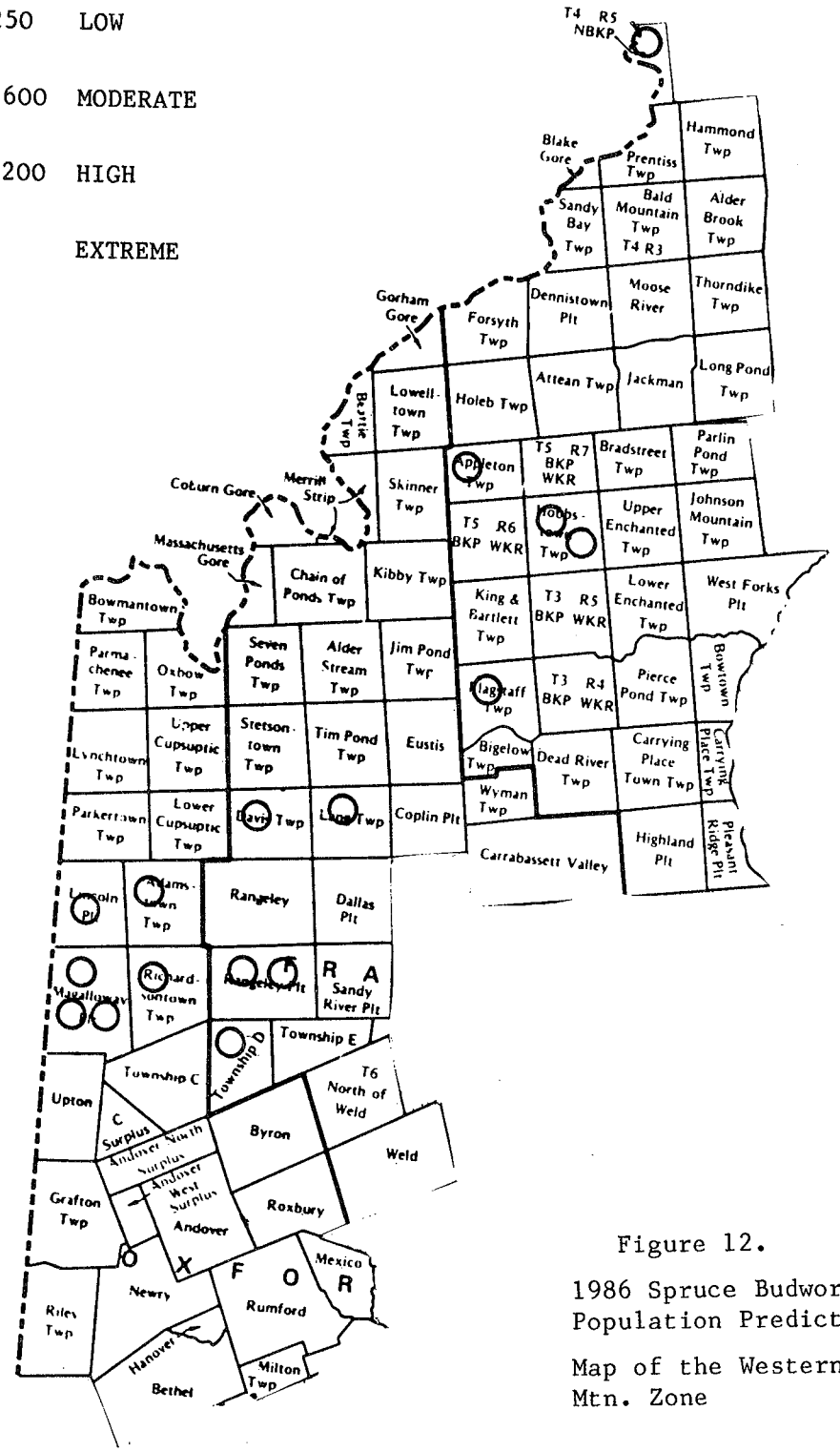


Figure 12.

1986 Spruce Budworm Population Prediction

Map of the Western Mtn. Zone

POPULATION PREDICTION LEGEND

No. Overwintering Larvae/
100 Sq. Ft. of Foliage

○	0–250	LOW
⊖	251– 600	MODERATE
◒	601–1200	HIGH
●	1201+	EXTREME

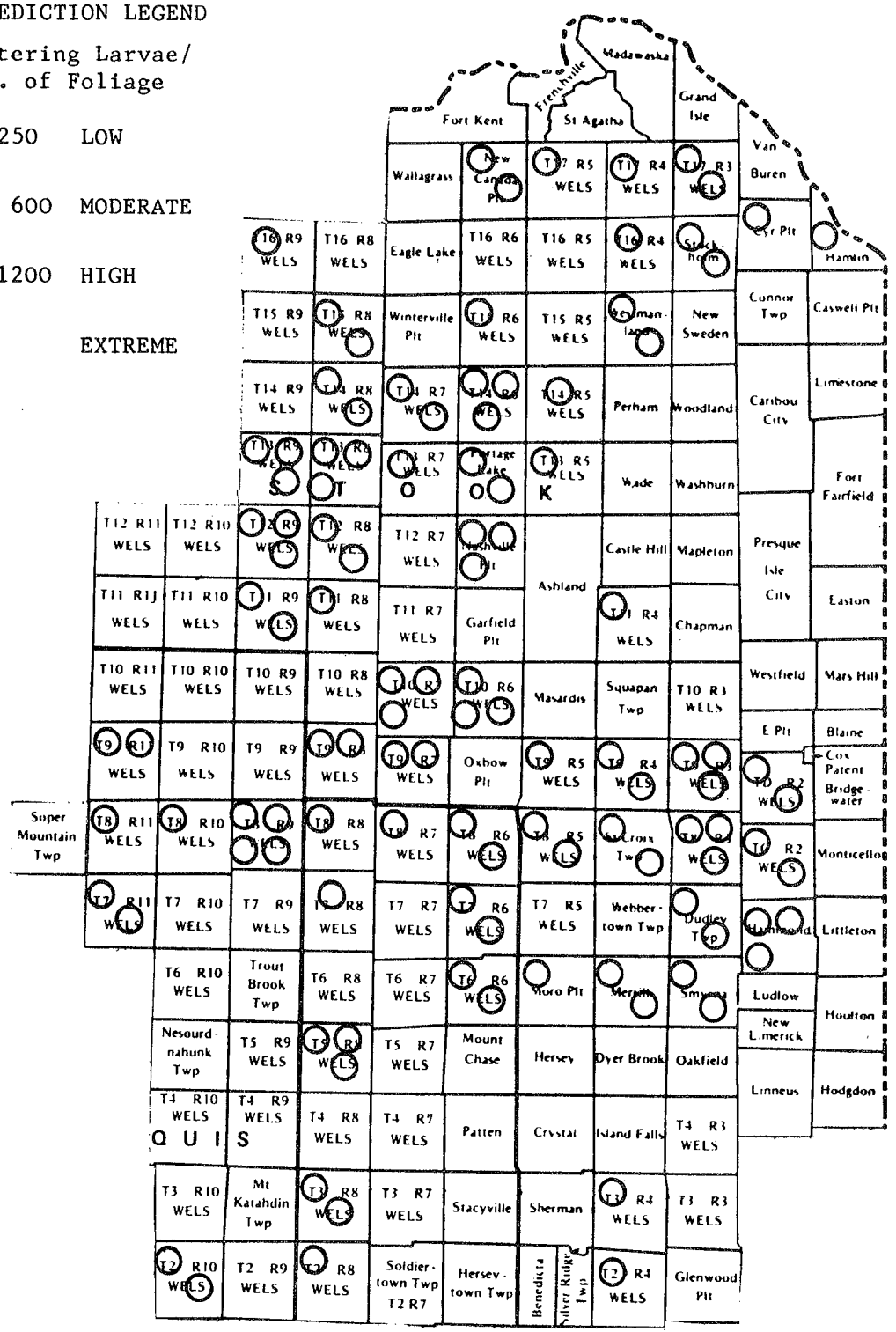


Figure 13.

1986 Spruce Budworm Population Prediction

Map of the Northeast Zone

POPULATION PREDICTION LEGEND

No. Overwintering Larvae/
100 Sq. Ft. of Foliage

○	0–250	LOW
⊖	251– 600	MODERATE
◒	601–1200	HIGH
●	1201+	EXTREME

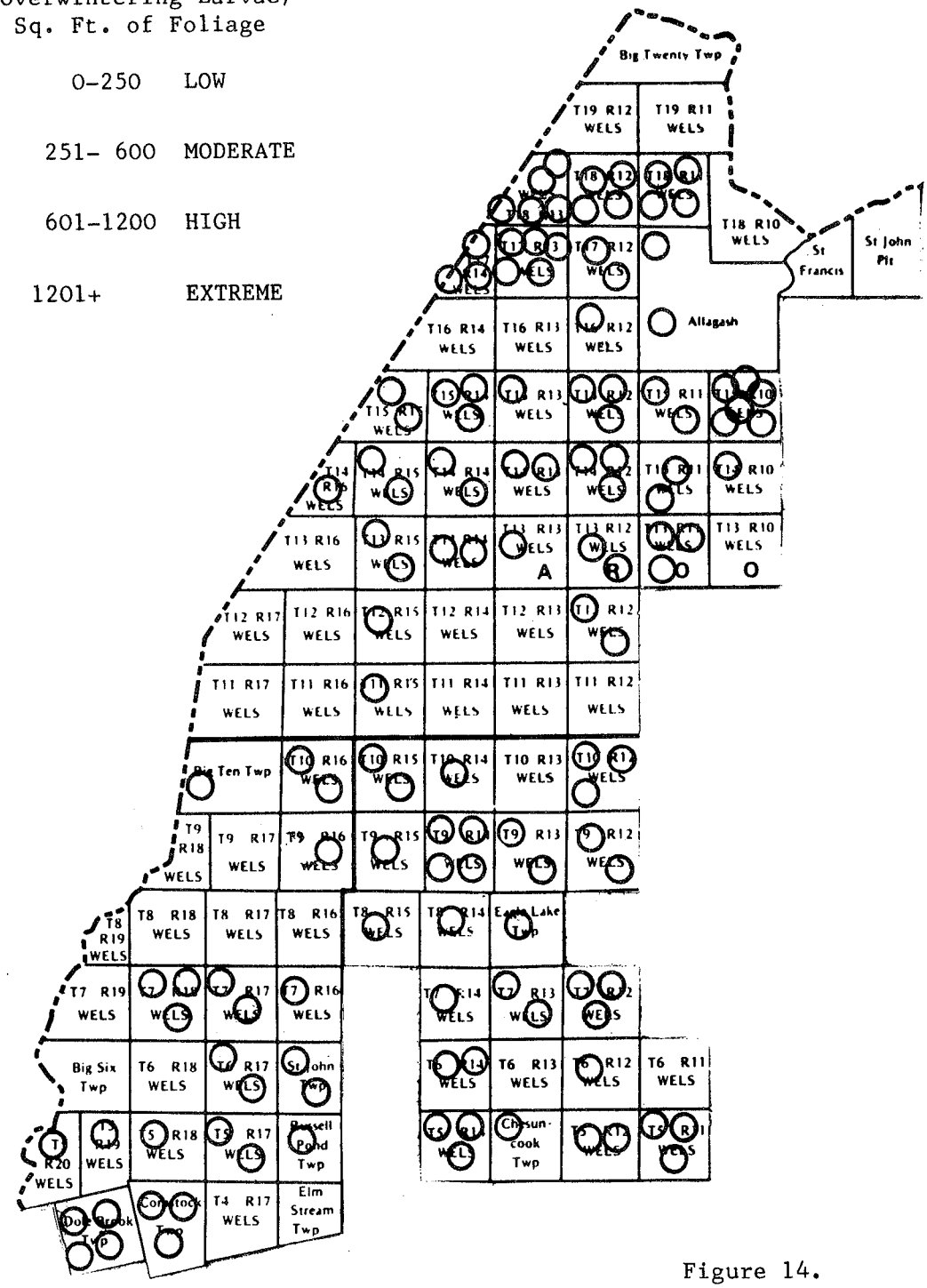


Figure 14.

1986 Spruce Budworm Population Prediction

Map of the Allagash–St. John Zone

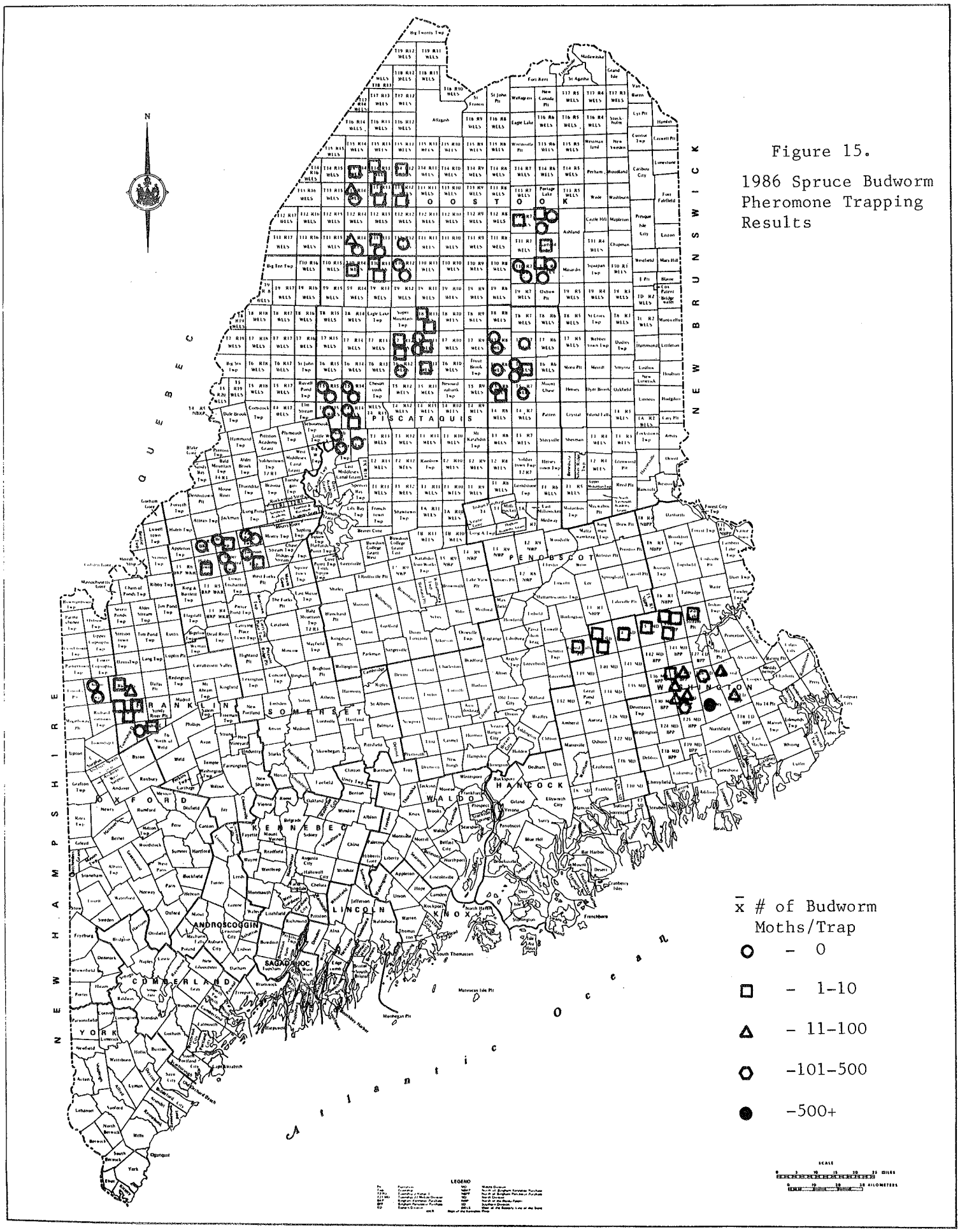


Figure 15.

1986 Spruce Budworm Pheromone Trapping Results

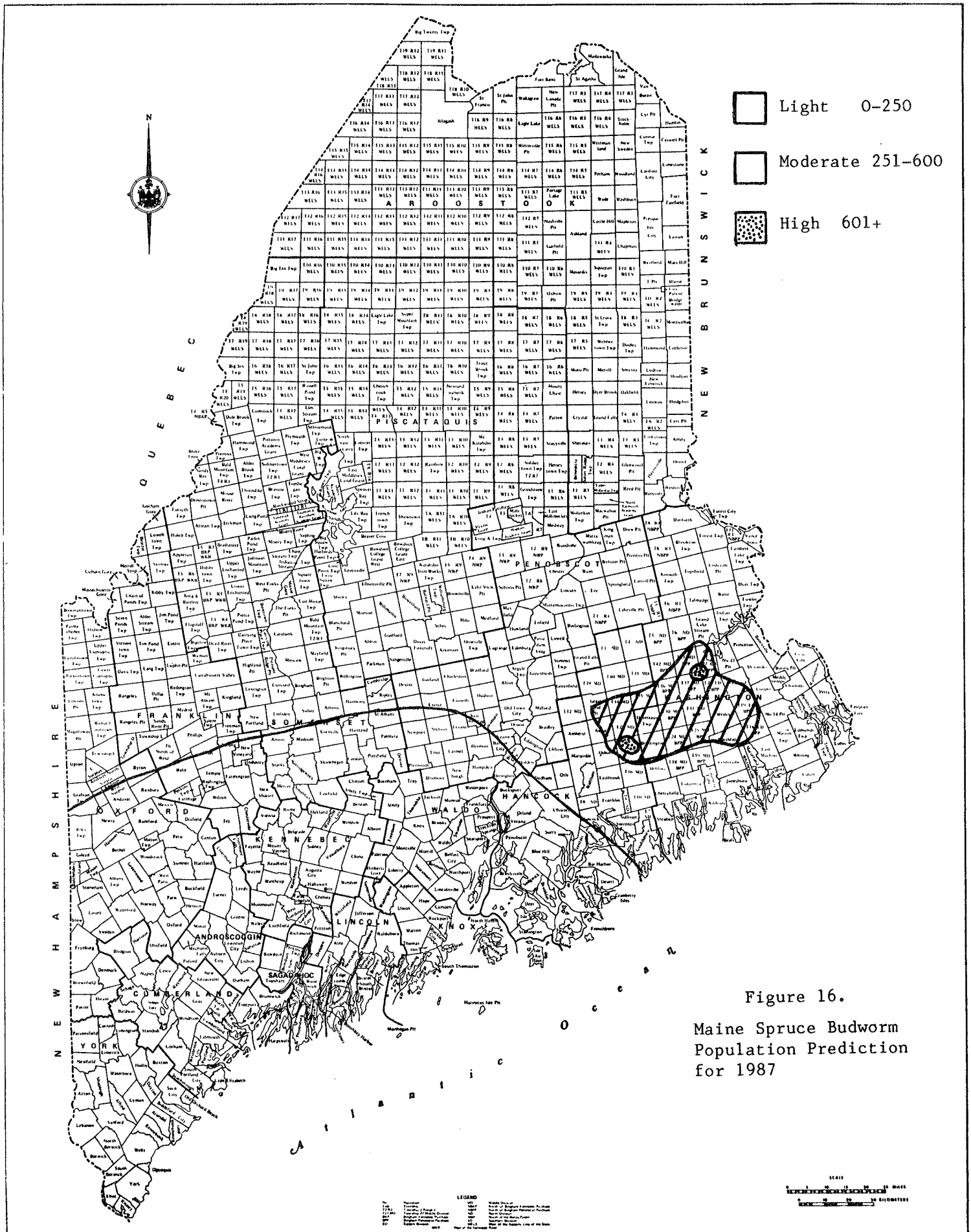


Figure 16.

Maine Spruce Budworm Population Prediction for 1987

evaluated and all were classified low (Figure 17). L-II collections made in connection with 1987 pheromone efforts found moderate counts in Waltham, Franklin and Gouldsboro. These towns are south or west of the traditional survey area.

Pheromone Survey For the first time in 1987 population prediction for the majority of Maine was done with pheromone traps. Even though the method had not been shown to be dependable, populations were thought to be below the resolution of the L-II method everywhere except the southeast. Pheromone traps were placed at 180 locations (Figure 18) throughout the spruce-fir type. Moths were caught at only 13 of these locations, the highest average catch per trap was 199 moths. Even though the low catch matched low defoliation estimates, the results were disappointing. Moths were not caught in several areas where larvae, pupae or even moths had been observed. Also, traps in areas which had heavy defoliation and moth activity caught less than 100 moths per trap in all but two locations; a much higher catch was expected. The large number of traps with no catch, the lack of catch in areas that still had budworm, and the relatively low catch in high population areas caused much concern for the expected sensitivity of the method.

A large-scale pheromone test, conducted in 1987, was designed to assess catch variability and predictive range. Complete results will be given in a future report, but preliminary analysis show extreme inter-trap variability over short distances in the same stand. The large variation in these data also suggests that a pheromone location will not predict budworm populations for a large block of forest unless a large number of traps are deployed in each block.

Prediction Based on the available data, 120,000 acres of defoliation were predicted, all in southeastern Maine (Figure 19).

1988 Results

L-II Survey No L-II collections were made by the MFS in 1988.

Pheromone Survey A total of 222 locations (Figure 20) were trapped in 1988 of which approximately 80% were baited with standard 0.03% PVC lures and 20% baited with 0.3% PVC lures. Moths were caught in 12 locations, all in the southeast. All of these catches in the southeast were relatively low considering heavy defoliation and moth activity in that area. The 1988 pheromone effort was disappointing for the same reason as in 1987. The high potency lures (0.3%), used to increase catch, apparently

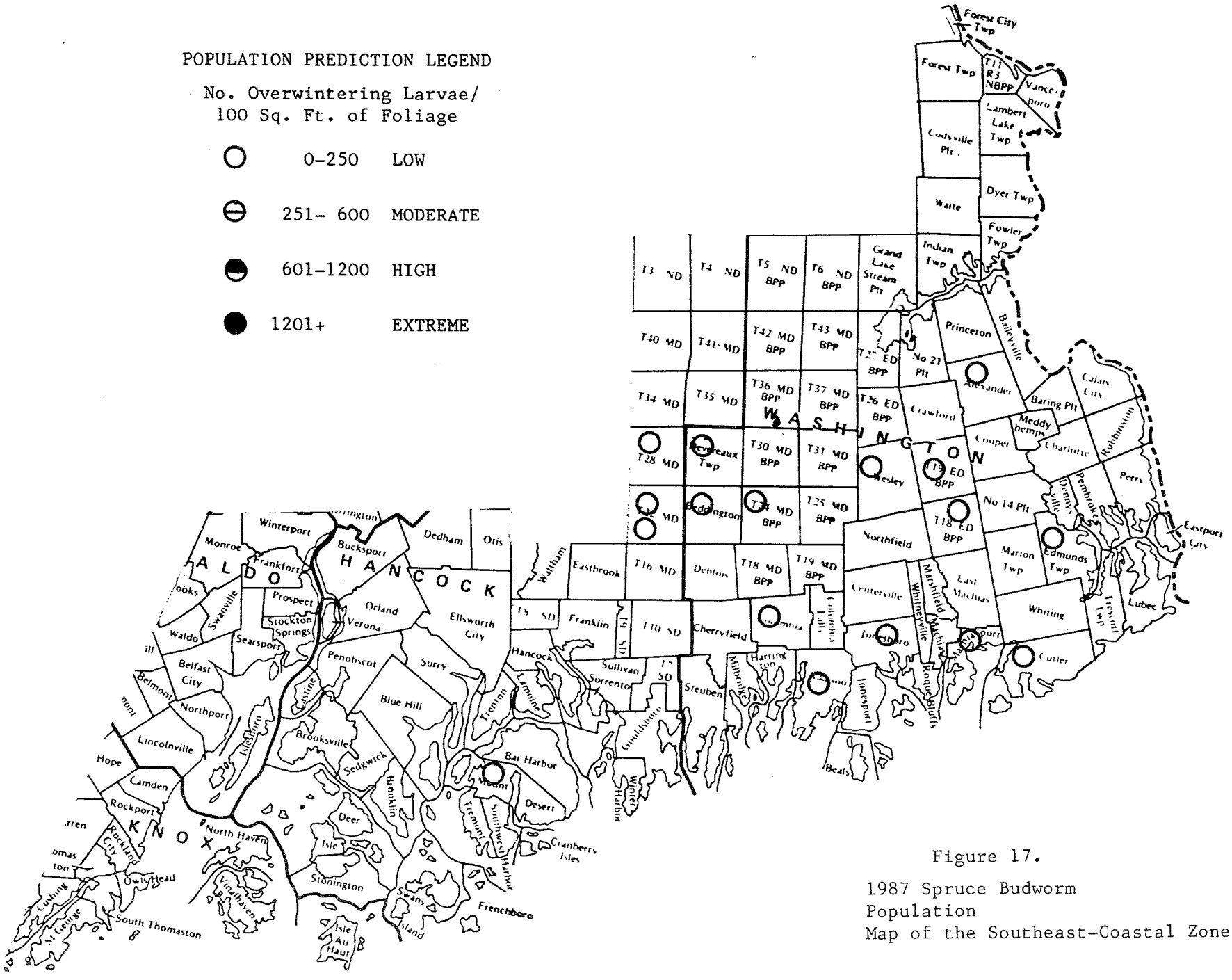


Figure 17.

1987 Spruce Budworm
Population
Map of the Southeast-Coastal Zone

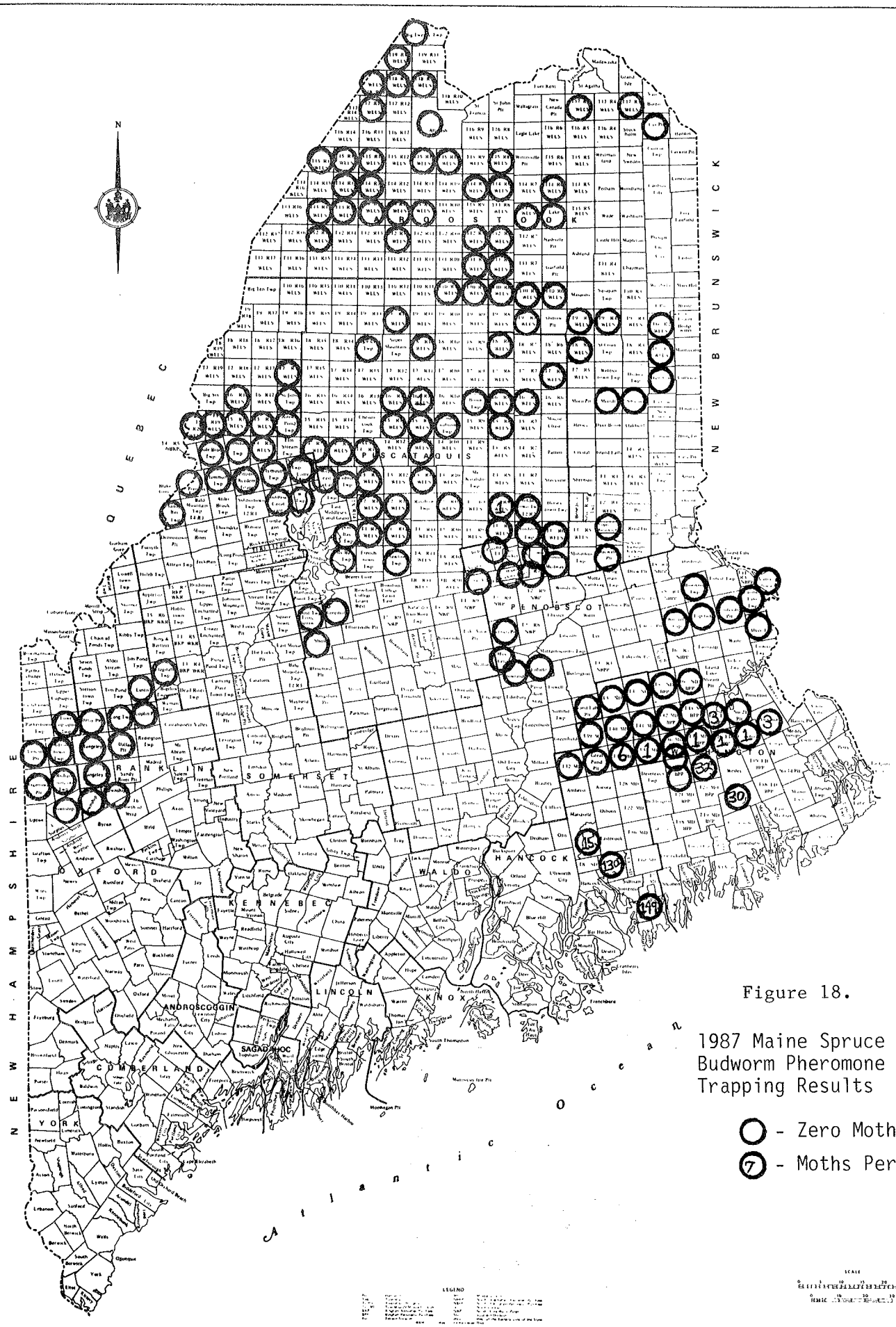


Figure 18.

1987 Maine Spruce Budworm Pheromone Trapping Results

○ - Zero Moths

(7) - Moths Per Trap

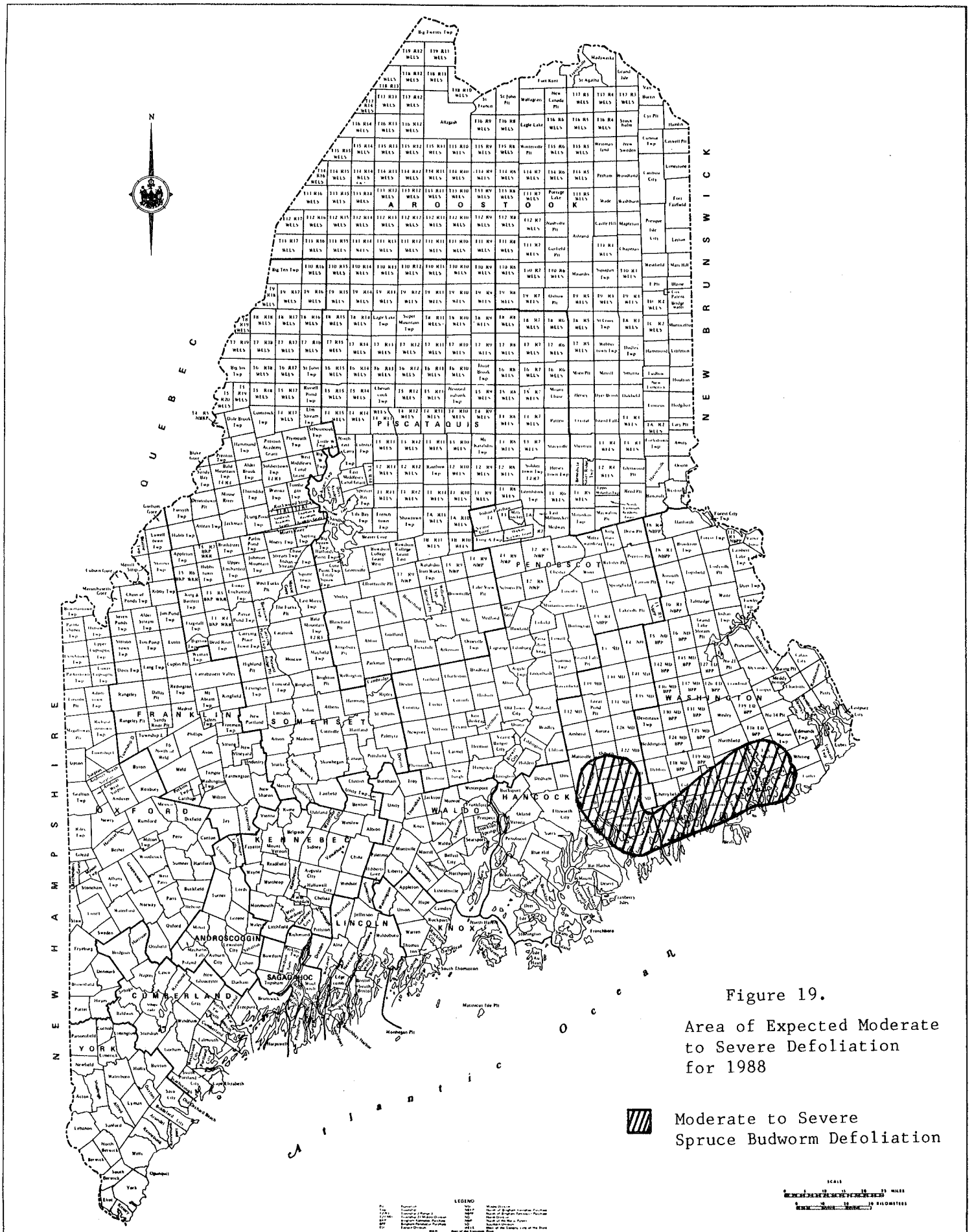


Figure 19.

Area of Expected Moderate to Severe Defoliation for 1988

Moderate to Severe Spruce Budworm Defoliation

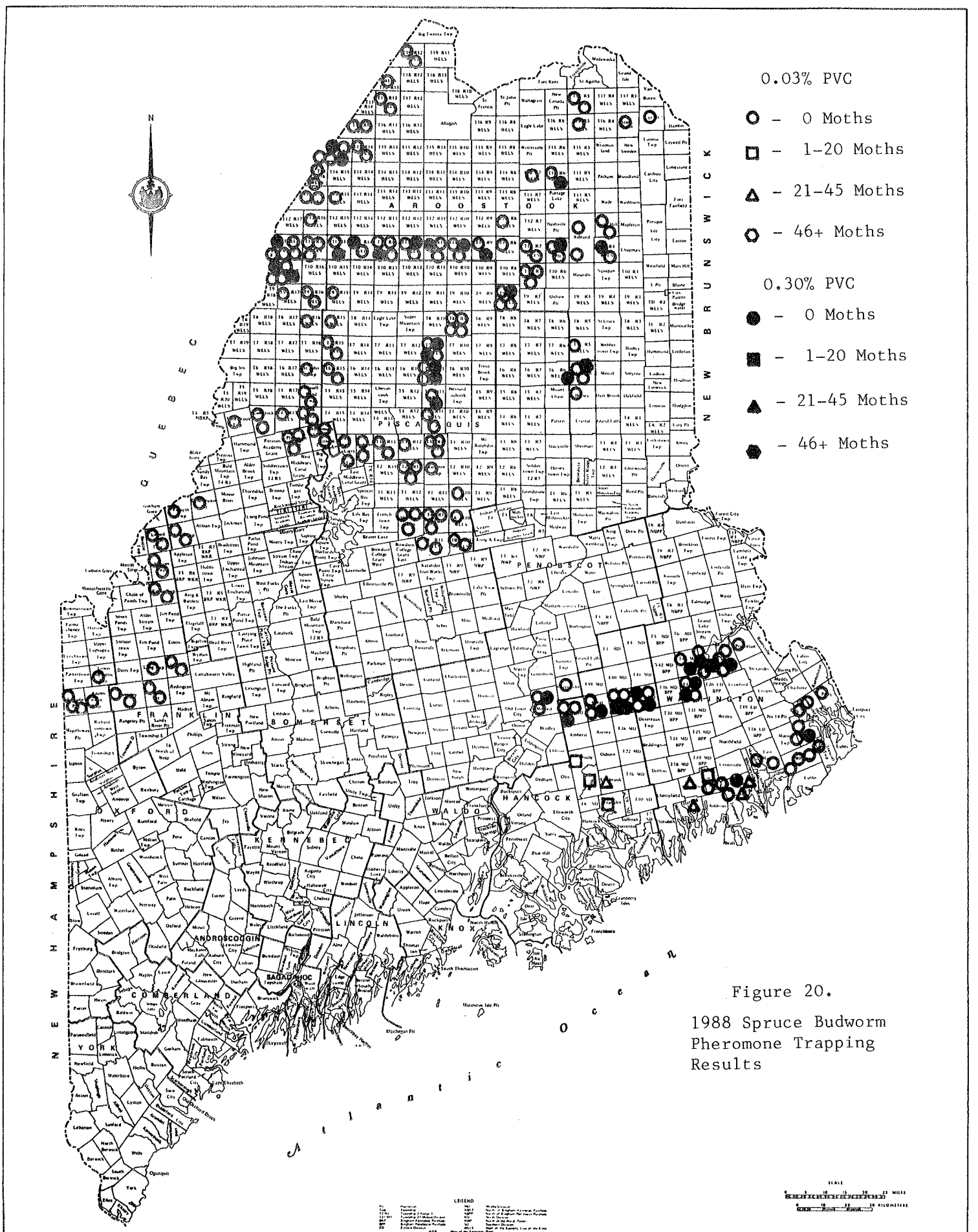


Figure 20.

1988 Spruce Budworm Pheromone Trapping Results

actually decreased catch due to moth disruption at short range.

Considering the 1987 and 1988 pheromone experience, the future use of the current standard pheromone method by the MFS is doubtful. MFS is planning a test in 1989 to compare the standard PVC and Biolure lures. Recent tests by Grimble in Maine and various workers in Canada indicate that the Biolure lure is more effective in very low population areas. Results of these tests will affect the use of pheromone for budworm survey.

Prediction Based on all available population prediction data and on 1988 defoliation maps, the MFS estimates that 1989 defoliation will be approximately the same size (55,000 acres) and of similar intensity as the 1988 area (Figure 21).

E. Status of the Outbreak

Annual levels of moderate to severe defoliation for the 70s and 80s outbreak in Maine had a rapid onset in the early 70s followed by a more gradual decline beginning in 1977 (Figure 22). This decline was interrupted twice by population resurgence in 1978 and 1983. Annual defoliated acreage dropped below pre outbreak levels in 1987 and continues to decline. The 1988 defoliation acreage is the smallest area mapped since 1946.

Defoliation during the recent outbreak (1961 - 1988) and total light trap catch (Figure 23) show similar patterns and demonstrate the value of the light trap survey. Based on data from the recent outbreak, light traps may provide an effective general budworm infestation prediction.

F. Tree Damage Survey

While collecting population prediction samples (L-II and pheromone) a survey of tree condition in the infested areas was conducted. At each sample point the following data were taken from balsam fir and red spruce.

Percent defoliation of current year's growth

Percent defoliation of 2 previous years growth

Tree Vigor

Presence of Dead Tops

Presence of Dead Trees

Presence of Balsam Woolly Aphid

Presence of Beetle Attack

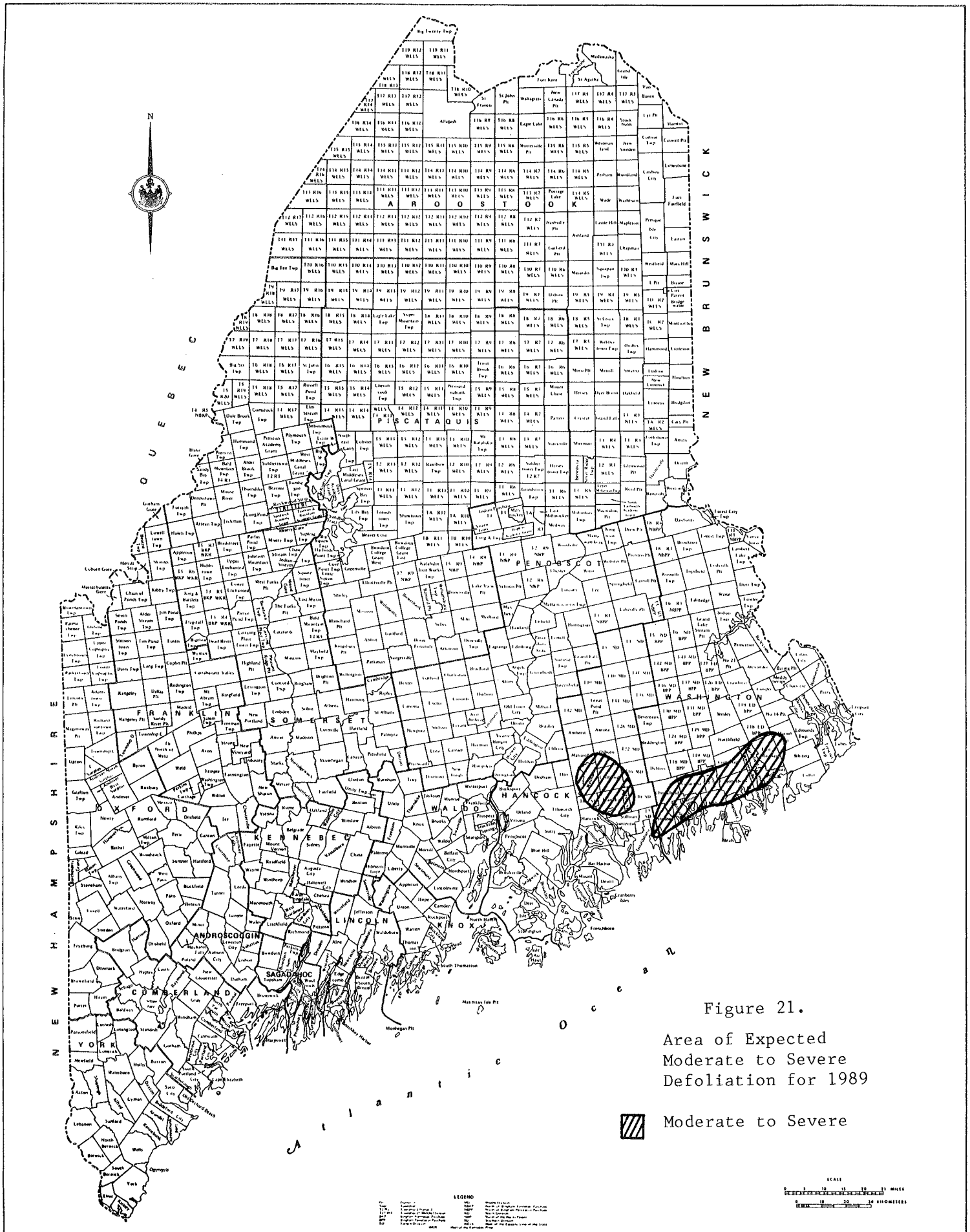


Figure 21.

Area of Expected Moderate to Severe Defoliation for 1989

Moderate to Severe

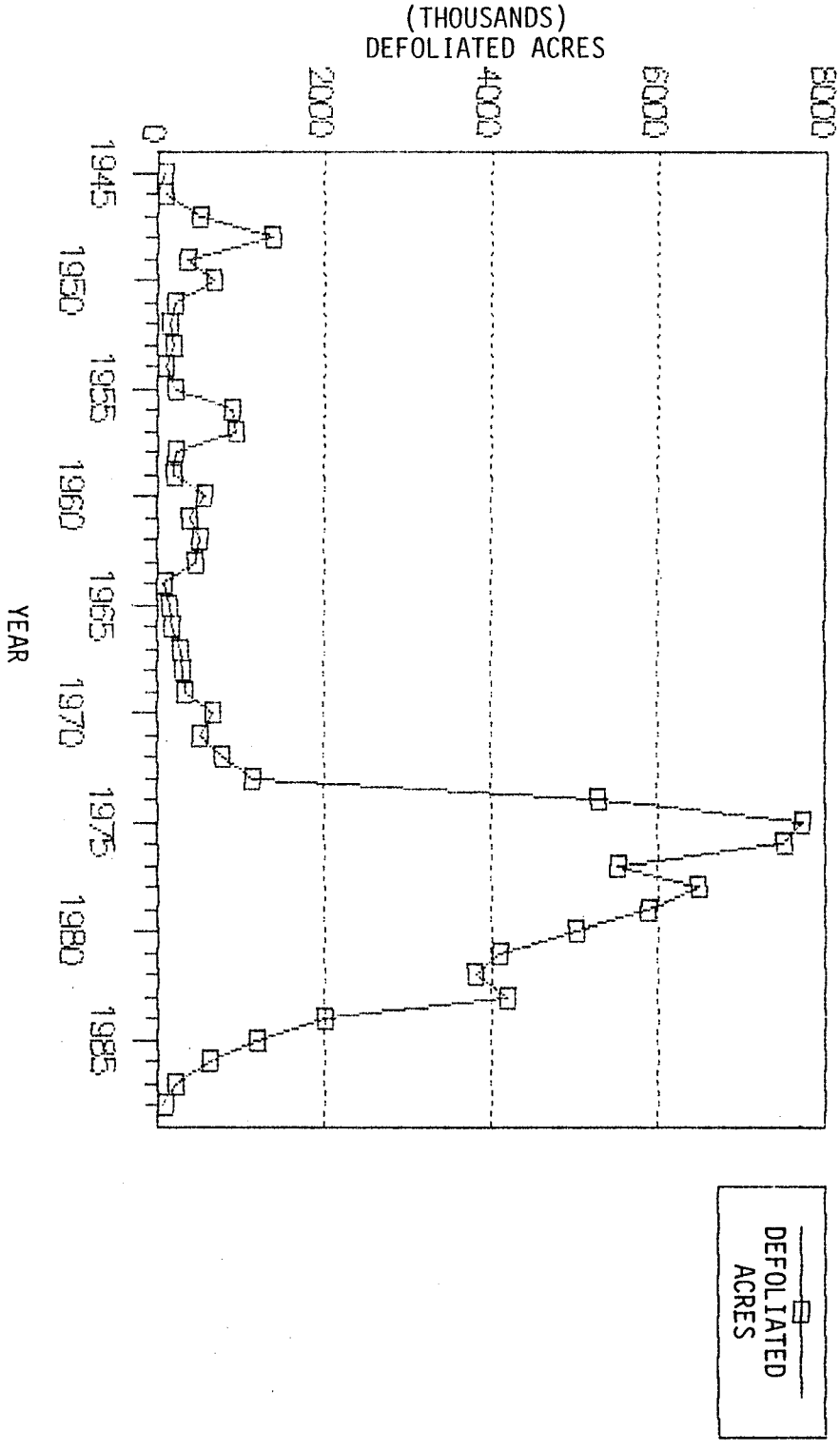


FIGURE 22. ACREAGE OF MODERATE TO SEVERE DEFOLIATION BY SPRUCE BUDWORM IN MAINE-1945-1988

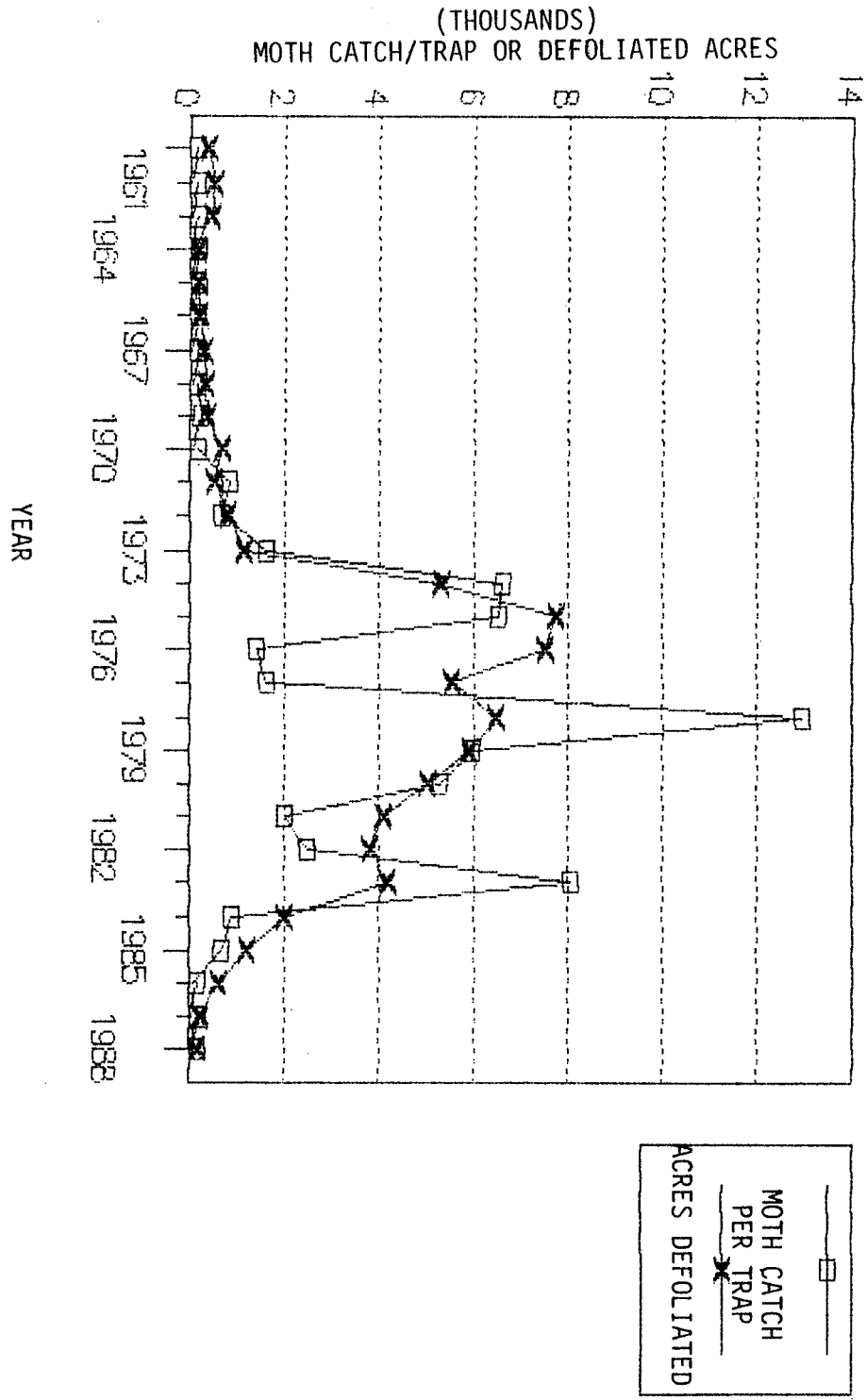


FIGURE 23. LIGHT TRAP MOTH CATCH PER TRAP AND AREA OF MODERATE TO SEVERE DEFOLIATION IN MAINE-1961-1988

These data were used to determine the general condition of stands. Stand condition data, in conjunction with predicted population data, were then used to determine hazard values and potential damage to fir and spruce.

G. Forecast of Tree Condition and Hazard for 1986 through 1988

Data collected during ground surveys were quantified into a hazard-rating using the system shown in Table 6. Statewide hazard was determined in 1986 but not in 1987 or 1988.

In 1986, a hazard rating was determined for each L-II sample location. The system had been used for several years and was designed for fir. The rating included predicted populations, current defoliation, past defoliation (2 previous years), tree vigor, and presence of dead tops. Hazard was grouped in classes as low, moderate, high, or extreme. Points were plotted on a map and used in combination with aerial damage data to produce a final hazard map for landowners.

Hazard ratings for 1986 were mapped by zone (Figure 24 through 29). All hazard values are for fir, but high or extreme values for fir generally indicate spruce is also in need of protection.

The portion of the budworm area in high or extreme hazard was much smaller in 1986 (0.1 million acres) compared to the 1985 area (1.5 million acres). Hazard intensity decreased in most areas due to very low predicted populations and little damage in 1985 and 1986.

In 1987, a hazard prediction was made for only a part of the southeast coastal zone (Figure 30). Small patches of high to extreme hazard were located in coastal Washington and south central Hancock counties . These areas total less than 50,000 acres.

No hazard prediction was made in 1988 for 1989, because no control was planned and the exercise was thought to be of little value at this point in the outbreak.

V. SPRAY OPERATIONS AND FORECAST OF CONDITIONS IN QUEBEC AND NEW BRUNSWICK, 1986-1988

Previous reports included discussion of results of the spray project, infestation conditions, forecasts for the coming seasons, and spray plans for New Brunswick and Quebec. This section provided a regional overview of the budworm situation. Because this report covers 3 years of data, the information will be presented in table 7.

Table 6.
Maine Forest Service Hazard Rating System Used in 1986

CURRENT DEFOLIATION

Category	Values	Hazard Values
Trace	0-5	0
Light	6-20	1
Moderate	21-50	2
Heavy	51-80	4
Severe	81 +	6

PREVIOUS DEFOLIATION
(2 PREVIOUS YEARS)

Trace	0- 9	0
Light	10- 49	3
Moderate	50-129	6
Heavy-Severe	130 +	9
Dead Tops		+3

OVERWINTERING LARVAL DEPOSIT
BASED ON NO./100 SQ. FT. OF FOLIAGE

L-II

Light	0- 250	1
Moderate	251- 600	2
High	601-1200	3
Extreme	1201 +	4

TREE VIGOR

Good	0
Fair	1
Poor	2
Very Poor (No Chance of Recovery)	3

HAZARD

Hazard Rating	Range of Total Values
Low	0- 6
Moderate	7-15
High	16-22
Extreme	23-25

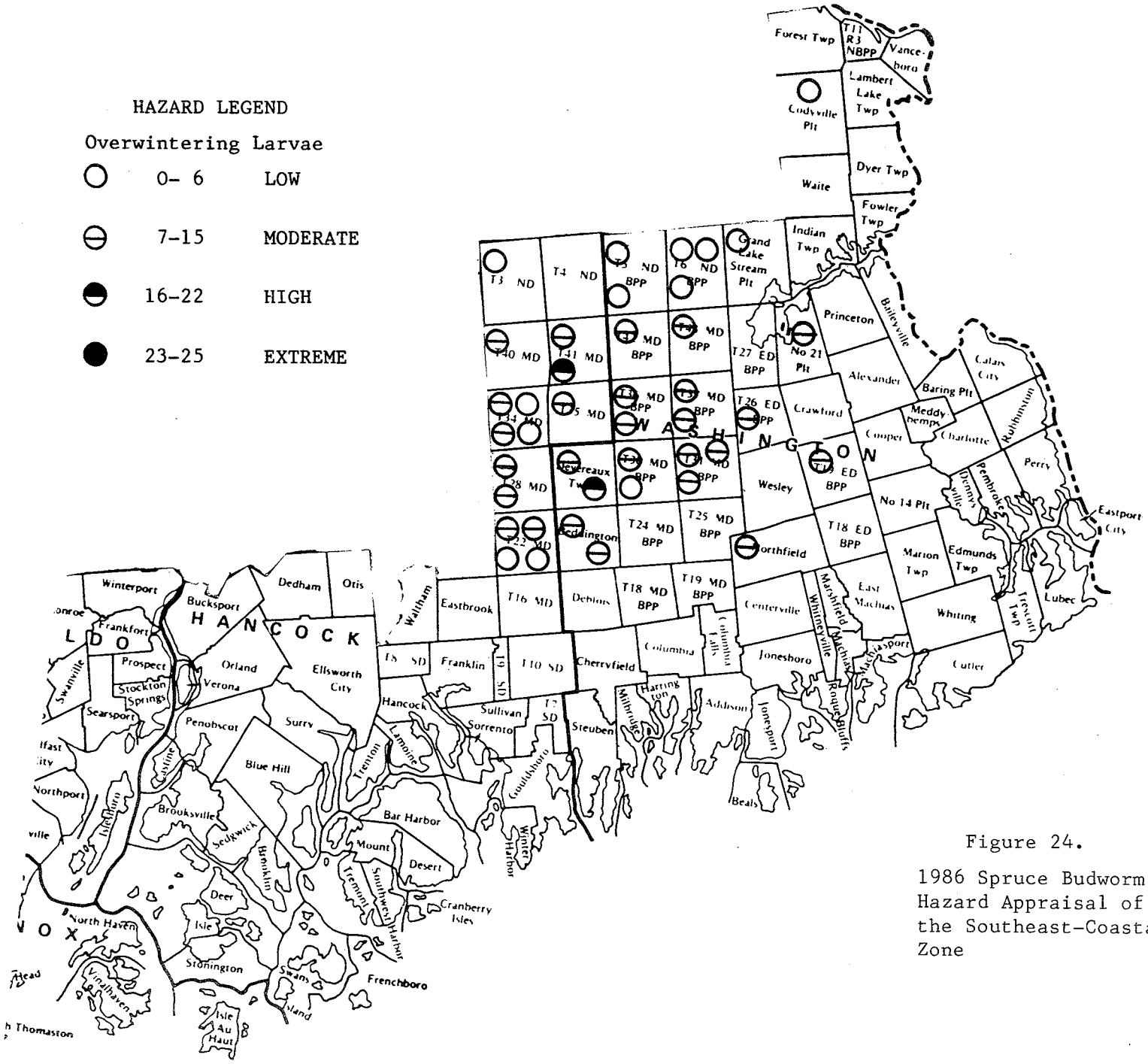


Figure 24.

1986 Spruce Budworm Hazard Appraisal of the Southeast-Coastal Zone

HAZARD LEGEND

Overwintering Larvae

○	0- 6	LOW
⊖	7-15	MODERATE
◒	16-22	HIGH
●	23-25	EXTREME

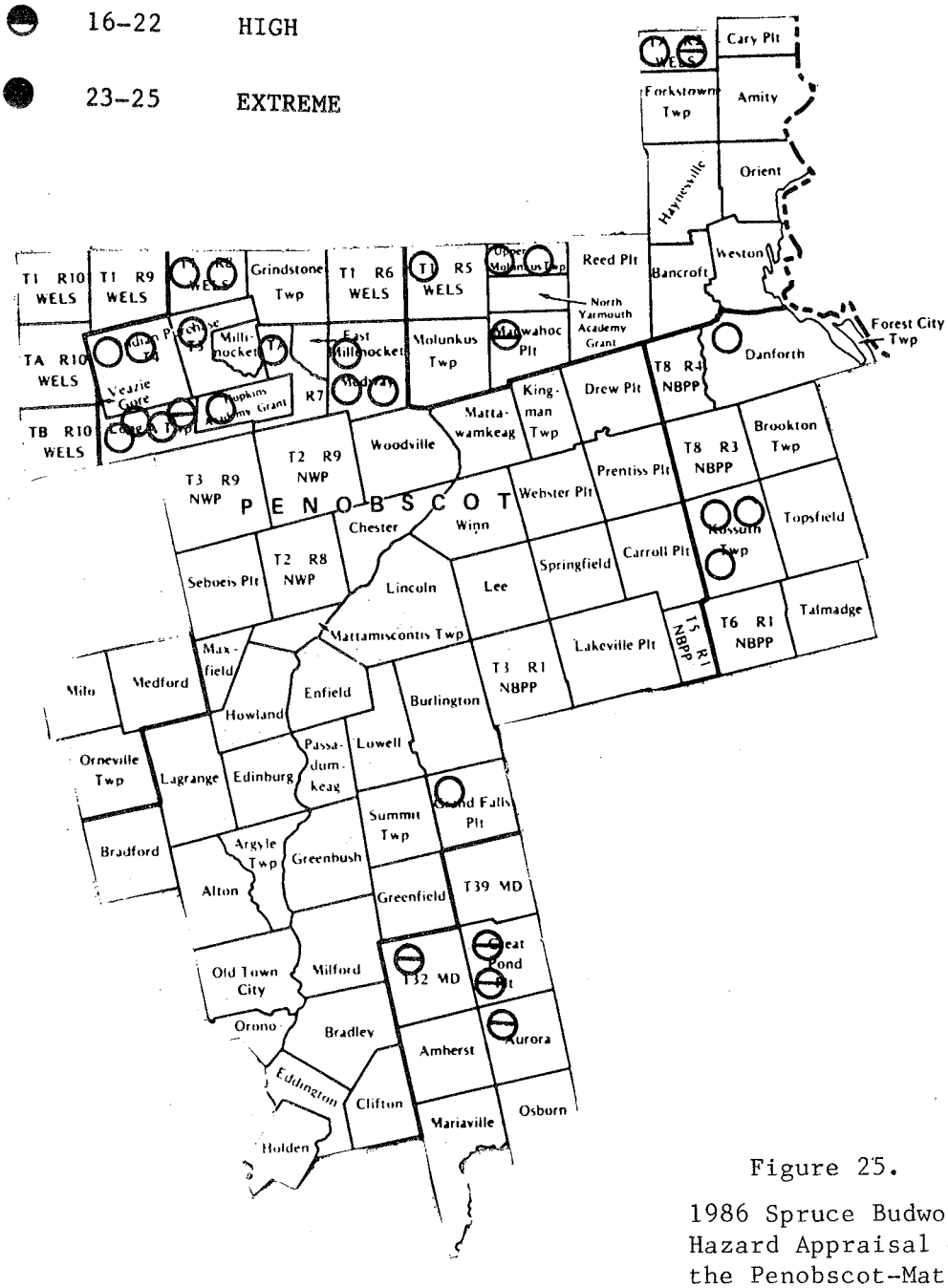


Figure 25.

1986 Spruce Budworm Hazard Appraisal of the Penobscot-Mattawamkeag Zone

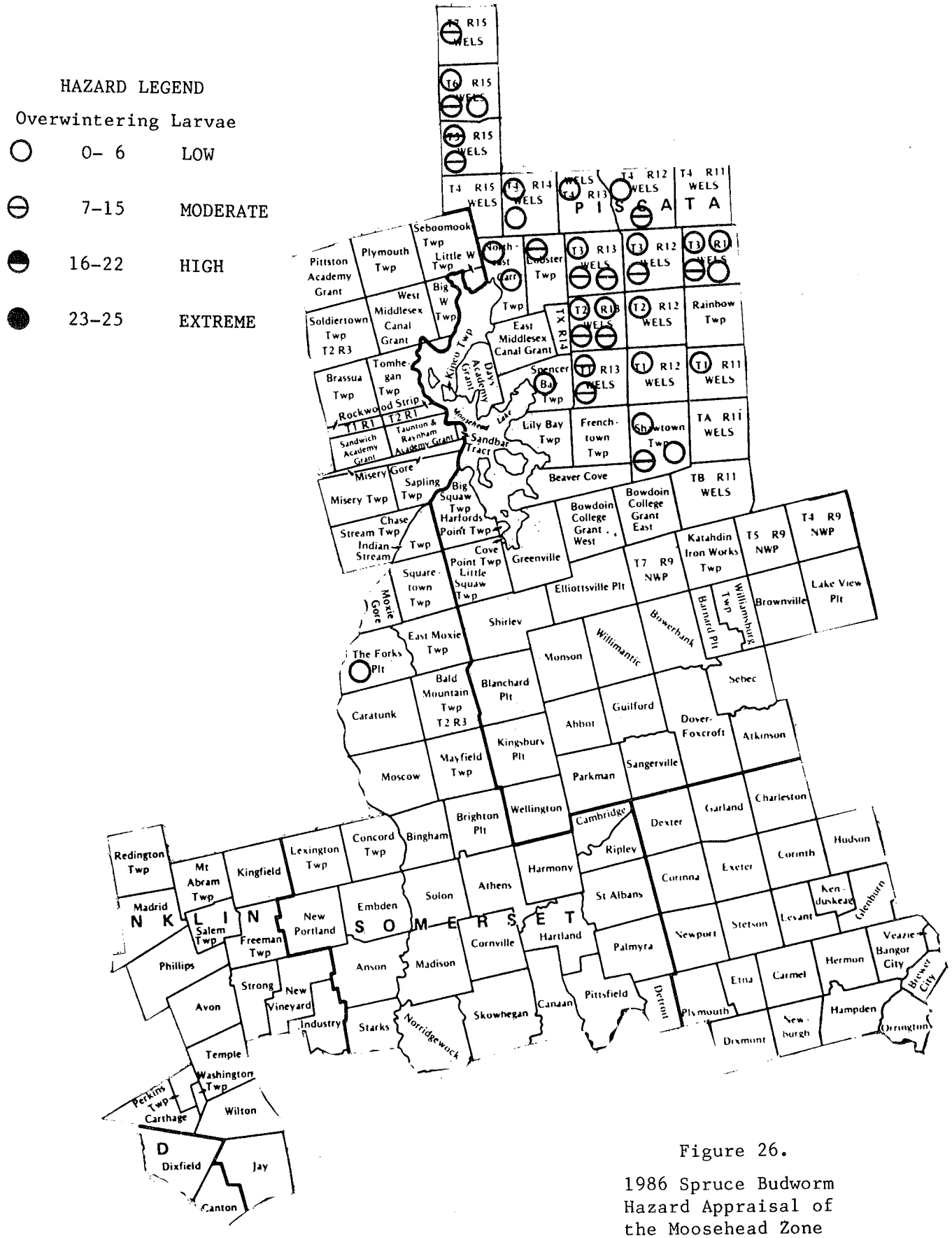


Figure 26.

1986 Spruce Budworm Hazard Appraisal of the Moosehead Zone

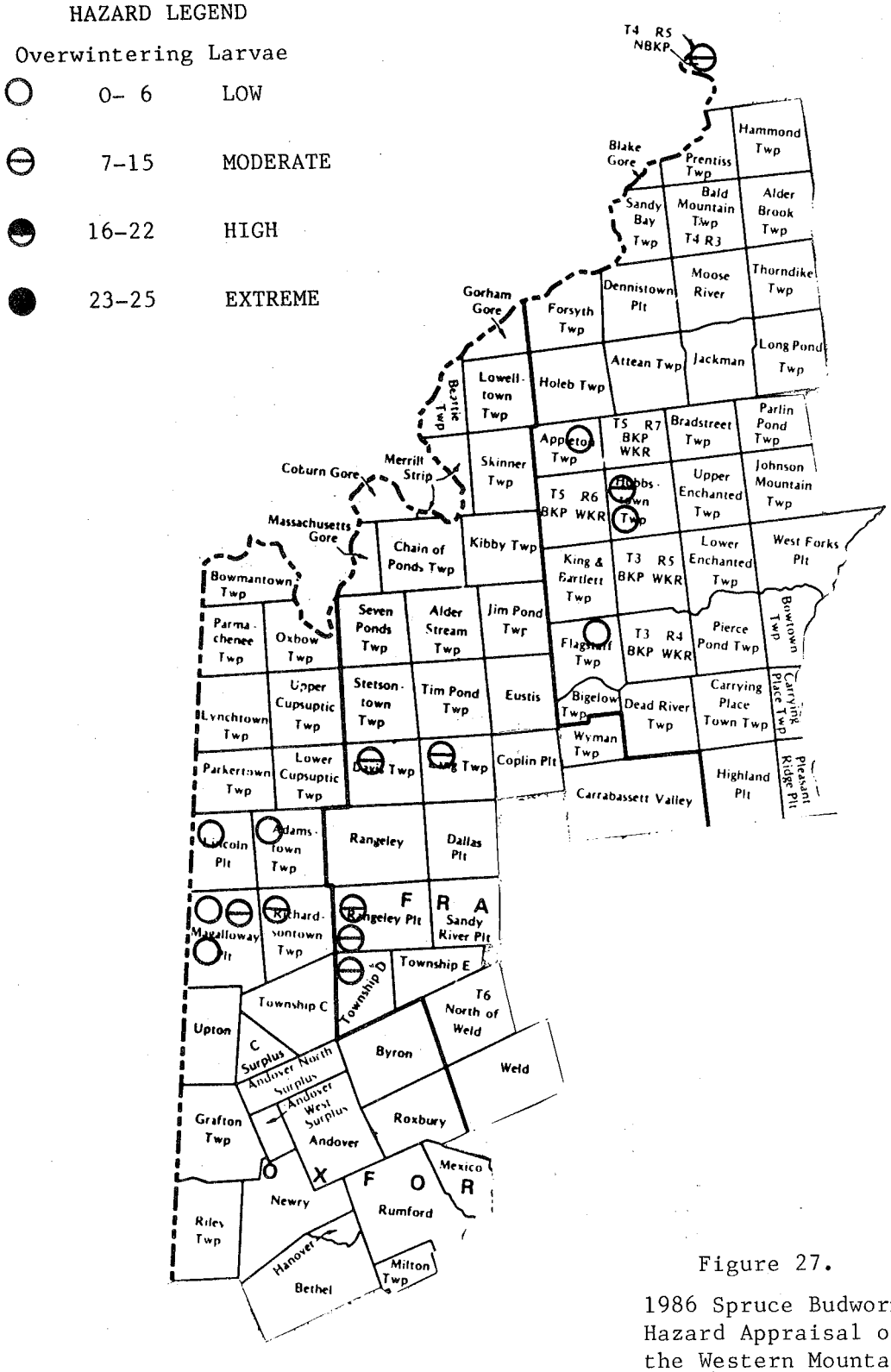


Figure 27.

1986 Spruce Budworm Hazard Appraisal of the Western Mountains Zone

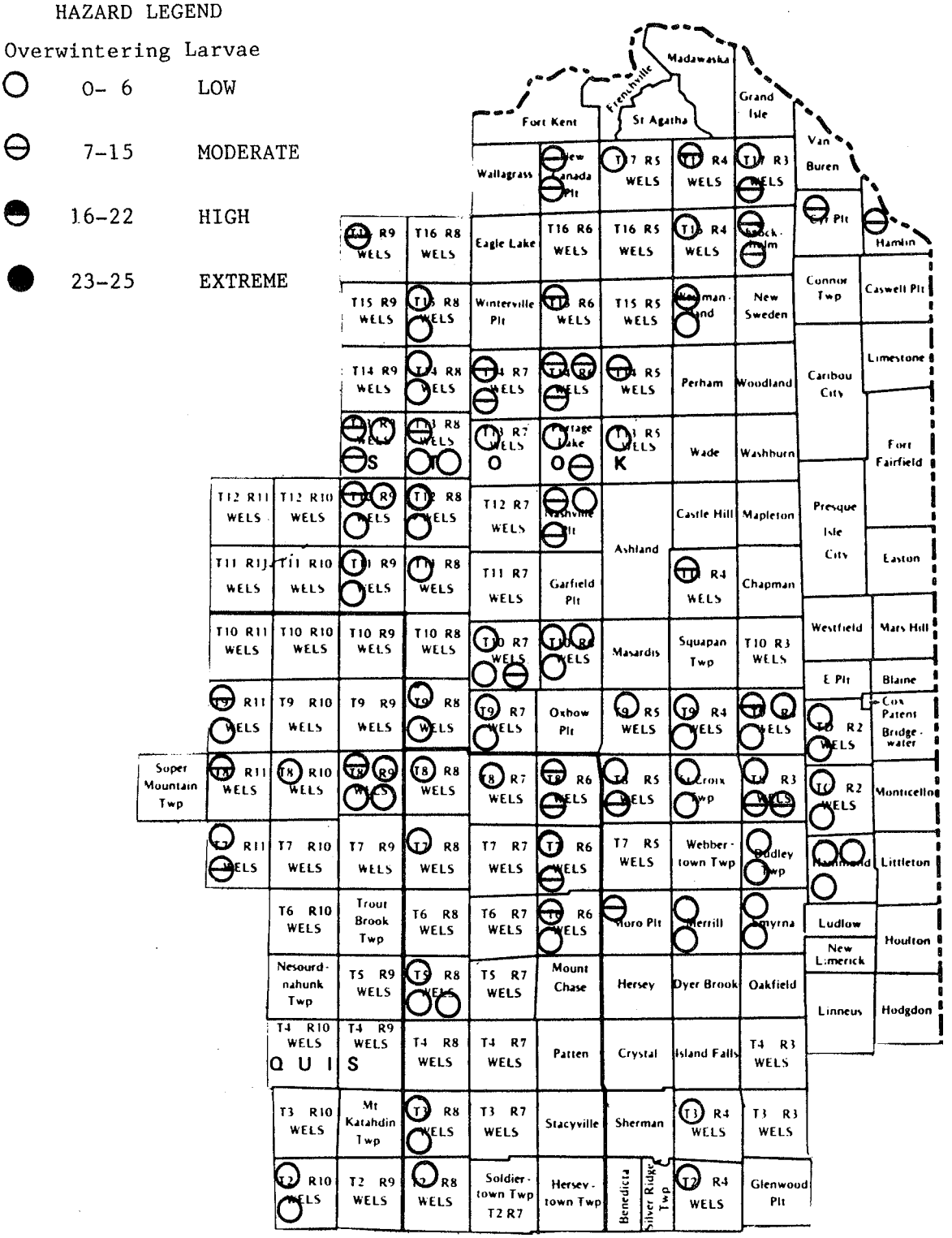


Figure 28.

1986 Spruce Budworm Hazard Appraisal of the Northeast Zone

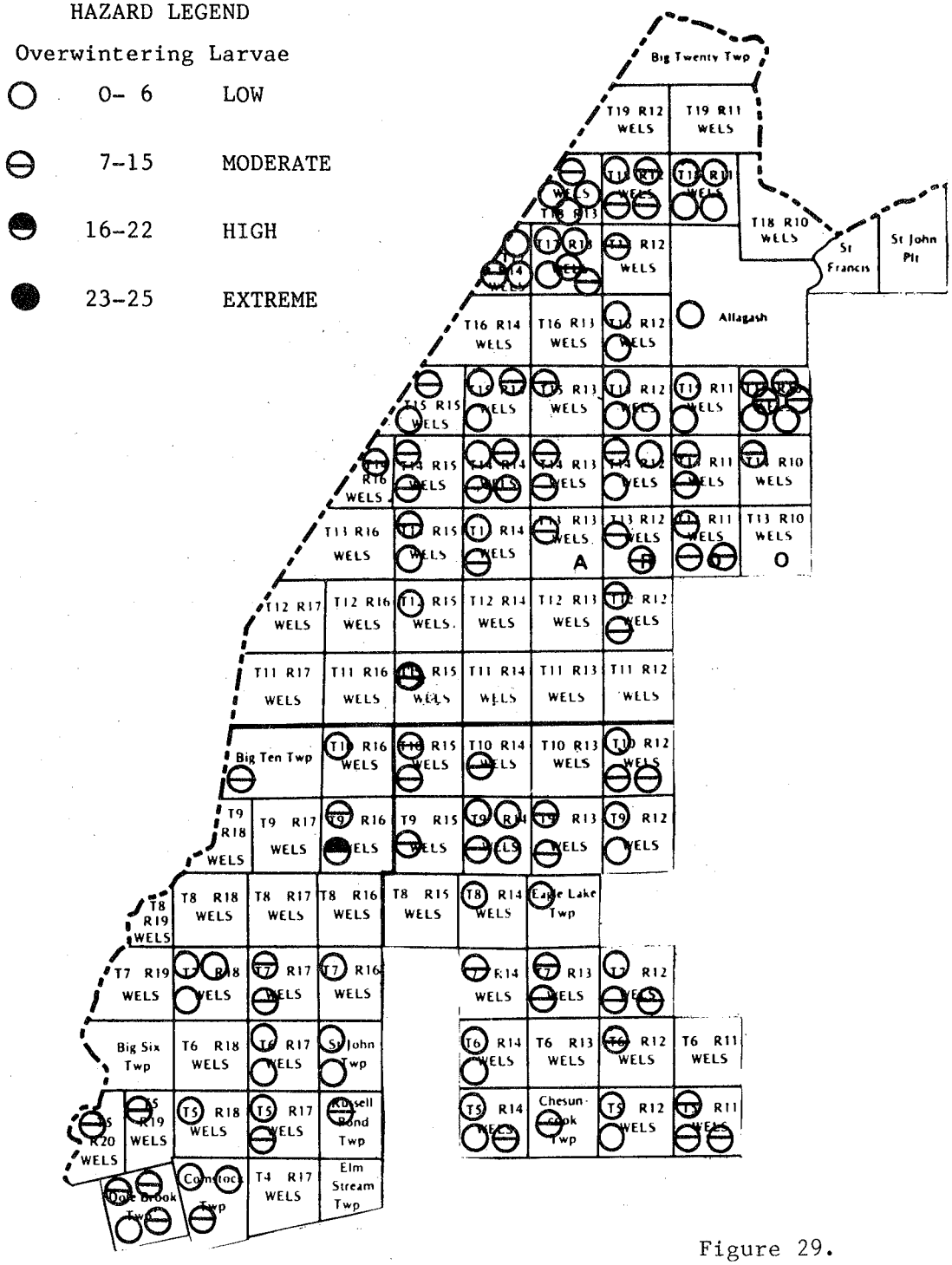


Figure 29.

1986 Spruce Budworm Hazard Appraisal of the Allagash-St. John Zone

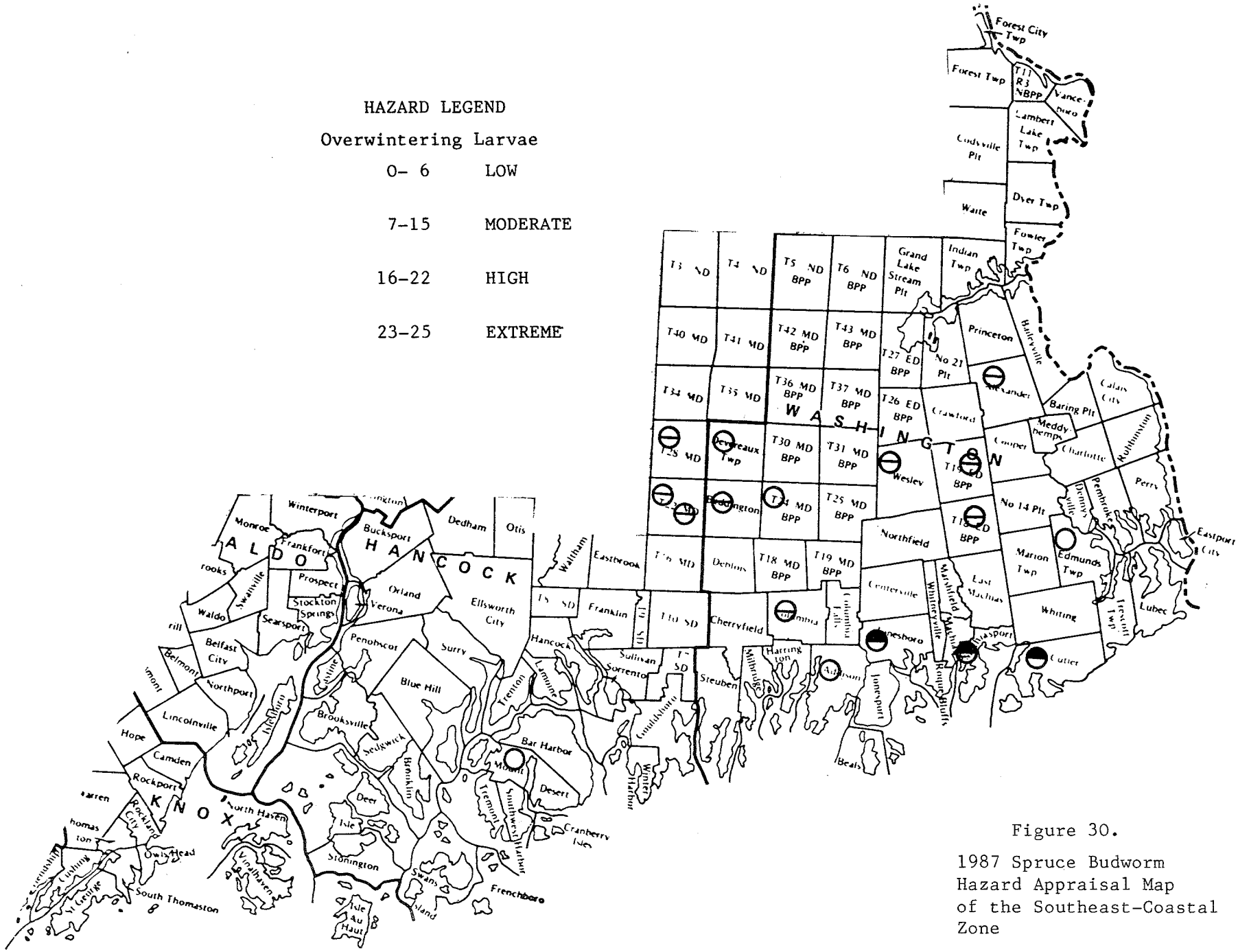


Figure 30.

1987 Spruce Budworm Hazard Appraisal Map of the Southeast-Coastal Zone

Table 7. Spruce Budworm Operations, Conditions, and Forcast for New Brunswick and Quebec - 1986,1987, and 1988

	New Brunswick		
	1986	1987	1988
Spray Area (ha)	496,000	478,300	448,000
Pesticide	78% chemical, Matacil and fenitrothion, and single applications, 22% Bt undiluted	82% chemical, fenitrothion and some Matacil, 17% Bt, Dipel and Futura	51% chemical, fenitrothion splits, 47% Bt, Futura and Dipel
Aircraft	29 total, 9-TBMs, 16-ag type, 4-helo (Bell 206)	TBMs and ag type	15 total, 12-TBMs, 1-DC-6, 2-ag type
Spray Results	Most blocks met the goal of less than 40% defoliation on fir and 50% defoliation on spruce	Generally successful in reducing defoliation and meeting project goals	Disappointing Bt results for many possible reasons, chemical results slightly below normal
Defoliation Estimate (ha) mod to sev	927,000, 13% decrease from 1985	430,000, 54% decrease from 1986	500,000, 16% increase from 1986, mostly in northcentral region
Population Prediction	Continuous decrease since 1981, 77% low points, forecast of 1.7 million ha, down 46% from 1985	Forecast for 1.5 million ha in the northern portion	Forecast for 1.65 million ha, 10% increase from 1987 in the northern portion, a spray area similar to that in 1988 is expected in the north

	Quebec		
	1986	1987	1988
Spray Area (ha)	51,155	197,992	192,073
Pesticide	18,160 Bt, Thuricide 48 LV, 33,038 fenitrothion split	100% Bt, 30 BIU/ha, Dipel	100% Bt, 30 BIU/ha, Dipel
Aircraft	5-ag type	8 total, 4-DC-4, 4-ag type	14 total, 2-DC-4, 12-ag type
Spray Results	Good protection, 32% defoliation in treated compared to 55% in untreated.	75% less than 55% defoliated, treatment success varied due to spotty high populations and some late spraying.	Results variable but not as good as recent years due to high populations and other factors, many blocks exceeded 50% defoliation.
Defoliation Estimate (ha) mod to sev	2,100,000, down sharply from 1985	74,000, down sharply from 1986	70,000, down from 1987
Population Prediction	Predict a continued problem in the Gaspe', North Shore, and Three Rivers areas.	Continued decline except in the Gaspe' area, increases in the Gaspe'.	Continued decline except in the Gaspe' where an increase is expected, spray area of 175,000 ha is expected in the Gaspe' 1989

VI. THE FUTURE OF BUDWORM IN THE REGION AND IN MAINE

During the height of the recent outbreak in the mid to late 70's the budworm infestation covered more than 200 million acres and stretched from Ontario and Michigan in the west to Newfoundland in the east. The mid 80's collapse brought populations to endemic or near endemic levels in eastern Ontario, western and central Quebec, Vermont, New Hampshire, all but southeastern Maine, Southern New Brunswick, Nova Scotia, and Newfoundland. Active infestations persisted in northwestern Ontario, the North Shore and Gaspe' in Quebec, and north central New Brunswick. The combined Quebec and New Brunswick areas exceeded 100,000 hectares and increased in intensity and size in 1988. Portions of the current New Brunswick area are within 15 miles of Maine and represent a concern for the future of the Maine forest. Also, population increases were noted in a portion of Quebec adjacent to northwestern Maine. This area had negligible populations in 1986 and 1987.

What is the future of budworm in Maine? Being a native insect, with a long history in Maine, there is no doubt that budworm will be back. When the infestation will return, and the nature of the next outbreak are subjects of conjecture. Some researchers expect a "traditional" (20 to 30 years) inter-outbreak interval in Maine and therefore don't expect budworm to return to Maine until approximately 2010. Some Canada workers have speculated that recent population increases in New Brunswick and Quebec suggest that the infestation has already started its resurgence. There is no reliable method of long range budworm population prediction.

A future budworm outbreak in Maine is likely to vary considerably from the recently concluded outbreak. The recent outbreak had a profound effect on the Maine forest. In general, it changed a dense and mature spruce-fir forest to a much more intensively managed and more varied forest. In order to manage the recent outbreak, landowners cut, salvaged, sprayed, and allowed stands to die. These management practices in response to budworm have left a forest composed of very young stands, regenerating from various cutting practices or tree mortality, interspersed with residual mature stands which survived the outbreak naturally or through spray protection. Even though budworm attacked young stands and more resistant spruce stands during the recent outbreak, the impacts were clearly most intense in the presence of large volumes of mature fir. If budworm returns within the next 10 to 20 years, the extensive mature fir stands which fueled the 70's outbreak will not be present. Surviving mature stands are likely to be cut during the next 10 to 20 years. Even if budworm doesn't return for 30 years, fir stands lost during the 70's and 80's will be

relatively young and probably not as susceptible to budworm. The demand for wood by the expanded forest industry in Maine will certainly continue the trend accelerated by the budworm outbreak, toward more intensive forest management. This more intensive management is certainly providing a new set of host conditions for future budworm outbreaks. Regardless of these changes, however, budworm is certain to return and provide new management challenges to Maine landowners.

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No. Title

1. LaBonte, G. A.; *The saddled Prominent Outbreak of 1970-1971 and Its Damages.* March, 1978.
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3. Maine Forest Service, Entomology Division; *Spruce Budworm in Maine: 1977.* March, 1978.
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8. Trial, Jr., H.; A. Thurston; *Spruce Budworm in Maine: 1978.* December, 1978.
9. Trial, Jr., H.; W. Kemp; D. Struble; *Evaluation of Split Application and Reduced Dosages of Sevin-4-Oil for Spruce Budworm Control in Maine: 1978.* November, 1979.
10. Struble, D.; W. Kemp; H. Trial, Jr.; *Evaluation of a Reduced Dosage of Orthene for Spruce Budworm Control in Maine: 1977 and 1978.* December, 1979. **Never published.**
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Printed under Approp. No. 1505-2100