Amphibian Monitoring on Mt. Mansfield, Vermont 1993-1998

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Background

Populations of amphibian species are monitored annually on Mount Mansfield using drift-fences. The goals of the monitoring are to (1) establish a baseline data set of abundance indices for the amphibian species caught in the fences, (2) monitor year-to-year changes in their abundance indices, (3) monitor changes in the number and type of obvious external deformities, (4) gather inventory data for the Vermont Herp Atlas, and (5) gather basic natural history information on the species present. Amphibians are targeted for this kind of study because their multiple habitat usage and permeable skin make them especially sensitive to changes in environmental conditions. Six years of data have now been gathered at this site. This is the longest-running set of amphibian monitoring data in the state. Three fences are opened and checked up to five times per month during rain events throughout the field season (April through October excluding August). The abundance indices are generated using the three most successful trap-nights per month. For more detailed information on methods, locations of fences, and survey results, see the 1995 VForEM annual report.

Changes in species composition

Table 1 summarizes 1998 captures for all species. Two species were caught at the fences this year that were not caught last year: Dusky salamander and Gray treefrog. Dusky salamanders have been caught at the fences in previous years but never as many as were caught this year (10). Dusky salamanders usually confine their movements to the thoroughly saturated soils of seeps, springs, and edges of brooks. The fences at this site were located to intercept the movements of species that travel through better-drained upland forests. I suspect that the increase in the number of this species caught is the result of very wet soil conditions which facilitated their movement from seeps near the fences, rather than an increase in the size of the population at this site. The Gray treefrog is a species that we have located in previous surveys of this site, but it rarely gets caught due to its excellent climbing ability.

The Redback salamander increased from 49% of the salamander population in 1997 to 63% of the population in 1998. This is a result of its apparent population increase. Similarly the American toad increased from 22% of the frog population last year to 35% of the population this year. This is not only the result of an increase in the number of toads, but also a concurrent decrease in the number of Wood frogs.

Table 1. Monitoring results from the two drift-fences at 1,200 ft. and one at 2,200 ft.on Mt. Mansfield, Underhill, Vermont during 1998. Traps were opened whenever conditions were appropriate for amphibian movement from April through October excluding August. Data used are from the three most successful trappings per month (ρ 7 days): March 31, April 17, and May 2; May 3, 7, and 21; May 30, June 13, and June 17; July 17, 24, 31; September 13, 15, and 29; and October 8, 11, and 29. Data from 18 of 31 trap-efforts are used. Trapping on March 31 was possible at the lower two drift-fences only. Malformity, maximum size, and first metamorph data are taken from all 31 trappings.

Common name	Scientific name	# of all ages	# of young of the year[1]	% young of the year	date of first meta-morph[2]	largest adult (total length in mm)	# per trapping[3]	% of group	% of total catch	# malformed/ total[4]
Salamanders										
Redback salamander	*Plethodon cinereus*	97	1	1%	Oct. 29	90	5.4	63%	29%	0/103
Eastern newt	*Notophthalmus viridescens*	24	0	0%	NA	90	1.3	15%	7%	0/27
Spotted salamander	*Ambystoma maculatum*	21	4	19%	Sept. 8	184	1.2	14%	6%	1/26
Dusky salamander	*Desmognathus fuscus*	10	0	0%	NA	99	0.6	6%	3%	0/11
Northern two-lined	*Eurycea bislineata*	3	0	0%	NA	90	0.2	2%	1%	0/6
Group totals		155	5	3%	---	---	8.6	100%	46%	1/173
Frogs and Toads										
Wood frog	*Rana sylvatica*	84	27	32%	July 17	58	4.7	46%	25%	1/107
American toad	*Bufo americanus*	64	12	19%	July 31	79	3.6	35%	19%	2/70
Spring peeper	*Pseudacris crucifer*	19	0	0%	NA	37	1.1	10%	6%	0/25
Green frog	*Rana clamitans*	14	9	64%	June 26	59	0.8	8%	4%	1/17
Gray treefrog	*Hyla versicolor*	1	0	0%	NA	NA	0.1	1%	<1%	0/1
Group totals		182	48	26%	---	---	10.1	100%	54%	4/220
Amphibian totals		337	53	16%	---	---	18.7	---	100%	5/393

[1]For each species, individuals under a given total length were considered potential young of the year. The chosen length was based on the timing of their appearance, gaps in their size continuum, and records in the literature. The cutoff sizes used were *A. maculatum* (70 mm), *D. fuscus* (30 mm), *E. bislineata* (60 mm), *N. viridescens* (45 mm), *P. cinereus* (32 mm), *B. americanus* (32 mm), *H. versicolor* (26 mm), *P. crucifer* (20 mm), *R. clamitans* (44 mm), *R. palustris* (34 mm), and *R. sylvatica* (33 mm). In addition, it was necessary to examine the minimum possible development time for each species. Individuals shorter than the cutoff lengths clearly overwinter (possibly as larvae for *N. viridescens* and *A. maculatum*) and show up in very early spring. These are not counted as young of the year.

[2]No trapping took place in August.

[3]Number per trapping are rounded to the nearest 0.1. All other figures are rounded to the nearest whole number.

[4] These may contain old deformities (traumatic) as well as malformities (developmental). Salamanders missing all or portions of their tails are not included. The total number checked may contain specimens that were caught more than once.

Young of the year and malformities

Table 1 also summarizes young of the year and malformity data. Although the number of young of the year was not radically different from the previous year, the number of malformities reported is quite different. Not a single malformed amphibian had been caught in any of the fences at this site since 1993, although a deformed Wood frog was caught by hand near one of the fences in 1994. This year, five of a total of 393 amphibians caught (~1.3%) had an external malformity of some sort. Four species were represented: American toad (2), Wood frog (1), Spotted salamander (1), and Green frog (1). Three of the five malformed individuals were young of the year. It should be noted that the sample size of young of the year amphibians is quite small for each species. Three of a combined total of 53 young of the year amphibians were malformed (3/53= 5.7%). This is not an alarming percentage, but the apparent increase is of interest. It is possible that this year's technicians did a more thorough job of checking than was done in previous years. At this point the apparent increase in malformities at this site is only a curiosity, but it should be monitored carefully in future years.

Trends

Table 2 shows abundance indices for all the species caught from 1993 to 1998. Linear regressions most closely fit most of the data plots, so they were used to show potential trends. Last year the data gathered suggested that seven of the eight species abundant enough to monitor had shown an average increase over the previous five years: American toad, Green frog, Pickerel frog, Wood frog, Eastern newt, Redback salamander, and Spotted salamander. This year's data show that two of these species were caught in greater numbers this year than last: American toad and Redback salamander. Fewer Green frogs, Red efts, and Wood frogs, were caught this year than last, but a linear regression run on the six-years of data continues to suggest positive increases for all of them. Although Pickerel frog was never caught frequently, it had appeared to be on the increase. It disappeared entirely from the fences this year. The Spotted salamander that had appeared to be on the increase through 1997 was caught in low enough numbers in 1998 to reverse its apparent trend. Spring peeper was the only species whose numbers had dropped over the five-year period ending last year. This year we caught more of them but not enough to reverse the trend of the last five years.

Table 3 shows selected statistics generated from the last six years of data, including statistics on the reliability of the apparent trends. The likelihood that an apparent trend reflects a true trend in population numbers is referred to as power. Statistically it is defined as the likelihood of correctly rejecting the null hypothesis (no trend). My goal is to achieve a power of 90% or greater. The powers of these data sets are dependent upon a number of variables: the length of the series of data gathering units (at this point six years), the number of times per year data are gathered (12-18), the number of locations from which data are gathered (in this case one, because although three fences are used, the data are combined), the variability of the data collected (differs for each species), the starting value of the abundance indices (differs for each species), the direction of the trend to be evaluated, how small a trend I hope to be able to detect (5% annually), and what statistical level of significance is acceptable: alpha = 0.10 (10% chance of incorrectly rejecting the null hypothesis). Trends that meet the 90% power criteria are bold faced and marked with an asterisk in the column at the far right of Table 3. All others are left in plain text without an asterisk. The power figures shown were generated using the Monitor.exe shareware program written by James P. Gibbs and available on the National Biological Survey's Inventory and Monitoring website (http://www.mp1-pwrc.usgs.gov/powcase.html). Also available through this site is a more extended discussion of power and the rationale for the power and alpha values used here.

Table 2. A comparison of drift-fence data from the 1993 through 1998 field seasons at Mt. Mansfield, Underhill, Vermont. Data used are from two fences at 1,200 ft. and one fence at 2,200 ft. in elevation.

Species name	# per trapping[1]						% of total catch					
	93	94	95	96	97	98	93	94	95	96	97	98
Caudates (Salamanders)												
	1.7	1.0	1.4	2.0	1.4	1.2	12%	10%	9%	12%	8%	6%
	0.3	0.3	0.3	0.0	0.0	0.6	2%	3%	2%	0%	0%	3%
	0.5	0.1	0.2	0.1	0.2	0.2	4%	1%	1%	1%	1%	1%
	< 0.1	0.0	0.0	0.1	0.0	0.0	< 1%	0%	0%	< 1%	0%	0%
	1.3	1.2	1.7	1.4	1.8	1.3	10%	12%	11%	8%	10%	7%
	1.2	4.2	1.3	2.5	3.3	5.4	9%	40%	9%	14%	18%	29%
	5.1	6.8	4.9	6.1	6.8	8.6	38%	66%	32%	36%	37%	46%
Anurans (Frogs and Toads)												
American toad	0.7	0.6	1.5	2.2	2.5	3.6	5%	5%	10%	13%	14%	19%
Gray treefrog	0.0	0.0	0.0	0.0	0.0	0.1	0%	0%	0%	0%	0%	< 1%
	1.7	1.1	2.2	0.9	0.3	1.1	13%	10%	14%	5%	2%	6%
	< 0.1	0.2	0.9	0.6	1.3	0.8	< 1%	2%	6%	3%	7%	4%
	0.1	0.0	1.1	0.3	0.3	0.0	1%	0%	7%	2%	1%	0%
	5.6	1.7	4.4	6.8	7.0	4.7	42%	16%	29%	40%	39%	25%
Group totals	8.2	3.6	10.1	10.8	11.3	10.1	62%	33%	66%	64%	63%	54%
Amphibian totals	13.4	10.4	15.0	16.8	18.1	18.7	100%	100%				

[1]Number per trapping are rounded to the nearest 0.1. All other figures are rounded to the nearest whole number. There were a total of 15 trappings counted in 1993, 14 in 1994, 18 in 1995, 17 in 1996, 12 in 1997, and 18 in 1998. Trappings counted were on those nights when at least two of the three traps were opened under appropriate weather conditions for amphibian movement.

Table 3. Statistical analyses of the Mt. Mansfield drift-fence data from 1993 through 1998. Percentages in bold type with asterisks are generated with a power greater than 90%.

Species name	# per trapping[1]						Statistics[2], power[3], and trends[4]						
	93	94	95	96	97	98	SD	Mean	CV	P 6 yrs.	P 10 yrs.	Ann. ?	? %
Caudates (Salamanders)													
Spotted salamander	1.7	1.0	1.4	2.0	1.4	1.2	0.36	1.45	0.25	0.98	1.00	-0.02	-1%
Dusky salamander	0.3	0.3	0.3	0.0	0.0	0.6	0.23	0.25	0.92	0.23	0.55	---	---
N. two-lined salamander	0.5	0.1	0.2	0.1	0.2	0.2	0.15	0.22	0.68	0.86	1.00	-0.04	**-12%***
Spring salamander	< 0.1	0.0	0.0	0.1	0.0	0.0	---	---	---	---	---	---	---
Eastern newt	1.3	1.2	1.7	1.4	1.8	1.3	0.24	1.45	0.17	1.00	1.00	+0.04	**+3%***
Redback salamander	1.2	4.2	1.3	2.5	3.3	5.4	1.65	2.98	0.55	0.16	0.28	+0.55	+36%
Group totals	5.1	6.8	4.9	6.1	6.8	8.6	1.36	6.38	0.21	0.98	1.00	+0.53	**+11%***
Anurans (Frogs and Toads)													
American toad	0.7	0.6	1.5	2.2	2.5	3.6	0.31	1.85	0.17	0.57	0.94	+0.60	**+167%***
Gray treefrog	0.0	0.0	0.0	0.0	0.0	0.1	---	---	---	---	---	---	---
Spring peeper	1.7	1.1	2.2	0.9	0.3	1.1	0.66	1.22	0.54	0.63	0.98	-0.19	**-11%***
Green frog	< 0.1	0.2	0.9	0.6	1.3	0.8	0.43	0.65	0.66	---	0.14	+0.19	+100%
Pickerel frog	0.1	0.0	1.1	0.3	0.3	0.0	0.41	0.30	1.37	---	0.10	---	---
Wood frog	5.6	1.7	4.4	6.8	7.0	4.7	1.95	5.03	0.39	0.70	1.00	+0.39	**+10%***
Group totals	8.2	3.6	10.1	10.8	11.3	10.1	2.85	9.02	0.32	0.71	1.00	+0.95	**+14%***
Amphibian totals	13.4	10.4	15.0	16.8	18.1	18.7	3.14	15.40	0.20	0.95	1.00	+1.47	**+13%***

[1]Number per trapping are rounded to the nearest 0.1. There were a total of 15 trappings counted in 1993, 14 in 1994, 18 in 1995, 17 in 1996, 12 in 1997, and 18 in 1998. Trappings counted were on those nights when at least two of the three traps were opened under appropriate weather conditions for amphibian movement.

[2]Standard deviation and coefficient of variation are generated from the data shown except for American toad. For American toad the standard deviation is generated from the residuals of a linear regression. For American toad only the standard deviation of the residuals is then used to generate the coefficient of variation.

[3]Power is determined through the use of the Monitor.exe freeware program using linear regressions (with an alpha of 0.10). The power shown is the power to detect a 5% annual decline with either six or ten years of data.

[4]Trends are taken from a linear regression. Annual change is shown in individuals per trap-night. Percentage of change is based on the percent of the starting population and rounded to the nearest whole number.

Standard deviation and coefficient of variation

The standard deviation of the means of the annual counts varies from a low of 0.15 for Northern two-lined salamanders to a high of 1.65 and 1.95 for Redback salamanders and Wood frogs respectively. Part of this difference is the result of the size of the indices generated (number caught). Consequently it is desirable to use a statistic that takes the mean number caught into consideration. The coefficient of variation (CV) does this. It is defined as the standard deviation divided by the mean. Given the data generated at Mt. Mansfield so far, the species that are the easiest to reliably monitor at these three fences (lowest CVs) are the Eastern newt (0.17), Spotted salamander (0.25), and Wood frog (0.39). The American toad also had a very low CV (0.17), but it was generated differently. In its case the standard deviation was generated by the residuals of a linear regression since it was showing such a large and steady annual increase in the numbers caught. Those species which are caught in very low numbers with an occasional spike showed a very high coefficient of variation: Dusky salamander (0.92) and Pickerel frog (1.37). These two species are therefore hard to monitor with any sensitivity at these fences.

Salamanders

Since most data plots most closely fit a linear regression, the average annual percent change for each species or group is based on a percentage of the starting index. The apparent decreasing trend (-1%) in Spotted salamander numbers shown over the last six years (Figure 1) is so small that I can not say with confidence that any trend actually exists, despite the relatively high power to show trends with this species. The Redback salamander index shows an apparent annual increase of 36% over the past six years. However, due to a very low starting index, the power to reliably detect a 10% annual increase is very weak, and the power to detect larger annual increases is not generated by the Monitor.exe program. Therefore, it is unclear how powerful the data are for this species. If the 1993 data are ignored and only the last five years of data are considered, a linear regression shows a 10% annual increase starting from a large enough population to generate a power greater than 90%. Although the Northern two-lined salamander index shows a 12% annual decrease within the limits of power designated (90%), it is based on such low annual catches that I am skeptical of its reliability. Figure 2 shows how much this apparent trend is influenced by the very high numbers caught in the first year of monitoring. I have more confidence in the 3% annual increase in the Eastern newt (Figure 3) and the 11% increase in salamanders overall (not graphed). No trends are listed in Table 3 for either Dusky or Spring salamander. Since they frequent other microhabitat types, neither of these species has been caught often enough to reliably monitor.

Frogs

Clearly I started monitoring at a low point in the American toad population at this site (Figure 4). The 167% annual increase in the index for this species fits a linear regression very well, $R^2 = .943$. The power of these data to detect any increase over 9% annually is 100 percent. It should be kept in mind that this increase is such a large percentage because it is based on a very small starting population. Still, it is the clearest and most impressive trend of all the species monitored. Although the trend of an 11% annual decline in Spring peepers is reliable, this species showed a large increase in 1998 (Figure 5), and the six-year decline could quickly disappear if capture numbers continue to increase at the same annual rate another year. The reverse is true for Wood frogs (Figure 5). Although their index has shown a 10% average annual increase over the past six years, it dropped precipitously in 1998, and another year of decline could easily even out the six-year trend. Although the graph for Green frogs suggests a pretty clear trend (Figure 3), the low starting population weakens the power to an unacceptable level this year. No trends are listed in Table

3 for either Gray treefrog or Pickerel frog. Due to their climbing ability it is unlikely that Gray treefrogs will ever be caught often enough to monitor. Pickerel frogs, however, are easily caught in the fences and once generated the relatively high index of 1.1 in 1995. Their erratic numbers at these fences generates such a high CV that at present no reliable trends can be shown. The indices for all frogs combined and all amphibians combined (not graphed) show an average annual increase over the last six years of 14% and 13% respectively.

Summary

The majority of amphibian species which can be reliably monitored at these fences at this time appear to be increasing in population. American toad shows the largest and most consistent increase. The apparent declines of two species (N. two-lined salamander and Spring peeper) are not yet convincing and would appear to be easily reversed. Pickerel frog disappeared entirely from the fences for the second time in six years. An apparent increase in the number of malformities needs to be watched. The statistical power of the data gathered over the past six years has been evaluated for the first time and shows that the data for six species and both species groups has reached acceptable power goals already. Each additional year of monitoring adds additional power to the evaluation of trends, as well as generating a great deal of other information such as average and maximum sizes, types and percentages of malformities, seasons of activity, and timing of metamorphosis which can then be added to the Vermont Reptile and Amphibian Database. Next year it will be very interesting to see whether Pickerel frog has reappeared, at what rate malformities continue to be found, and whether the apparent trends in these species continue.

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