BIRDS AS MORTALITY AGENTS OF THE INTRODUCED PINE
SAWFLY, <u>DIPRION</u> <u>SIMILIS</u> (HARTIG), COCOONS

A Thesis

by

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ABSTRACT

Birds as Mortality Agents of the Introduced Pine Sawfly, *Diprion similis* (Hartig), Cocoons

(August 1982)

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Birds were studied as mortality agents of prepupae of the Introduced Pine Sawfly, *Diprion similis* (Hartig), during an outbreak in Avery County, North Carolina. Cocoons were collected from five study plots of Eastern White Pine over a one year period and analyzed for bird predation. Of the total sample size of 33,840 sawfly cocoons collected, 29.6% were predated by birds, making them a major mortality factor. Black-capped and Carolina Chickadees and the Tufted Titmouse were found to be the three principle avian predators of sawfly cocoons.

Data analysis of the collected cocoons indicated the percent avian predation did not vary with the time of the year. Variations in predation rates on cocoons within the five plots were partially explained by bird movement within the study area. One white

pine plot which was surrounded by hardwoods had very high avian predation, suggesting the importance of the combined habitats of pines and hardwoods to insectivorous birds.

Suggestions for pest management by inducing insectivorous birds to nest within forest areas and other possibilities for habitat improvement were made.

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INTRODUCTION

There are many insectivorous bird species which have received attention due to their apparent role as mortality agents of forest insect pests (Coulson et al., 1979). As a result of the increased understanding of the complex interactions within forest systems, the roles of vertebrate predators as controlling factors in large scale insect outbreaks is now better recognized. Otvos (1979) stated birds act as direct mortality agents of insect pests, as well as having the capability of indirect control.

The Introduced Pine Sawfly, *Diprion similis* (Hartig), has been in North America for nearly 60 years (Coppel et al., 1974) and is recognized as a major defoliator of the Eastern White Pine, *Pinus strobus* (Linnaeus). In 1977 this insect was discovered in Avery County, North Carolina (Drooz et al., 1979) and because of its potential extensive larval defoliation it was recognized as posing a serious threat to an important component of the Southern Appalachian forest (Ghent and Mitchell, 1980).

By the year 1980 *Diprion similis* had been detected in two distinct outbreaks, covering 1,947,000 hectares in North Carolina, Tennessee, and Virginia (Ghent and Mitchell, 1980). Severe defoliation of Eastern White Pines could be observed in Avery and Burke Counties of

North Carolina during the spring and summer of 1980. Data collected by the U. S. Forest Service in 1978 showed the total insect parasitism of the sawfly was less than one percent, suggesting that little natural control of the insect was occurring.

The complete life history of the sawfly is well described for Wisconsin by Coppel et al. (1974). Generally, eggs begin to appear in May, with the first generation larvae being found up through July. Second generation larvae appear in July through mid-August. Cocoon spinning by the second generation is usually complete in September. The inactive prepupal larvae passes the winter in the cocoon stage. Coppel et al. (1974) states that the natural mortality during the cocoon stage is of primary significance in the limitation of sawfly populations. This study focuses upon the inactive prepupal lifestage.

The seasonal history of the pine sawfly in Avery County was worked out in 1980 by Huber (1981). Three peaks of adult emergence were noted, the first two being first generation adults while the third was the second generation adults. By the end of September all sawfly larvae had spun cocoons. The USDA Forest Service, Division of Pest Management, initiated experimental studies designed to control the sawfly outbreak by biological means. The role of avian predators as potential mortality agents was seen as a necessary part of this project.

This study was conducted under the auspices of the Forest Service, through their office in Asheville, North Carolina, and their parasite rearing laboratory in Linville Falls, North Carolina.

The objectives of the study were:

1. To determine which avian species preyed upon cocoons of *D. similis* using field observations.
2. To identify all avian species found within the study area.
3. To examine data taken from collections of *D. similis* cocoons from five study plots to determine the significance of birds as mortality agents.
4. To utilize all data collected to determine which avian species may be important predators of *D. similis* cocoons and to suggest steps in the management of these species.

REVIEW OF THE LITERATURE

Birds can seldom be depended upon, unaided, to rid us of insect pests (Ainslie, 1930). There are, however, many instances in the literature which suggest that birds in many cases play a very significant role in forest pest management. Otvos (1979) has stated that insectivorous birds play an important role in the population dynamics of many forest insect pests, especially those at low to moderate population levels.

Few quantitative studies on the importance of birds as mortality agents have been done (Otvos, 1965). There are examples in the literature of avian predation upon various insects, with little, however, on the Introduced Pine Sawfly. Bark count analysis indicated that woodpeckers were an important factor in the control of the Codling Moth, *Carpocapsa pomonella* (Linnaeus), in apple orchards in Nova Scotia (MacLellan, 1958). In a study the following year MacLellan (1959) found that woodpeckers find over 50% of the overwintering Codling Moth larvae on tree trunks. He concluded from this that woodpeckers were effective predators against the pest. Knight (1958) stated that the Downy Woodpecker, *Picoides pubescens* (Linnaeus), and Hairy

Woodpecker, *Picoides villosus* (Linnaeus), have been recognized for years as a major factor in the reduction of Englemann Spruce Beetle, *Dendroctonus engelmanni* (Hopkins). Four species of woodpeckers were found to be predaceous on the Western Pine Beetle, *Dendroctonus brevicomis* (LeConte), in California (Otvos, 1965).

Woodpeckers, nuthatches, creepers, chickadees, and wrens were thought to be among the most important predators of overwintering arthropods in our forest (Jackson, 1979). Ninety five percent of *D. similis* cocoons found on trees above the snow line in Wisconsin showed signs of predation by overwintering birds (Coppel and Sloan, 1970). The Black-capped Chickadee, *Parus atricapillus* (Linnaeus), and Downy Woodpecker were found to be the most important predators of *D. similis* cocoons in Wisconsin (Coppel et al., 1974). A decline of 23.5% during the winter in Larch Casebearer, *Coleophora laricella* (Hubner), populations were attributed to birds by Sloan and Coppel (1968) while a later work showed a significant reduction in the Larch Casebearer population due to the activity of overwintering birds (Coppel and Sloan, 1970).

There are some evidences of a minimal role played by birds during insect outbreaks. Morris et al., (1958) concluded that the effects of birds and mammals on a Spruce Budworm, *Archips fumiferana* (Clem.), population during the outbreak years was negligible. In a study of this same insect George and Mitchell (1948) estimated the degree of control by birds to be only 3.5 to 7.0%. However, it has been noted that birds feed heavily upon the larvae and pupae of the Spruce Budworm (Dowden et al., 1953) with the waxwings, several warblers, and fringillids being observed as consumers (Mitchell, 1952). Some researchers believe that predators have no effect on prey populations, while others are convinced they are the most important of all mortality factors (Buckner, 1966).

In work done on the Southern Pine Beetle, *Dendroctonus frontalis* (Zimmerman), Kroll and Fleet (1979) suggest that woodpeckers are the greatest single mortality agent operating in the Southern Pine Beetle-timber complex. Downy and Pileated, *Dryocopus pileatus* (Linnaeus), Woodpeckers were discovered to be eight to 58 times more abundant within infestated areas than in noninfestated areas (Kroll et al., 1974). This suggests a numerical response on the part of the birds.

Similarly, during an extreme outbreak of a bark beetle, *Dendroctonus engelmanni*, woodpecker populations increased drastically due to food availability (Yeager, 1955). It is suggested that avian predation represents only one component of a complex array of mortality agents associated with the bark beetle community (Coulson et al., 1979). Dahlsten and Copper (1979) found that nesting boxes increased the populations of Mountain Chickadees, *Parus gambeli* (Ridgway), during an outbreak of Douglas-fir Tussock Moth, *Orgyia pseudotsugata* (McDunnough), while Dahlsten and Herman (1965) found the Mountain Chickadee to be the most effective avian predator of the Lodgepole Needle Miner, *Recurvaria* sp.

It is generally conceded that birds are likely to be important only at low to moderate pest densities, for at high densities their effect is probably overwhelmed by the vast numbers of insects (Buckner, 1966). However, in a study on the Larch Sawfly, *Pristiphora erichsonii* (Hartig), it was found that at a high pest density more species of birds and a larger proportion of each bird population fed on the sawflies, especially thrushes, finches, grosebeaks, woodpeckers, and jays (Buckner and Turnock, 1965). One of the

reasons suggested for the inability of birds to control insect populations at high outbreak densities is the obvious vast differences in reproductive potential of insects compared to birds, amounting to several thousand-fold increases for insects as contrasted to a rare twelve-fold for birds (Otvos, 1979).

MATERIALS AND METHODS

This study was divided into two parts, collection and classification of cocoons and avian predator identification.

Cocoon Collections and Classifications

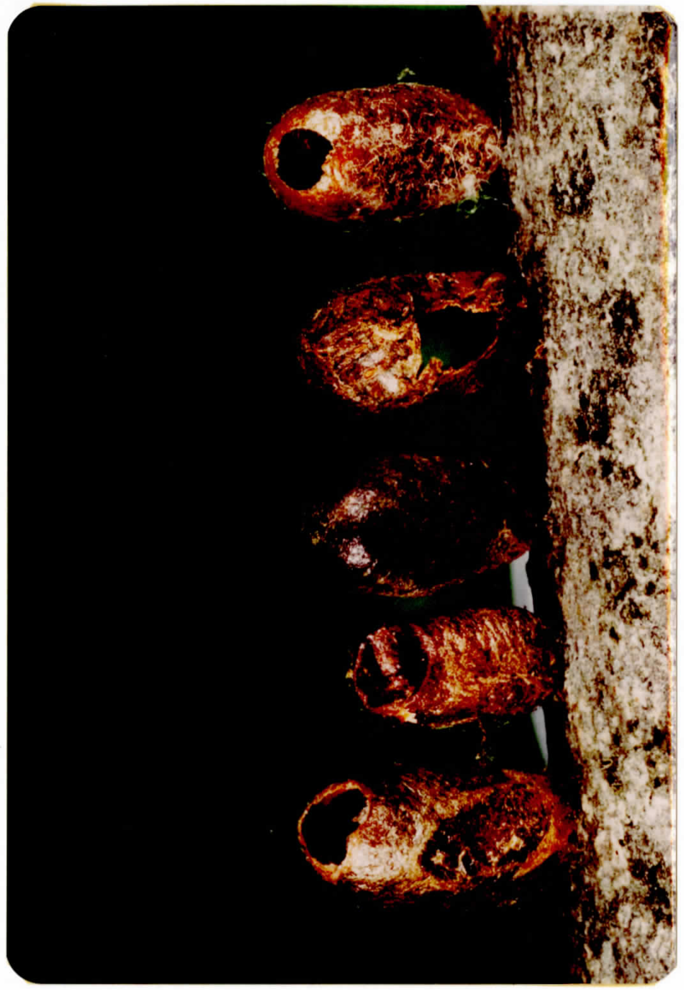
Five sample plots of Eastern White Pine were used in the collection of *D. similis* cocoons. The plots were chosen to represent various conditions of pine stands in the area, e.g. young stands versus old stands, large versus small, isolated versus open. The plots ranged in size from .08 hectare to 1.45 hectares. A Ranging Optical Tape Measure 600 was used to measure the plot sizes. The age of the trees varied among the plots, with three having young pines (12-16 years old) whereas two of the plots had older trees (30-50 years). The height of the trees ranged from 20-25 feet in the young stands and 55-85 feet in the older ones. The habitats of the areas surrounding the plots, a necessary consideration when studying bird behavior, were also quite varied. Although the collection method was the same in all the plots, the above differences among the plots made each ecologically unique (see Appendix A).

Cocoons were collected from July 1, 1980 through August 15, 1981 at approximately six week intervals. When cocoon collections began it was necessary to describe the physical condition of each cocoon. Cocoons from which adult sawflies had emerged were easily recognized by the presence of a large circular hole at their terminal end. Those sawfly cocoons which were intact, that is to say with no outward visible signs of emergence or disruption, were also easily recognizable. It was important to determine which type of predators, i.e. birds, rodents, or insects, had attacked the cocoons. Aside from a brief description by Coppel et al. (1974) very little literature has been written on the appearance of sawfly cocoons after vertebrate predation.

It has been determined from other studies that mammals can be important predators of *D. similis* cocoons. Shrews and voles were reported to be important predators of pine sawfly cocoons in Poland by Hardy (1939) while Coppel and Mertins (1977) described rodents of the genus *Peromyscus* as important cocoons predators of the sawfly in Wisconsin, having the ability to climb trees and eat the cocoons off the branches. This same climbing ability was observed in the North Carolina outbreak. Cocoons were fed to *Peromyscus* sp. in a laboratory situation to see what external marks were left after larval extraction. Loose cocoons, as well as some glued to a substrate, were given to the rodent. Approximately 75 cocoons were examined after being attacked. Analysis of these cocoons revealed a rather distinctive appearance. In most cases the rodent was seen holding the cocoon by each end, biting and chewing at the mid section of the cocoon. Quite often a hole would be chewed in each side of the cocoon and the prepupae extracted (Figure 1a.). In virtually all cases the holes left after extraction were very large.

To assist in the bird predation identification "bird logs" were constructed. A small section of tree was used, with stoops being put in by drilling holes and gluing twigs into place. Sawfly cocoons were glued to the logs and they were hung at various heights and locations over a five month period. Examination of these predated cocoons, along with other observations in the pine stands, shed much light on proper classification of the cocoons.

Figure 1a. Examples of cocoons subject to predation. From left to right: (1) bird predation, showing characteristic hole, (2) bird predation, showing puncture hole, (3) cocoon parasitised by *Monodontomerus dentipes*, (4) rodent predation, note holes in both sides of the cocoon, (5) cocoon parasitised by *Exenterus amictorius*.



Bird predated cocoons show three different patterns in their external appearance:

1. Puncture Mark - the most distinctive mark, apparently left as the beak punctures the cocoon and pulls out the larvae (see Figure 1b).
2. Tear and Flap - when a ripping action of the beak is involved during extraction (noted for several species) a portion of the cocoon around the extraction hole is left as a small flap (see Figures 1a and 1b).
3. Single Hole - in many instances a portion of the cocoon, generally a small piece, was removed during extraction, leaving a small hole. The hole normally occurs near the terminal end of the cocoon but may be found at times at other locations. It is frequently not circular but jagged (see Figures 1a and 1b).

There is one insect parasite of the sawfly, *Exenterus amictorius* (Panzer), which leaves a similar hole as it emerges from the cocoon (see Figure 1a). The insect emergence hole is basically circular with a

Figure 1b. Examples of cocoons taken from bird logs showing the various physical appearances of cocoons preyed upon by birds. Note the characteristic puncture mark (center of cluster), hole (left of center), and tear and flap (below right).

slightly jagged edge. Mertins and Coppel (1971) describe it as 2.1-2.5 mm in diameter at the end of the host cocoon. Although similar, it is usually distinctively smaller and more circular than a bird predated hole. Any significant confusion would be minimal since the parasitism rate for this insect was slightly over one percent in 1980 (Ghent and Mitchell, 1980), making it quite uncommon.

Insect parasite emergence holes for the most part were very distinctive. Virtually all those found were made by *Monodontomerus dentipes* (Dalman), which leaves a very distinctive hole (see Figure 1a.). Other emergence holes encountered were from *Dahlbominus fuscipennis* (Zetterstedt) and, as previously mentioned, *Exenterus amictorius*.

Cocoons of the sawfly are tough, cylindrical, silken capsules, averaging 9.3 X 4.9 mm wide for females and 8.0 X 4.1 mm wide for males (Coppel et al., 1974). The size of the cocoons made them easily recognizable on trees and other substrates. The preferred sites for cocoons appeared to be needle bases, bases of small twigs, and back crevices of the preferred host, *Pinus strobus* (Huber, 1981). Cocoons could be found on other substrates, ranging from various tree species in close proximity to the infested stands to herbaceous shrubs and flowers under or near the trees.

From five to ten collections were made from each plot during the inclusive period. Of particular significance was the uniform distribution of the cocoons over the plots. This made the choice of where to sample within each plot much less important than if the cocoons had a different kind of distribution. A preselected unbiased set of samples were chosen in each plot, from which no less than 250 cocoons were collected. Cocoons were collected both low (within arm's reach) and high (up to a maximum of 25 feet) using an extendable pruning hook, with every effort being made to obtain equal numbers of cocoons from both areas. Cocoons were collected regardless of appearance using no selectivity. Virtually all cocoons were taken from *Pinus strobus* and on rare occasions from *Cornus*, *Betula*, and *Rubus*.

Originally, five categories of cocoons were established:

1. Normal Emergence - those cocoons which showed normal *D. similis* emergence holes.
2. Viable - cocoons which were intact, with no external evidence of damage or disruption.
3. Avian Predated - cocoons which showed external evidence of bird predation.
4. Apparent Parasitism - cocoons which had external evidence of insect parasitism.

5. Miscellaneous - those cocoons which were obviously attacked by rodents and those which would not reliably fall into the other four categories.

The percentage of the sample for each category was calculated.

For the purpose of comparing the effects of predation versus no predation the categories were combined as follows:

1. No Apparent External Predation - this is the total of Normal Emergence and Viable cocoons.
2. Apparent External Predation - the total of Avian Predated, Apparent Parasitism, and Miscellaneous cocoons.
3. Avian Predation Only - cocoons showing external evidence of bird predation.

All data collected were in percentages, consequently they were normalized using arcsine transformation. One-way analysis of variance (Anova) and regression analysis were done.

Predatory Bird Identification

Birds were identified using both visual and auditory means, with problem birds being identified using the

following texts: Robbins et al., 1966, Bull and Farrand, 1977, Pearson et al., 1959, and Peterson, 1980. Binoculars were used for distant viewing.

Species were recorded on each day of field observation as they were seen or heard. Identification was done throughout the study area but more often within the individual cocoon collection plots. Only those birds which were positively identified were recorded. Observations were made approximately twice a week at various times of the day, with an attempt being made to collect data at the times of peak activity for all species. Since this time does differ among various species the observation times can roughly be divided into early and late mornings and afternoons.

A relative frequency of occurrence was calculated for each species according to a method used by Linsdale, (1928). One hundred and six days of field observations (approximately 300 hours) were used to calculate the percent frequency, which consisted of dividing the number of times the species was observed by the number of days of observation. This process was varied slightly within the collection plots, since in many cases they were visited more than once a day. In this case the percent frequency was the number of times the species was recorded within the plot divided by the number of times the plot was visited.

Data collected on observed predatory activity consisted of recording the species, the location, and the date at which the observations were made. Particular attention was paid to the methods of larval extraction by various species. Observations which reflected the general behavioral activities of birds associated with predation were recorded. A relative frequency of predation was calculated using the method described above.

EXPERIMENTAL RESULTS

Cocoon Collection and Analysis

Defoliation of Eastern White Pines was severe in Avery County, North Carolina, during the spring and summer of 1980, indicating a high density of *Diprion similis*. Insect parasitism and vertebrate predation upon sawfly cocoons were salient mortality factors during this time. Through direct field observation of birds preying upon cocoons and through the examination of collected cocoons the extent of bird predation was ascertained.

Observations of avian predation on the sawfly cocoons began at a time of high insect activity. All life stages could be found in the area, with the sounds of frass falling to the ground common in heavily infested places. In an effort to control the infestation a parasitoid augmentation program had been initiated by the Forest Service, resulting in the release of thousands of insect parasites of the sawfly. The collection and examination of sawfly cocoons were used as a possible means of determining quantitatively the effect of avian predation on this life stage of the insect.

Field observations in the spring and summer of 1981 made it clear that a huge reduction in the sawfly population had occurred as a result of natural mortality factors. Data collected by the Forest Service showed reductions of over 90% in sawfly larvae at selected sites which had been monitored during the period 1980 to 1981. Natural control factors had obviously reduced the severity of the infestation.

From the five study plots established (2.52 hectares in total area) a total of 33,840 *D. similis* cocoons were collected. Cocoons taken from the field were classified, based on external appearance, into five different categories; Normal Emergence (Group 1), Viable (Group 2), Avian Predated (Group 3), Apparent Parasitism (Group 4), and Miscellaneous (Group 5). The percentages for each category from the five collection plots over the year is presented in Table 1.

There was a higher percentage of Normal Emergent cocoons, i.e., cocoons from which adult sawflies emerged. There was, however, a greater percentage of cocoons attacked by birds than intact (Viable) cocoons within the area. The Avian Predation percentage of 29.6 suggests that birds were a major factor in sawfly mortality, being much more important than other mortality factors, for example only 2.7% for Apparent Parasitism and 1.0% for Miscellaneous.

TABLE 1. Cocoon Collection Summary

Plot Number	1 Normal Emergence		2 Viable		3 Avian Predated		4 Apparent Parasitism		5 Miscellaneous	
	Number of Cocoons	Percent of Total	Number of Cocoons	Percent of Total	Number of Cocoons	Percent of Total	Number of Cocoons	Percent of Total	Number of Cocoons	Percent of Total
1	2203	38.7	918	16.1	2330	40.9	190	3.3	52	0.9
2	9330	68.3	1798	13.2	2111	15.5	316	2.3	107	0.8
3	4151	58.2	1613	22.6	1029	14.4	267	3.7	70	1.0
4	1569	53.1	651	22.0	523	17.7	132	4.5	80	2.7
Summary Plots 1-4	17253	58.6	4980	16.9	5993	20.4	905	3.1	309	1.0
5	254	5.8	80	1.8	4027	91.5	21	0.5	18	0.4
Summary All Plots	17507	51.7	5060	15.0	10020	29.6	926	2.7	327	1.0

To determine if predation varied more at certain times of the year than others, and to make this analysis clearer, the groups in Table 1 were combined to make two categories; No Apparent External Predation (Groups 1 and 2) and Apparent External Predation (Groups 3, 4, and 5). An additional category of Avian Predation Only (Group 3) was established to look at bird predation exclusively. All percentages were transformed with arcsine transformation, making the data normal (Sokal and Rohlf, 1981), (Appendix B).

The data from all five plots were initially intended to be combined, data from all plots were homoscedastistic (F_{max} = 3.362; $p < .05$), but after considering the data it was obvious that the data from plot five were much different. A t-test comparing the means from plot five to plots one through four in the categories Apparent External Predation and No Apparent External Predation showed significant differences: $t(43) = 2.48$, $p < .02$, $t(43) = 2.49$, $p < .02$. Consequently, the data from plot five were considered independently from the other four plots in these two categories. A t-test run on the Avian Predation Only category showed no significant difference between the

means from plots one through four and plot five: $t(43)= 1.05$, $p>.05$). Data from all five plots were therefore combined for Avian Predation Only and the other data for plot five was not used for further analysis.

In order to determine if the percentage of those cocoons preyed upon varied from month to month during one year, a one-way analysis of variance (Anova) of time in months compared to percent predation was made. For this analysis the year started in the month of October (1980) since this month represented a natural break in the sawfly life cycle. By the month of October all sawflies would be in the prepupae (cocoon) stage within the area. From Table 2 one can see that there was no significant relationship between time and percent predation.

Even though predation over time did not show a trend, the behavior of a particular predator might. Therefore avian predation, being the focus of this study, was analyzed further. One-way Anova was run on avian predation compared to time. As Table 3 shows, there was no significant difference between time and percent avian predation. Consequently, one can conclude that the percent of cocoons preyed upon was not significantly related to the time of the year.

TABLE 2. Analysis of Variance of Predation over Time

Source	ss	df	MSS	F
Between Months	836.224	8	104.528	1.41*
Within Months	2231.559	30	74.385	
Total	2440.615	38		

*p>.05, not significant

TABLE 3. Analysis of Variance of Percent Avian Predation over Time

Source	ss	df	MSS	F
Between Months	799.258	8	99.907	1.12*
Within Months	2675.398	30	89.180	
Total	3474.655	38		

*p>.05, not significant

Since the data were normalized by arcsine transformation, the No Apparent External Predation category is not simply one minus the Apparent External Predation category. Therefore an independent data analysis of the cocoons not preyed upon was made. One-way Anova showed a highly significant difference between time and the percent of those cocoons not preyed upon (Table 4). A significant difference between percent of cocoons not preyed upon over time does indicate differences between months but not necessarily a trend over months. Regression analysis, as shown in Table 5, indicated that although there was a significant difference between the months, a regression line would not account for a significant amount of the variance. Therefore, there is no trend between the percent of those cocoons not preyed upon over time.

In conclusion, the data showed that the percent predation did not vary over time. Even though the cocoons not preyed upon were different over time, the analysis did not indicate a trend.

Avian Predators

Fifty four species of birds were identified in the entire study area. Of this total, 22 (40.7%) were permanent residents, while 32 (59.3%) were migratory.

TABLE 4. Analysis of Variance of Cocoons not Preyed upon over Time

Source				
Between Months	5537.230	8	692.153	17.359*
Within Months	1196.172	30	39.872	
Total	6733.402	38		

*p<.01, highly significant

TABLE 5. Regression Analysis of Cocoons not Preyed upon over Time

Source	ss	df	MSS	F
Between Months	5537.23	8	692.153	17.359*
Due to Regression	200.25	1	200.25	.075
Around Regression	5337	2	2668.5	66.93*
Within Months	1196.172	30	39.872	
Total	6733.402	38		

*p<.01, significant

The percent frequency was calculated for each species. (For entire bird list see Appendix C).

There were ten species of birds observed as predators of pine sawfly cocoons, representing 18.5% of the total bird species. Of the ten species, seven (70%) were permanent residents in the area (Table 6).

Black-capped and Carolina Chickadees are extremely similar in appearance, behavior, and in some cases even song. Both of these species were identified as predators, seen feeding together. It was, however, not possible to always differentiate between the two in the field. For this reason both species were considered together in all quantitative calculations. The chickadees were by far the most frequently encountered birds, with the Tufted Titmouse also common (see Table 6).

The percent frequency within each cocoon collection plot was calculated since the majority of the observations in this study were done at these sites. Species were recorded as they were observed during each visit to the plot. The data for the percent frequency in each plot for the predatory species is presented in Table 7. The chickadees were the most common species in all collection plots. Five of the species were not

TABLE 6. Predatory Birds and Percent Frequency*

Species	Percent Within Entire Study Area
Black-capped / Carolina Chickadees	75.5
Tufted Titmouse	50.0
Blue Jay	34.9
Northern Cardinal	18.9
Solitary Vireo	11.3
Hairy Woodpecker	8.5
Downy Woodpecker	7.5
Chipping Sparrow	6.6
Fox Sparrow	1.9

*Number of days species was observed/total number of days of observation X 100.

TABLE 7. Percent Frequency by Plot of Predatory Birds.*

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Black-capped Carolina Chickadees	42.3	18.8	47.2	66.7	69.2
Tufted Titmouse	26.9	18.8	24.5	34.6	50.0
Blue Jay	34.6	12.5	30.2	14.8	3.8
Cardinal	7.7	12.5	11.3	4.9	18.9
Solitary Vireo	0	0	9.4	1.2	2.5
Hairy Woodpecker	0	0	3.8	2.5	2.5
Downy Woodpecker	0	0	3.8	2.5	4.9
Chipping Sparrow	0	0	11.3	0	3.8
Fox Sparrow	0	0	0	0	3.8

*Number of times species was observed in the plot/number of times the plot was visited X 100.

recorded in plots one and two, suggesting little specificity of these species for these areas. The Fox Sparrow, was seen only in plot number five, and only once, illustrating its migratory habit.

Combining all observations made at the five collection plots gives a total percent frequency for each predatory species. Table 8 contains these data, with all calculations based on a total of 202 visits to the collection plots. As the table shows, the chickadees had the highest total percent frequency at the collection plots of all the species. There were large variations between the total percent frequency of certain species, for example the difference between the two species of chickadees and the Fox Sparrow, indicating a great difference in abundance between these three species. The percentages for the Solitary Vireo, Hairy and Downy Woodpeckers, and Chipping Sparrow illustrate the apparent similarity in frequency throughout between these species.

The percent frequency for the entire study area per month was calculated for each predatory species. A summary of these data is shown in Table 9 (see Appendix D for the complete table of results), showing the months October through March. In looking at these

TABLE 8. Total Percent Frequency in All Collection Plots*

Species	Percent Frequency
Black-Capped / Carolina Chickadees	55.0
Tufted Titmouse	31.7
Blue Jay	19.8
Northern Cardinal	8.4
Solitary Vireo	4.0
Hairy Woodpecker	3.0
Downy Woodpecker	4.0
Chipping Sparrow	3.5
Fox Sparrow	0.5

*Total number of times the species was observed in all collection plots/total number of times collection plots were visited X 100.

TABLE 9. Percent Frequency by Month*

	Black-capped Carolina Chickadees	Tufted Titmouse	Blue Jay	Northern Cardinal	Solitary Vireo	Hairy Woodpecker	Downy Woodpecker	Chipping Sparrow	Fox Sparrow
October (80)	72.7	9.1	63.6	0	0	0	0	0	0
November (80)	66.7	33.3	16.7	0	0	0	0	0	0
December (80)	42.9	42.9	14.3	0	0	0	14.3	0	0
January (81)	83.3	83.3	50.0	25.0	0	16.7	25.0	0	0
February (81)	80.0	20.0	80.0	0	0	20.0	0	0	0
March (81)	75.0	75.0	37.5	25.0	0	25.0	25.0	0	12.5

*Number of times species was observed that month/total number of observations that month X 100.

months the obvious absence of the migratory species, with the exception of the Fox Sparrow, seen only one time during its migration through the area. The chickadees were the most frequent species with the Tufted Titmouse and Blue Jay showing rather large frequencies in certain months. The table shows the variations in frequence from month to month, attributed most likely to the variety of times of day data were collected along with the probable movement in and out of the plots by the birds.

The determination of the principle predators of pine sawfly cocoons was based, in part, on percent predation. Table 10 lists each predatory species, along with its percent predation, calculated using a total of 43 observations of avian feeding. The data reveal quite clearly that the chickadees had the highest percent predation of all species. Both the chickadees and Tufted Titmouse (also with a comparatively high percent predation) are permanent residents in the area, and constitute an important component of the total overwintering bird population.

To see whether or not there was a difference in observed predation at particular times of the year, the number of observations of bird predation per month was calculated (see Table 11). Combining the cold

TABLE 10. Percent Predation of Predatory Species*

Species	Percent Predation
Black-capped / Carolina Chickadees	44.0
Tufted Titmouse	27.9
Blue Jay	2.3
Northern Cardinal	4.7
Solitary Vireo	4.7
Hairy Woodpecker	4.7
Downy Woodpecker	4.7
Chipping Sparrow	4.7
Fox Sparrow	2.3

*Total number of times the species was observed feeding on sawfly cocoons/total number of observations of feeding X 100.

TABLE 11. Number of Observations of Bird Predation by Month

1980						1981							
Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
2	1	1	0	2	0	16	3	5	2	0	3	6	2

months (October-March) and warm months (July-September and April-August) allowed a t-test to be run to determine if a significant difference between these two time frames, in terms of numbers of observations, could be found. Analysis showed no significant difference, ($t(13)=.189$, $p>.05$), between these two periods, suggesting that there is no greater number of observed avian predators in colder months than warmer months. The number of observations of predation in January 1981 was inexplicably larger than any other month. However, with January excluded, the differences between all months must be attributed to chance alone.

DISCUSSION

The severity of the sawfly infestation of Eastern White Pines was drastically reduced in the area over a period of one year (1980-81). This reduction can be partially explained by bird predation. The total sample size of 33,840 cocoons is large enough to estimate the effectiveness of birds as predators of the sawfly cocoons. Of the total number of cocoons collected, avian predation constituted 29.6%, making birds a major mortality factor.

Not all birds were important as predators of sawfly cocoons. The two species of chickadees were by far the most common predatory birds in the study area and study plots. The Tufted Titmouse and Blue Jay were also common compared to the other predatory species. The percent of predation by predatory species quite clearly shows the significant avian predators of *D. similis* cocoons as observed in the field. The chickadees and titmice are permanent residents, being seen commonly throughout the year. The chickadees were observed feeding at virtually all levels of the pines, grasping the cocoon between their feet and ripping and tearing at the cocoon. This activity for the Black-capped

Chickadee was also noted by Coppel in Wisconsin (Coppel and Sloan, 1971). Occasionally the chickadee would remove the cocoon from the branch, extract the larvae, then discard the cocoon, thus making the analysis of this cocoon unlikely. This activity was also noted for the Tufted Titmouse, Blue Jay, and Northern Cardinal. The Tufted Titmouse and Northern Cardinal were seen flying to other areas with cocoons. The Hairy and Downy Woodpeckers moved up larger branches, pecking violently at the cocoons. The clustering of cocoons was very common on the trees, and often chickadees could be seen feeding on an entire cluster, one cocoon at a time. The chickadees and Tufted Titmouse, the three principle avian predators in the area, were major components of the predatory bird populations throughout the year. There is no doubt that sawfly prepupae within the cocoon were an important part of their diets.

Of the vertebrate predators only birds were found to be significant. For example, rodents accounted for only three percent of the cocoons showing evidence of predation, suggesting they had little influence on the sawfly. This is quite different from what was found in studies done in Wisconsin on rodent predation

of *D. similis* cocoons (see Coppel and Mertins, 1977). It is important to note that the parasitism rate calculated in this study was based solely on external appearance of collected cocoons. Data collected by the Forest Service on parasitism rates was done by cutting open intact cocoons and examining their contents. Based on actual emergence of parasites from collected cocoons, parasitism was a minor mortality factor. However, actual emergence of parasites is but one of many evidences of the magnitude of the overall parasitism. In this study of bird predated cocoons it was not determined whether the cocoons had or had not been parasitized.

The variations in percentages in the cocoon collection data for each category at the different plots cannot wholly be explained. It is important to note that this sawfly outbreak was of relatively short duration as compared to other insect outbreaks which have occurred (see Mitchell, 1952; Yeager, 1955; Morris et al., 1958; Knight, 1958; George and Mitchell, 1948). The short duration of the outbreak would not allow any significant numerical response on the part of the birds. Buckner (1966) states that there is an inevitable time lag in any predator prey system.

Since there was not likely any significant increase in populations of particular species in the area there would be no increase in feeding pressure for particular areas. In addition to this, one must take into account that bird populations are continually changing within large areas, or within study plots (Robbins, 1978). The movement of groups of birds, especially in winter when food resources are low, in and out of the individual plots would certainly account for some of the variation in avian predation.

Although variations among the plots is noted, the first four were more similar than that of number five. The avian predation rate was 91.5% of all cocoons sampled in this area, obviously the most important mortality factor acting in this area. Cocoons were attacked in large clusters (see Figure 2) with virtually none left intact. The one major difference between plot five and the others was the extensive hardwood habitat associated with it. Having extensive areas of hardwoods on the perimeter of a plot possibly attracted and helped maintain large numbers of predatory birds.

The percent predation did not vary over time, even though the absolute number of sawfly cocoons available did vary due to the seasonal history of the sawfly

Figure 2. Cluster of *D. similis* cocoons attacked by birds. Both holes and puncture marks can be seen.

and life cycle stages. It would be expected that the percent predation would reflect the numbers of cocoons available, however, this was not the case. The reason for this could be attributed to the probable stability of predatory bird populations, as well as the possibility that the prepupae of the sawfly constituted only a part of the predatory species diet throughout the year.

The use of vertebrates in the biological control of forest insects is as yet in the early stages of development (Buckner, 1966). As this study, and others, have shown, birds may play a potentially important role in insect pest suppression. The development and management of nesting and roosting areas needed to enhance and maintain nongame birds populations should be seen as an important consideration in future integrated pest management decisions.

The principle predators of the Introduced Pine Sawfly in North Carolina are cavity nesting species. To be able to thrive and reproduce in suitable numbers they must have proper habitats available. Conner (1978) and Evans (1978) both have presented management recommendations aimed at nongame bird species. In brief, the recommendations suggest measures which would enhance nesting habitat in a variety of ways, for example: (1) discontinuing the removal of dead and dying trees from the area; (2) create suitable nesting sites by frill girdling trees; (3) keep in mind certain requirements which individual species need, such as basal area of trees, and vegetation density; (4) maintain and enhance the integrity of the ecosystem found in the physical and vegetational features of the landscape. These types of practices would need to be incorporated into land management decisions for the years ahead to be effective.

There is the possibility of habitat manipulation through the use of nesting boxes. Coppel and Mertins (1977) stated that little has been done in North America with regard to nest box usages, simply because most forested areas have no shortage of nesting sites for insectivorous birds. It is reasonable to assume, however, that if particular species utilize nest boxes in the forest that these boxes can aid in enhancing their productiveness as predators in the forest.

The severity of the pine sawfly outbreak in Avery County was somewhat shortlived due to the effectiveness of the biological agents involved. Any attempts to enhance bird populations in the area over the long

term would probably be unnecessary at this point. The sawfly will become less important as a food source as its population dwindles. There is, however, every indication that maintaining proper habitat for the cavity nesting species involved as predators would be highly beneficial both now and during any subsequent serious outbreaks. Nesting boxes should be considered a possible means of keeping the cavity nesters near the areas of severe sawfly activity, by placing them in close proximity to affected pine stands.

In conclusion, the incorporation of steps to establish and maintain a proper habitat for insectivorous birds in future integrated pest management decisions should be seen as highly beneficial during injurious insect outbreaks.

APPENDICES

Appendix A

Detailed Plot Descriptions

Plot Number One

a. Location and Description - found 100 yards off 183 South, one quarter mile from U. S. 221 junction in the Linville Falls Community. The plot was set in a small residential setting.

b. Plot Size - .17 hectare

c. Age of Trees - 12-14 years

d. Height of Trees - 20-25 feet

Plot Number Two

a. Location and Description - one half mile south of U. S. 181 off the Blue Ridge Parkway on rural route two. This plot was set in a semi-residential area with extensive hardwood habitat on three sides.

b. Plot Size - .35 hectare of the total stand size of 2.04 hectares.

c. Age of Trees - 12-15 years

d. Height of Trees - 20-25 feet

Plot Number Three

a. Location and Description - milepost 313.7 on the Blue Ridge Parkway. This plot was relatively open with open field conditions

existing adjacent to the plot. There were 35 mature pines in this plot, all being used to collect the sample. An open field separated several of the trees with a road intersecting a small portion of the plot at one end.

b. Plot Size - .47 hectare

c. Age of Trees - 30-35 years

d. Height of Trees - 55-65 feet

Plot Number Four

a. Location and Description - milepost 316.5 on the Blue Ridge Parkway at the Linville Falls Picnic Area. The plot lies close to the Linville River on one side and is surrounded on two sides by a rather extensive hardwood border. The Blue Ridge Parkway forms the other side of the plot. The area was essentially divided into two sections, an upper and lower, with rather open conditions existing in both.

b. Plot Size - 1.45 hectares

c. Age of Trees - 30-50 years

d. Height of Trees - 45-85 feet

Plot Number Five

a. Location and Description - milepost 318.5 on the Blue Ridge Parkway in a nonresidential setting. This plot was surrounded by extensive hardwood habitats on three sides, with the fourth side being formed by an open field leading to additional hardwood habitat.

b. Size of Plot - .08 hectare of total stand size of .73 hectare

c. Age of Trees - 14-16 years

d. Height of Trees - 25-30 feet

Appendix B

Raw and Transformed Data for Each Plot by Month Sampled

Plot Number One

Month[a]	Conditions of Cocoons								
	No Apparent External Predation			Apparent External Predation			Avian Predation Only		
	No.	%	arcsine	No.	%	arcsine	No.	%	arcsine
1	350	55.6	48.22	279	44.4	41.78	198	71.0	57.42
2	306	53.6	47.06	265	46.4	42.94	249	94.0	75.82
3	424	53.6	47.06	367	46.4	42.94	317	86.4	68.36
4	372	51.0	45.57	357	49.0	44.43	336	94.1	75.94
6[b]	284	41.6	40.16	398	58.4	49.84	375	94.2	76.06
7	172	62.5	52.24	103	37.5	37.76	96	93.2	74.88
9	305	55.6	48.22	244	44.4	41.78	233	95.5	77.75
10	350	66.3	54.51	178	33.7	35.49	174	97.8	81.47
11	470	59.4	50.42	191	40.7	39.64	176	92.4	74.00

[a]Months started with October 1980, although the first sample was in July 1980 and the last in August 1981.

[b]In missing numbers of months, no samples were taken.

Plot Number Two

Month[a]	Conditions of Cocoons								
	No Apparent External Predation			Apparent External Predation			Avian Predation Only		
	No.	%	arcsine	No.	%	arcsine	No.	%	arcsine
1	1167	92.0	73.57	101	8.0	16.43	70	69.3	56.35
2	1203	74.5	59.67	411	25.5	30.33	344	83.7	66.19
3	1173	81.6	64.60	265	18.4	25.40	238	89.8	71.37
4	1166	80.9	64.08	276	19.1	25.92	243	88.0	69.73
6[b]	982	71.8	57.92	385	28.2	32.08	311	80.8	64.01
7	1207	75.7	60.47	387	24.3	29.53	303	78.3	62.24
9	889	79.9	63.36	223	20.1	26.64	206	92.4	74.00
10	1287	86.2	68.19	206	13.8	21.81	182	88.3	70.00
11	1027	88.2	69.91	145	12.6	20.79	107	78.7	62.51

[a]Months started with October 1980, although the first sample was in July 1980 and the last in August 1981.

[b]In missing numbers of months, no samples were taken.

Plot Number Three

Month[a]	Conditions of Cocoons								
	No Apparent External Predation			Apparent External Predation			Avian Predation Only		
	No.	%	arcsine	No.	%	arcsine	No.	%	arcsine
1	652	71.0	57.42	266	31.0	33.83	158	66.6	54.70
2	508	80.6	63.87	122	19.4	26.13	111	90.1	71.66
3	583	84.6	66.89	106	15.4	23.11	55	51.9	46.09
4	566	79.3	62.94	148	20.7	27.06	106	71.6	57.80
6[b]	490	76.7	61.14	149	23.3	28.86	136	91.3	72.84
7	458	80.0	63.44	114	20.0	26.56	84	73.7	59.15
9	571	81.2	64.30	132	18.8	25.70	87	65.9	54.27
10	818	83.9	66.34	157	16.1	23.66	135	86.0	68.03
11	545	84.5	66.81	101	15.6	23.26	79	75.1	60.07

[a]Months started with October 1980, although the first sample was in July 1980 and the last in August 1981.

[b]In missing numbers of months, no samples were taken.

Plot Number Four

Month[a]	Conditions of Cocoons								
	No Apparent External Predation			Apparent External Predation			Avian Predation Only		
	No.	%	arcsine	No.	%	arcsine	No.	%	arcsine
1	248	73.2	58.82	91	26.8	31.18	67	73.6	59.08
2	220	84.6	66.89	40	15.4	23.11	27	67.5	55.24
3	231	77.3	61.55	68	22.7	28.45	29	42.6	40.74
4	154	59.0	50.18	107	41.0	39.82	72	67.3	55.12
6[b]	250	71.6	57.80	99	28.4	32.20	78	78.8	62.58
7	308	80.0	63.44	77	20.0	26.56	52	67.5	55.24
9	216	70.1	56.85	92	29.9	33.15	64	69.6	56.54
10	278	73.5	59.02	100	26.5	30.98	84	84.0	66.42
11	315	83.8	66.27	61	16.2	23.73	50	82.0	64.90

[a]Months started with October 1980, although the first sample was in July 1980 and the last in August 1981.

[b]In missing numbers of months, no samples were taken.

Plot Number Five

Month[a]	Conditions of Cocoons								
	No Apparent External Predation			Apparent External Predation			Avian Predation Only		
	No.	%	arcsine	No.	%	arcsine	No.	%	arcsine
4[b]	122	10.4	18.81	1051	89.6	71.19	1041	99.9	88.19
6	79	9.0	17.46	803	91.0	72.54	801	99.8	87.44
7	58	6.4	14.65	843	93.4	75.11	835	99.1	84.56
9	30	4.0	11.54	714	96.0	78.46	707	99.0	84.26
11	45	6.4	14.65	655	93.4	75.11	643	98.2	82.29

[a]Months started with October 1980, although the first sample was in July 1980 and the last in August 1981.

[b]In missing numbers of months, no samples were taken.

Appendix C

Complete Bird List by Percent Frequency

Species	Percent Frequency
Parus atricappilus Black-Capped Chickadee (Linnaeus)	75.5
Parus carolinensis Carolina Chickadee (Audubon)	
Parus bicolor Tufted Titmouse (Linnaeus)	50.0
Sitta carolinensis White-breasted Nuthatch (Latham)	47.2
Corvus brachyrhyncos American Crow (Brehm)	35.8
Cyanocitta cristata Blue Jay (Linnaeus)	34.9
Pipilo erythrophthalmus Rufous-sided Towhee (Linnaeus)	30.2
Turdis migratorius American Robin (Linnaeus)	30.2
Melospiza melodia Song Sparrow (Wilson)	20.8
Richmondena cardinalis Northern Cardinal (Linnaeus)	18.9

Dumetella carolinensis Gray Catbird (Linnaeus)	14.2
Junco hyemalis Northern Junco (Linnaeus)	14.2
Dendroica pensylvanica Chestnut-sided Warbler (Linnaeus)	13.2
Vireo solitarius Solitary Vireo (Wilson)	11.3
Passerina cyanea Indigo Bunting (Linnaeus)	9.4
Seiurus aurocapillus Ovenbird (Linnaeus)	9.4
Picoides villosus Hairy Woodpecker (Linnaeus)	8.5
Picoides pubescens Downy Woodpecker (Linnaeus)	7.5
Contopus virens Eastern Peewee (Linnaeus)	7.5
Spizella passerina Chipping Sparrow (Beckstein)	6.6
Geothlypis trichas Common Yellowthroat (Linnaeus)	6.6

Colaptes auratus Common Flicker (Linnaeus)	5.7
Thryothorus ludovicianus Carolina Wren (Latham)	5.7
Regulus satrapa Golden-crowned Kinglet (Lichtenstein)	5.7
Carpodacus purpureus Purple Finch (Gmelin)	4.7
Mniotilta varia Black and White Warbler (Linnaeus)	4.7
Dendroica caerulescens Black-throated Blue Warbler (Gmelin)	4.7
Quiscalus quiscula Common Grackle (Linnaeus)	3.8
Corvus corax Northern Raven (Ridgway)	3.8
Buteo jamaicensis Red-tailed Hawk (Gmelin)	2.8
Megaceryle alcyon Belted Kingfisher (Linnaeus)	2.8
Vireo olivaceus Red-eyed Vireo (Linnaeus)	2.8

Hylocichla mustelina Woodthrush (Gmelin)	2.8
Sayornis phoebe Eastern Phoebe (Latham)	2.8
Dendroica pinus Pine Warbler (Wilson)	2.8
Spinus tristis American Goldfinch (Linnaeus)	2.8
Agelaius phoeniceus Red-winged Blackbird (Linnaeus)	2.8
Spizella pusilla Field Sparrow (Wilson)	2.8
Cathartes aura Turkey Vulture (Wied)	1.9
Bonassa umbellus Ruffed Grouse (Linnaeus)	1.9
Archilochus colubris Ruby-throated Hummingbird (Linnaeus)	1.9
Ardea herodius Great Blue Heron (Linnaeus)	1.9
Piranga olivacea Scarlet Tanager (Gmelin)	1.9

Sialia sialis Eastern Bluebird (Linnaeus)	1.9
Passerella iliaca Fox Sparrow (Merrem)	1.9
Strix varia Barred Owl (Latham)	0.9
Dryocopus pileatus Pileated Woodpecker (Linnaeus)	0.9
Vireo flavifrons Yellow-throated Vireo (Vieillot)	0.9
Dendroica discolor Prairie Warbler (Vieillot)	0.9
Dendroica coronata Yellow-rumped Warbler (Linnaeus)	0.9
Seiurus motacilla Louisiana Waterthrush (Vieillot)	0.9
Bombycilla cedrorum Cedar Waxwing (Vieillot)	0.9
Sturnus vulgaris European Starling (Linnaeus)	0.9
Tyrannus tyrannus Eastern Kingbird (Linnaeus)	0.9

Appendix D

Percent Frequency by Month of Predatory Species

Month	Percent Frequency of Species								
	Chickadees	Tufted Titmouse	Blue Jay	Northern Cardinal	Solitary Vireo	Hairy Woodpecker	Downy Woodpecker	Chipping Sparrow	Fox Sparrow
July, 1980	100	60	20	30	20	10	10	10	0
August	87.5	50	12.5	12.5	37.5	12.5	0	37.5	0
September	100	28.5	71.4	14.3	0	0	0	0	0
October	72.7	9.1	63.6	0	0	0	0	0	0
November	66.7	33.3	16.7	0	0	0	0	0	0
December	42.9	42.9	14.3	0	0	0	14.3	0	0
January, 1981	83.3	83.3	50	25	0	16.7	25	0	0
February	80	20	80	0	0	20	0	0	0
March	75	75	37.5	25	0	25	25	0	12.5
April	75	50	12.5	25	12.5	0	0	12.5	0
May	33.3	50	16.7	33.3	0	33.3	0	0	0
June	33.3	33.3	0	16.7	16.7	0	0	16.7	0
July	100	87.5	12.5	50	12.5	0	12.5	12.5	0
August	25	25	0	25	0	0	0	0	0

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