W-0034

Snowmobile Effects on Movements of White-tailed Deer: A Case-study

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INTRODUCTION

Snowmobiling has become a very important recreational activity in the northern forested regions of Wisconsin, so that, in recent years, extensive networks of snowmobile trails have been developed. These trails enable large numbers of people to enter areas which formerly were inaccessible to them during the winter months. The effect of this large-scale snowmobile activity on wildlife populations has not been thoroughly investigated. This study was initiated to determine the effects of snowmobile traffic on the winter home-ranges, movements, and activity patterns, of White-tailed Deer (*Odocoileus virginianus*) in northern Wisconsin. Dorrance *et al.* (1975) studied the effects of snowmobiles on White-tailed Deer in Minnesota, and Lavigne (1976) studied the response of White-tailed Deer to snowmobiles in Maine.

During periods of deep snow, Deer* are largely restricted to lowland coniferous swamps that are called 'deer-yards'. In some winters, the Deer are under heavy stress (Dahlberg & Guettinger, 1956; Verme, 1965; Verme & Ozoga, 1971), reducing food-intake, decreasing their metabolic rate, and almost always losing body-weight (Silver *et al.*, 1969; Moen, 1976). Excessive energy-loss could result if the Deer have to run through deep snow, leave areas of good cover and browse, or change their normal periods of activity to avoid disturbance by snowmobiles. This behaviour could adversely affect their winter survival and fawn production.

*'Deer' in this account refers throughout to White-tailed Deer, no other species being involved.—Ed.

METHODS

Study Areas

Two deer-yards, Ghost Creek and Spider Lake, located in the Chequamegon National Forest in north-western Wisconsin, were chosen as study areas. We studied Deer in both yards during February and March of 1973, but restricted our studies to the Ghost Creek yard during February and March of 1974.

The topography in the two yards is gently rolling, and they are heavily forested with the northern lowland and mesic forests of Wisconsin (Curtis, 1959). Mixed conifer swamps composed of White Spruce (*Picea glauca*), Black Spruce (*Picea mariana*), Balsam Fir (*Abies balsamea*), Northern White Cedar (*Thuja occidentalis*), and Black Ash (*Fraxinus nigra*), dominated the lowlands. The upland types consisted of northern hardwood stands with Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), Hemlock (*Tsuga canadensis*), and Yellow Birch (*Betula lutea*); of aspen stands with Aspen (*Populus tremuloides*), White Birch (*Betula papyrifera*), and Balsam Fir; or of pine stands with White Pine (*Pinus strobus*) and Balsam Fir.

A total of 61 White-tailed Deer were trapped with box traps (Clover, 1956) and cannon nets (Hawkins *et al.*, 1968). A radio transmitter was attached as a collar on each doe. In 1973, 5 adult does and 5 doe fawns were so radio-collared at Spider Lake, and 7 adult does and 4 doe fawns were radio-collared at Ghost Creek. In 1974, 15 adult does and 3 doe fawns were radio-collared at Ghost Creek. The radio frequencies were spaced between 52.55 and 53.50 MHz.

TABLE I. *Number of Snowmobiles and Time That Snowmobiles Were Present in the Ghost Creek Yard.*

1973			1974		
Date	*No. of snowmobiles**	*Total time (hours)†*	*Date*	*No. of snowmobiles*	*Total time (hours)*
16/2	7	2.0	2/2	8–27	6.3
17/2	7	2.5	3/2	10–24	1.8
18/2	8	2.5	9/2	13–14	4.2
23/2	8	3.5	10/2	8	2.5
24/2	8	4.5	16/2	7–17	5.3
25/2	7	4.0	17/2	35	1.5
2/3	29	1.0	23/2	11–13	3.7
3/3	15–49	5.5	24/2	26	2.0
4/3	27–31	2.0	2/3	11–18	5.7
10/3	22	1.3			

*The range in numbers indicates that the number of snowmobiles in the area varied during the day.
†Total time during the day that snowmobiles were in the deer-yard. This may have been one continuous period or shorter periods of time separated by times when no snowmobiles were present.

Tracking System

Locations of individual Deer were determined by triangulation from two permanent antenna towers at each study area. The towers were constructed at positions that ensured the greatest angular accuracy. The two towers in each area were approximately 800 m apart and 15 m high. Trees were cleared from an area within a 30-m radius of each tower.

Each tower consisted of a pair of directional Yagi antennas which were connected so that a distinct null signal occurred when the antennas were directly facing a Deer—which then became the third angle in the triangulation which 'fixed' its position. A man stationed in a small house at the base of each tower operated the antennas and recorded locations. The two operators in each study-area were in contact by field telephone, so that readings could be made simultaneously. A location could be obtained every 5 to 6 minutes in 1973, and every 2 to 3 minutes in 1974. Most bearings were accurate to within ± 2°, and the animals used in the experiments were in positions that minimized this error. The tracking system had an effective range of 2.4 km.

Experimental Design

Six parameters were analysed to determine the impact of snowmobiles on the Deer. These were home-range sizes, distances from the snowmobile trail, habitat use, activity periods, long-distance movements, and individual snowmobile–Deer encounters.

In 1973, a 19-km snowmobile trail system was laid out at Ghost Creek but no snowmobiles were run at Spider Lake. Deer at both yards were radio-tracked during 5 days a week from approximately 1300 to 2200 hours. Since it took 5–6 minutes to get one location. and there were 10–11 deer in the two yards, about one location per hour was obtained for each Deer. At Ghost Creek, snowmobiles were run on Friday, Saturday, and Sunday; Thursday and Monday served as controls. Snowmobiles repeatedly travelled the same trail during runs. A complete run took 45 minutes (Table I).

In 1974 we designed the experiment to measure better the reaction of individual Deer. A more extensive trail-system was established, and two-way radios were installed in two of the snowmobiles and at one of the towers. Prior to each test, all radio-collared Deer were located and plotted on an aerial photo. When the snowmobiles arrived, the leader radioed the tower and obtained the location of a radio-collared Deer. He then selected the trail that brought the snowmobiles closest to that individual Deer. The snowmobiles passed and, if the trail permitted, circled the Deer for 15 to 30 minutes. The leader then radioed the tower, selected another Deer, and the procedure was repeated.

Deer were radio-tracked immediately before, during, and after, the snowmobile tests. From various places along the trail, the leader of the snowmobiles also determined the location of the challenged Deer by using a portable receiver. Each set of locations taken before, during, and after, snowmobiling was considered as one encounter. A total of 44 encounters were conducted on 8 different Deer (Table II). In the third weekend of March, a group of 20 cross-country skiers were used in the same manner as the snowmobiles.

In 1973, when snowmobiles ran the entire trail network, the distances between individual Deer and the trail were measured on days without snowmobile tests and before, during, and after, tests. In 1974, when snowmobiles challenged individual Deer, we calculated the mean distance that individual Deer were from the snowmobile trail immediately before the snowmobile test and also during the test. These two means were considered the best estimates of the Deer's location.

Home-ranges were calculated by eliminating the 5% of outermost locations and then drawing the smallest convex polygon which contained all other locations. Any doubtful locations caused by errors in the system were eliminated.

TABLE II. *Summary of Snowmobile–Deer Encounters in 1974.**

Deer No.	*No. of encounters*	*No. of snowmobiles per encounter*	*No. of individual snowmobile passes*	*Total hours snow-mobiling*
65	12	6–35	835	9.0
55	11	8–35	837	9.4
50	10	8–35	414	4.2
40	2	13–23	49	1.0
34	2	8–11	102	1.4
20	4	7–35	175	2.2
10	1	6–11	100	1.0
95	2	8–14	34	0.3

*One encounter is each set of locations taken before, during, and after, snowmobiles made passes near an individual deer.

Deer activity was monitored by the tower operators who recorded whether the animals were moving when their radio-locations were obtained. Movement was indicated by variation in signal strength.

A data analysis programme for plotting Deer locations was written for use with a hybrid computer. The distance moved, home-range size, and centre of activity, of radio-collared Deer, were computed. Successive Deer locations and home-range maps were plotted with an x-y plotter. These plots were superimposed on appropriately-scaled aerial photos, so that total home-ranges and habitat uses could be determined.

RESULTS

Totals of 2,464 locations on 21 animals and 3,896 locations on 16 animals were obtained in 1973 and 1974, respectively. In 1973, after the trapping period, 5 Deer at Spider Lake and 5 Deer at Ghost Creek remained in positions that insured good angular accuracy. Another 2 Deer at Ghost Creek were in good positions during part of the time. In 1974, 6 Deer at Ghost Creek remained in good positions, and 2 Deer were in good positions during part of the time. These 20 animals were used in the analysis.

The Wisconsin Department of Natural Resources calculated a winter severity-index for Deer in northern Wisconsin (Kohn, 1972). This index indicated that both the winters of our study were mild, being the easiest winters for Deer since 1964. The mean weekly snow-depth never exceeded 50 cm (Fig. 1). Deer moved into the yards during December and January of both winters, but in January 1973 an ice-crust which could not support a Deer made travel difficult for Deer. Logging operations began in both yards in early February 1973 and continued until spring, though most Deer remained in the vicinity of these logging operations. In 1974 there were no logging operations and the Deer were never tightly concentrated. During both winters, Deer maintained an extensive trail system throughout the yard and appeared stron and healthy.

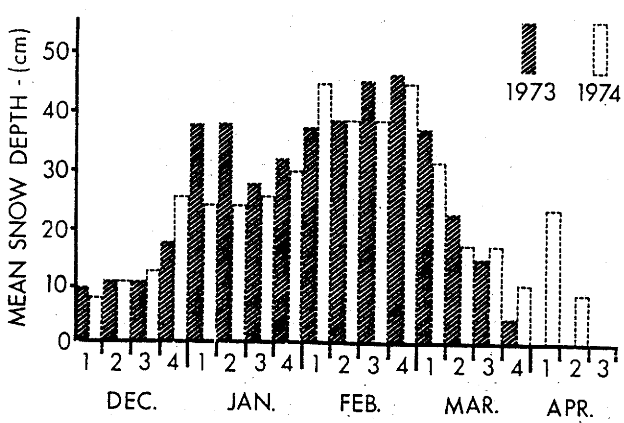

Fig. 1. *Mean weekly snow-depths recorded at the Solon Springs, Wisconsin, weather station.*

Home-Ranges

In 1973, the home-ranges during February and March for the 5 Deer in good positions (*see* above) at Ghost Creek averaged 57.8 ha (varying from 33.2 to 112.5). The home-ranges for the 5 Deer in good positions at the Spider Lake control yard averaged 61.2 ha (varying from 25.1 to 129.5), which was not significantly different ($t = 0.15, P > 0.50$) from the Ghost Creek Deer (Table III). When the locations during and after the snowmobile tests were subtracted at Ghost Creek, the average home-range was 53.8 ha (varying from 31.5 to 112.5), which was not significantly different ($t = 0.31, P > 0.50$) from the control.

Table III. *February and March Home-Ranges in Hectares for Deer in 1973* (sample sizes are in parentheses).

Ghost Creek, 1973		*Spider Lake, 1973*	
Deer No.	*Home-range*	*Deer No.*	*Home-range*
50	38.0 (127)	45	129.5 (202)
40	33.2 (92)	25	25.1 (193)
30	47.3 (141)	15	52.2 (200)
20	57.9 (84)	05	42.5 (95)
95	112.5 (109)	75	56.7 (84)
Mean ± SE	57.8 ± 14.3[a]		61.2 ± 17.9[a]

[a]Not significantly different. $t = 0.15, P > 0.50$.

TABLE IV. *Mean Distances in Metres that the 5 Deer in good positions at Ghost Creek were from the Snowmobile Trails in February and March of 1973, Showing no Significant Effect of Snowmobile Activity in That Year*—though *see* text. (Sample sizes are in parentheses.)

Deer No.	*No snowmobiling* $\bar{X} \pm$ SE	*During snowmobiling* $\bar{X} \pm$ SE	*After snowmobiling* $\bar{X} \pm$ SE	F* *value*	P
50	134.7 ± 8.5 (79)	114.6 ± 15.8 (29)	122.8 ± 14.9 (19)	0.785	>0.25
40	135.0 ± 14.3 (44)	152.4 ± 18.0 (27)	141.7 ± 19.5 (17)	0.298	>0.25
30	59.1 ± 4.6 (69)	85.0 ± 8.2 (33)	115.2 ± 11.3 (20)	14.600	<0.0005
20	165.2 ± 9.8 (73)	200.9 ± 14.6 (23)	214.9 ± 23.8 (13)	3.201	<0.05
95	199.9 ± 20.4 (63)	233.2 ± 20.4 (29)	193.2 ± 17.1 (24)	0.731	>0.25

*One-way analysis of variance.

Distance from the Trail

Locations of the same 5 Deer in good positions during snowmobile tests at Ghost Creek were compared with their locations before and after the tests in 1973 (Table IV). A one-way analysis of variance accepted the hypothesis ($P > 0.25$) that there were no significant differences in the mean distances between individual Deer and the snowmobile trail before, during, or after, snowmobile tests for 3 of the 5 Deer tested. However, it rejected this hypothesis ($P < 0.05$) for the other 2 Deer. The mean distance which these 2 Deer were from the snowmobile trail was much greater after snowmobile tests than before them.

Habitat Changes

To determine whether Deer sought the more densely-vegetated habitats when snowmobiles were present, we used a chi-square analysis to compare the habitat types preferred by Deer during snowmobile tests with those used when snowmobiles were absent. No significant differences ($P > 0.25$) in habitat use were detected in 1973 (Table V).

In 1974 we analysed habitat use before, during, and after, each snowmobile encounter. We found a change in habitat during 13 of the 43 encounters, but in only 6 of those 13 encounters did the Deer move into denser cover when snowmobiles were present (i.e. from Aspen or Sugar Maple into Balsam Fir or mixed conifers).

Activity Periods

Activity data from the tracking towers were analysed for 33 Deer (5,859 locations) during the 2 winters. Table VI summarizes these data. In 1973, activity data for Deer at Ghost Creek and Spider Lake were compared, to determine whether snowmobile traffic altered deer activity. The chi-square test for differences in probabilities showed that the distributions of activity patterns were not significantly different ($P > 0.25$) for the 2 yards. In addition, the activity patterns at Ghost Creek on days when snowmobiles were present were no different ($P > 0.05$) from activity patterns when snowmobiles were absent.

In 1974 the hypotheses was rejected ($P < 0.001$) that the distributions of activity patterns were the same

TABLE V. *Percentage of Locations in Various Habitat Types for the 5 Deer in Good Positions at Ghost Creek in 1973* (sample sizes are in parentheses).

Habitat type	*Without** *snowmobiles*	*During** *snowmobile tests*
Logging operation	50.3 (293)	54.7 (75)
Balsam Fir–White Pine	24.5 (143)	24.9 (34)
Aspen–Balsam Fir	13.0 (76)	10.1 (14)
Northern hardwoods	3.4 (20)	3.7 (5)
Other	8.8 (51)	6.6 (9)

*Distributions not significantly different. $\chi^2_{(4)} = 1.79, P > 0.25$.

on days when snowmobiles were present as when they were absent. Individual tests for hourly intervals showed that the proportion of moving locations for the hours between 1900 and 2200 was significantly higher ($P < 0.001$) when snowmobiles were present than when they were absent. But as indications of deer activity were based on variations in strength of signals, it is not known whether the indicated change in activity was due to the animals actually walking around or merely moving their heads while lying down.

Long-distance Movements

Long-distance moves and shifts in areas of intensive use were exhibited by 11 Deer during the study. Four other Deer moved to positions which were more than 1.6 km away shortly after they were trapped, but before snowmobile tests started. These 4 Deer were not intensively radio-tracked.

During the winter of 1973, 4 radio-collared Deer made long-distance moves at Ghost Creek. Two of these Deer inhabited both the area of the logging operation and a conifer swamp 1.2 km away. Moves between these two areas occurred both on days when snowmobiles were present and on days when snowmobiles were absent. However, one of these 2 Deer moved 1.6 km to a previously unused area during snowmobile tests, only to return to the trail system while snowmobiles were still operating. Another of the 4 Deer moved over 305 m straight away from the snowmobile trail during snowmobile tests but returned to the area of the trail system on the next day. The fourth Deer used one area from 12 to 22 February, then moved 1.6 km away to a new area

TABLE VI. *Deer Activity as Determined by the Percentage of Radio-locations per Hour that Indicated Movements.*

Period of Day (hours)	*Percentage of moving locations* (sample size in parentheses)					
	Spider Lake	*Ghost Creek*				
	1973[a] without sm	1973[a] with & without sm	1973[b] without sm	1973[b] with sm	1974[c] without sm	1974[c] with sm
9–10					44 (129)	25 (8)
10–11					43 (136)	41 (49)
11–12	50 (26)	60 (10)			51 (146)	53 (34)
12–13	68 (26)	60 (10)			34 (53)	
13–14	88 (33)	63 (49)			47 (182)	
14–15	66 (64)	72 (65)			56 (306)	54 (84)
15–16	65 (97)	77 (81)	75 (56)	80 (25)	52 (449)	58 (31)
16–17	79 (116)	76 (115)	71 (96)	100 (19)	46 (487)	53 (43)
17–18	89 (119)	77 (128)	71 (97)	97 (31)	47 (409)	
18–19	65 (116)	49 (136)	43 (106)	73 (30)	49 (342)	
19–20	29 (117)	23 (128)	17 (102)	39 (26)	28 (388)[d]	71 (21)[d]
20–21	26 (125)	15 (161)	14 (148)	30 (13)	14 (395)[d]	34 (92)[d]
21–22	38 (78)	35 (105)	32 (91)	57 (14)	2 (84)[d]	25 (28)[d]
22–23	54 (52)	52 (77)				
23–24	62 (13)	60 (15)				
No. of deer	8	9	7	7	16	16

sm = snowmobiles

a, b Distributions not significantly different. $\chi^2_{(12)} = 13.8$ and $\chi^2_{(6)} = 7.4$, $P > 0.25$.

c Distributions significantly different. $\chi^2_{(8)} = 94.2$, $P < 0.001$.

d Significantly different proportions $\chi^2_{(1)} = 18.0, 18.7, 14.5$, respectively. $P < 0.001$.

and remained there until 21 March when it moved out of the tracking system's range.

At Spider Lake, a Deer spent 22 February to 19 March 1973 in the logging operation. On 20 March it shifted to another logging operation 1.2 km away and remained there until radio-tracking ended. Two other Deer at Spider Lake regularly moved between the logging operation and a conifer swamp 1.6 km away.

Four Deer at Ghost Creek in 1974 made regular shifts within areas of intensive snowmobile use. These moves could not, however, be related to snowmobile activity or to our presence. Shifts in areas of intensive use were a common part of winter activity for some Deer. However, other Deer did not move even when snowmobiles were very close. During one night-time encounter in 1974, 2 radio-collared Deer did not move from a location that was 43 m from the trail while 10 to 20 snowmobiles circled them 6 times during a 45-minutes period. In a daytime encounter, 3 other Deer were observed feeding 69 m from a trail and then lay down while 8 snowmobiles made 7 passes on the trail. These 3 Deer immediately left the area when we stopped the snowmobiles and began to approach them on foot.

Snowmobile–Deer Encounters

Forty-three snowmobile–Deer encounters involving 8 Deer were analysed to determine the number of encounters in which individual Deer moved distances of at least 23 m* closer to or farther from the snowmobile trail than they had previously been. The locations of 8 Deer before snowmobile tests were compared with their locations during snowmobile tests. If the Deer did not move more than 23 m, we recorded no change in location.

The Deer were within 61 m of the trail during 21 of the 43 encounters. Of these 21 encounters, the Deer in 11 encounters moved away but in 10 encounters the Deer remained in effectively the same position during snowmobile tests. Of the 22 Deer encounters beyond 61 m, the Deer in 5 encounters moved farther away from the trail; in 9 encounters the Deer did not change position, and in the remaining 8 encounters the Deer moved closer to the trail. Deer were most affected by snowmobiles when they were within 61 m of the trail.

When Deer moved away from the trail, it was to an average of 70 m from the trail before snowmobile tests and 135 m from the trail during such tests. When Deer moved closer to the trail, it was to an average of 142 m from the trail before snowmobiling and 71 m from the trail during snowmobiling.

Time of day played an important part in the movements of Deer. The locations of deer before snowmobile tests were compared with their locations during snowmobiling for night-time and day-time encounters in 1974. Deer moved away from the trail in 14 of 27 day-time encounters and in 2 of 14 night-time encounters in spite of the fact that they averaged 59 m from the trail at night and 93 m from the trail during the day. When cross-country skiiers replaced snowmobiles on the trail system, radio-collared Deer were encountered 11 times and were always within 152 m of the trail. In 7 out of 8 day-time encounters, Deer moved away from the trail, but they did not move away from the trail in 2 of the 3 night-time encounters when skiiers were within 30 m of the Deer.

*In answer to our query, Professor Rongstad replied (in litt. 2 January 1979), 'The 23 m was used because this was a distance that we were sure of detecting with the tracking system.'—Ed.

DISCUSSION

Snowmobile impact on Deer was significant in only 2 of the 6 parameters which we studied. In 1973, 2 out of 5 Deer were significantly farther from the snowmobile trail on days when snowmobiles were present and, in 1974, intensive snowmobiling caused a significant increase in Deer activity (Table VI) during a normally inactive period between 1900 and 2200 hours.

Dorrance *et al.* (1975) found a significant negative correlation between the numbers of White-tailed Deer seen along a trail and the numbers of snowmobiles using the area. In 1973 we found an initial disturbance of Deer as snowmobiles ran the trails for the first time on a specific day. It was common for the lead snowmobiler to spot from 20 to 25 Deer during the first run through the trail network but to see no more than 6 or 7 Deer on subsequent runs. In 1974 some Deer, particularly those within 61 m of the snowmobile trail, reacted by moving at least 23 m away from the trail.

Lavigne (1976) reported that the number of White-tailed Deer staying within sight of a snowmobile trail increased as the winter progressed. He believed that this may have been correlated with a progressive weakening of the Deer, decreased activity in midwinter, and habituation to snowmobile disturbances. In our study, displacement from the vicinity of the snowmobile trail was not considered a serious disturbance as activity patterns and habitat uses were not altered.

Dorrance *et al.* (1975) reported 2 Deer moving at least 1.6 km away from a snowmobile trail and attributed this move to the research worker's presence. They concluded that Deer responded to low intensities of human disturbance. We found that some Deer made long-distance movements and that these moves were a common part of the animals' winter activities; they were not caused by our presence.

Lavigne (1976) found that disturbance of Deer by snowmobiles did not cause them to abandon preferred bedding and feeding sites, but observed that deer in heavy cover were less likely to run from snowmobiles than were those in light cover. Likewise, we found no significant differences in overall winter habitat use during snowmobile tests, and no indication that Deer moved into thicker cover during periods of snowmobiling.

The results of our experiments in 1973 indicated that snowmobile traffic had little effect on the overall winter movements of the 5 radio-collared Deer with which we were most concerned (*see* above). One of the main factors in determining winter home-ranges, activity patterns, and habitat use, was the placement and timing of logging operations. Deer probably became accustomed to the noise of machinery and power-saws, and this decreased their reaction to snowmobiles.

Our study confirmed Lavigne's (1976) report that Deer were more likely to move away from people hiking or skiing than from people riding snowmobiles. Our cross-country skiing experiments showed that in 8 of 11 encounters, Deer moved at least 23 m away from the snowmobile trail.

On 2 occasions in 1973, 3 people entered the 18 ha logging operation at Ghost Creek to obtain pictures of radio-collared Deer. Men using power-saws and crawler tractors were felling trees on both days. The logging operation was surrounded on 3 sides by a creek bordered by open areas which permitted easy spotting of any Deer leaving the logging operation. The 3 people spread out and walked slowly through the area. On 7 March, 12 of the 35 Deer present left the logging operation when we approached, and on 8 March 12 of 30 Deer then present left the area. Deer remained close to noisy heavy equipment and men working with power-saws, but moved away when approached silently.

It appeared from these and other observations that White-tailed Deer were more sensitive to the human form than to humans riding snowmobiles or other vehicles. Kabat *et al.* (1953), and Dahlberg & Guettinger (1956), reported that when White-tailed Deer are in poor physical condition, they lose their natural fear of Man. As 1973 and 1974 were mild winters, Deer were probably more wary of disturbances than they would have been in a severe winter.

Lavigne (1976) observed White-tailed Deer running on snowmobile trails ahead of snowmobiles during winters with severely restricted off-trail mobility. He found that 6 Deer, encountered singly, were chased 43–200 m down the snowmobile trail before leaving it. In our study, Deer were never seen running down the trail ahead of snowmobiles, but always moved laterally from the trail. They used the snowmobile trail when it was convenient, but did not seem to prefer it over their own trails. We found that Deer did not follow the snowmobile trail beyond their own trail system.

Moen (1976) recognized that metabolic energy conservation is substantial when White-tailed Deer are able to move at relatively slow speeds, stay on level ground, and avoid deep snow. A snowmobile trail through a 'yard' may conserve energy for Deer by providing an open trail, but any energy saved would be lost if snowmobile traffic was continually forcing Deer to leave the trail. During periods of deep snow, Deer are concentrated in areas with an over-storey of coniferous trees. A snowmobile trail passing through such an area would greatly increase the number of contacts between snowmobiles and Deer.

RECOMMENDATIONS

Snowmobile trail networks and cross-country ski trails should be designed to by-pass traditional, heavily-used deer yards. The trails should be routed away from forest types such as Northern White Cedar, eastern Hemlock, and swamp conifer areas where Deer concentrate during severe weather. Trails should be confined to the upland deciduous forest types.

In this way a minimum of disturbance will occur when Deer are closely concentrated. Sections of snowmobile trails which pass through areas with large concentrations of Deer should be closed when critical winter conditions develop.

ACKNOWLEDGEMENTS

This research was supported by the International Snowmobile Industry Association and the University of Wisconsin's Graduate School, College of Agricultural and Life Sciences, and Engineering Experiment Station. Thanks are extended to the snowmobile companies for loan of snowmobiles and clothing. L. Kerr and his staff at the University of Wisconsin Clam Lake Field Station, G. Curtis, and personnel of the Chequamegon National Forest, were most helpful during the study.

SUMMARY

The effects of snowmobile traffic on the winter home-ranges, movements, and activity patterns, of White-tailed Deer (*Odocoileus virginianus*), were studied during two winters in northern Wisconsin. There were no significant differences in home-range size and habitat use of the Deer in areas with and without snowmobiling. However, snowmobiling caused some Deer to leave the immediate vicinity of the snowmobile trail. Deer were most affected when they were within 61 m of the snowmobile trail.

Daily activity patterns of Deer were little affected by snowmobiles except in one period when Deer were more active between 1900 and 2000 hrs than when snowmobiles were absent. Darkness reduced the reaction of the Deer to a disturbance. Deer appeared to react more to a person walking than a person on a snowmobile. We recommend that snowmobile trails be routed away from areas where deer concentrate during the winter, but feel that, so far as any effect on White-tailed Deer is concerned, the environment is not very seriously changed by the advent of snowmobiles.

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Engineering, Science, and the Environment

During December 1978, three symposia were held in London, England, organized mainly by engineers, in order to discuss environmental issues which result from engineering activities, great and small, that are concerned with economic and social development. (1) The first of these, on 6–7 December, was arranged by the Institution of Water Engineers and Scientists, and was entitled 'Engineering and the Environment: Harmony or Conflict?'. It was held in the Science Society's Lecture Theatre in Saville Row, London. (2) The second symposium, organized by the Institution of Civil Engineers in association with the Royal Society of Tropical Medicine and the International Association for Water Pollution Research, was larger in size, more international in character, and more specific in subject; entitled 'Engineering, Science, and Medicine, in the Prevention of Tropical Water-related Diseases', it occupied the 4 days from 11 to 14 December 1978 and was held at the headquarters of the Institution of Civil Engineers. (3) The third symposium was a one-day meeting, on 15 December, arranged by the World Bank and also held at the headquarters of the Institution of Civil Engineers, its subject being 'Sanitation Project Planning'.

As adviser on environmental matters to Sir William Halcrow & Partners, consulting engineers, who are conducting many development projects connected with water in various countries ranged practically around the world, I was privileged to participate in all these three gatherings. Their organization had been initiated well in advance. Papers had been pre-printed and distributed, and a rather strict time-limit was imposed on authors and discussants. When, however, it came to drawing up conclusions and guidelines for the future, there did not seem to be so much precision; but the main objective of these symposia was well established—namely the dialogue, or rather multilogue, between men and women trained in many different disciplines.

(1) The first of these symposia—the one held by the water engineers—was concerned mainly with conditions in the United Kingdom. The concern was mostly for 'environment impact analysis' which, during recent years, has become a regular feature of new water projects, whether the water was intended for storage, drainage and agricultural use, water supply, or sewerage. Admittedly the need for such analysis adds substantially to the work of the engineer and, while conflict sometimes arises,

harmony is being achieved today more often than disharmony. Of five papers concerned with the UK, three were from engineers, the others being from a sociologist and an applied biologist.

Of the remaining two papers, one was on environmental factors in overseas situations. Examples such as irrigation and water conservation projects in Malaysia and Guyana, the creation of a number of impounding reservoirs in Antigua, and water supplies for rangeland development in the arid lands of Somalia, showed how forward-looking consulting engineers can adapt economic development to environmental constraints. In the last-named example, the dangers were mentioned of providing too many water-points for cattle in arid lands without adequate prediction of their carrying capacity during a succession of drought years.

The final paper was an excellent account of the 'Effects of the National Environmental Policy Act on Water Resources Projects in the USA'. The Corps of Army Engineers, which during approximately the last 200 years has completed more than 4,000 civil works projects, and to which the author of this paper, Dr Grant Ash, is environmental policy adviser, has been much criticized by environmentalists in the past, but latterly has fallen right into line with the comprehensive legislation (NEPA) of 1969.

(2) The second of these symposia was opened, after the formalities, by an introductory paper on 'Engineering, Health, and Policy, in Developing Countries—Some Strategic Issues', by the Director of the Ross Institute of Tropical Hygiene, Dr D. J. Bradley. He pointed out that, following biological research around the beginning of this century which revealed the life-cycles of disease organisms and the part played by vectors, and with particular reference to malaria, prevention became largely an engineering matter. The engineer was central to effective malarial control—by drainage, by level-of-water fluctuations, or by irrigation management and oiling—until just prior to the Second World War. But since 1950 the discoveries of sulphanilomides, DDT, and penicillin, took over, and, in particular, persistent insecticides killed the interest in engineering control of malaria, while the health aspects of domestic water supply and excreta disposal became neglected. Interest in the general environmental aspects of health reached a very low level by 1960, but since then renewed interest in water supply, rural as well as urban sanitation, and environmental means of disease control, have brought the engineer right back into the picture.

This theme was developed further by E. B. Worthington in the next paper to be presented, on some ecological problems concerning engineering and tropical diseases. It was illustrated with the particular examples of *schistosomiasis* and *onchocerciasis,* wherein detailed engineering design to control the flow of water, whether in irrigation schemes or natural streams, could have a major influence on the distribution of the vectors.

In this symposium no fewer than 45 pre-circulated papers were presented and discussed, covering nearly every water-related tropical disease, and with few exceptions they illustrated the need for much closer relations than hitherto between the engineering, biological, chemical, and medical disciplines. Appropriate technology in the supply of water and disposal of waste came to the fore, and the fact that the prevention of disease is a social as well as a medical and engineering problem was emphasized, for example in papers by Gilbert White and R. Shaffer—the latter on the Masai of Kenya. There is no need to elaborate, for this symposium, as also its predecessor, is due to be published in full.

(3) After all this, the World Bank's one-day meeting at the end might have been an anti-climax, but this was not so because it brought in a good deal of new blood among the participants. Thus, in spite of some inevitable repetition, new light was thrown on several key problems. Particularly was this the case in connection with the disposal of human waste, which provides the channel of transmission for many of the water-borne diseases.

Since the United Nations Water Conference of March 1977 in Argentina,* it has become widely recognized that water-borne sanitary systems, which have become almost traditional in the western world and are deeply engrained in much engineering thinking, are often inappropriate in the tropics—especially in arid climates. Such systems are fabulously expensive, use large quantities of what is often the most precious natural resource, and sometimes spread rather than prevent water-borne diseases. It was encouraging, therefore, to hear Dr J. M. Kalbermatten, the World Bank's Water and Waste Adviser, make out the case for other systems of disposal—starting with the simple pit-latrine and its many derivatives, including composting and recycling.

This was by no means the only theme presented by the advisers and consultants of the World Bank, and discussed by a large attendance of diverse specialists. The current attitide of the Bank in grant-aiding development projects all over the world only after a full analysis and prediction of their environmental effects, was well illustrated and enthusiastically approved.

All in all, any scientist or technologist who listened to this series of symposia must have gone away with the thought that an integrated and interdisciplinary approach to the current problems of human needs gives hope for the future.

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*See the account by Dr Worthington published already in our Summer issue of that year (*Environmental Conservation*, 4 (2), pp. 153–4, 1977).—Ed.