ECOLOGY AND MANAGEMENT
OF THE BULLSNAKE,
PITUOPHIS MELANOLEUCUS SAYI
IN THE NEBRASKA SANDHILLS

Final report

Jules J. Fox

July 1, 1986

CONTENTS

INTRODUCTION

Nest predation was long ago recognized as one of the primary limiting factors to the annual recruitment of waterfowl populations (Kalmbach, 1939). Recent studies have indicated that waterfowl nest success is reaching an all-time low in the midcontinent area as nest predation has increased in severity (Cowardin et al., 1983, 1985). Mammals are the principal predators of waterfowl nests in North America (Sargeant and Arnold, 1984). In the Nebraska sandhills however, a somewhat unusual nest predator was discovered that outranks all mammalian predators in this area in terms of nest destructions. This predator is the bullsnake, *Pituophis melanoleucus sayi.*

During the years 1938-1942, waterfowl nesting studies conducted upon the Crescent Lake and Valentine National Wildlife Refuges recorded bullsnakes to be destroying an estimated 35-52% of the dabbling duck nests at these refuges. Current nesting studies at these refuges reveal that bullsnakes are still problem predators, destroying 43% of the nests censused in 1984 (refuge records). With this introduction, the management of bullsnakes in the Nebraska sandhills means just one thing; controlling bullsnake numbers in the waterfowl nesting meadows.

Many techniques have been tried in the past to control snake populations. Fitch (1960) has provided a still-current summary of these techniques which have included bounties, clubbing, shooting, trapping, dynamite, and various poisons. These methods were usually directed toward snakes concentrated in and around communal hibernacula and usually resulted in unsatisfactory control.

The present study of bullsnake ecology and management at the CLNWR was initiated with the primary goal of using radiotelemetry to reveal aspects of the spatial biology of bullsnakes that could be exploited towards the reduction of bullsnake numbers in the waterfowl nesting meadows. Three particular methods were closely examined for their potential to reduce bullsnake numbers in the waterfowl nesting meadows; 1. locating and destroying communal hibernacula, 2. habitat management, and 3. removal trapping.

The preliminary report for this study contained the majority of the descriptive information that was collected for this bullsnake population, as well as the methods that were used during this study and a description of the study area. This final report begins with a general description of the utilization of the waterfowl nesting meadows by bullsnakes and their movements to and from the meadows. Following this are the results of the investigation of the three proposed bullsnake control techniques.

MEADOW UTILIZATION and MIGRATIONS

The utilization of the waterfowl nesting meadows by bullsnakes was discovered during this study to be very discrete. The bullsnakes used the meadows discontinuously throughout their activity season and not at all during the winter. All of the snakes that were tracked in the meadows were found to be migrating back and forth between the meadows and the uplands many times each year for two reasons; ecdysis and hibernation. These two activities were always performed in the uplands and never in the meadows. The specifics of the migrations involved with each activity are somewhat different, so they are described separately as follows.

Three to five times a summer each of the bullsnakes that were being tracked in the meadows individually migrated to upland sites for purposes of ecdysis. The specific sites used by the snakes were usually unoccupied pocket gopher (*Geomys bursarius*) burrows, but the burrows of ornate box turtles (*Terrapene ornata*), badgers (*Taxidea taxus*), and other unidentified burrows were used as well. Most of the snakes seemed to have favorite burrows or groups of burrows in the uplands that each always used for ecdysis. The bullsnakes remained inactive at these sites for periods of five to sixteen days, the migrated back to the meadows when ecdysis was completed. Ecdysis was determined to have taken place by the finding of a slough that bore the individual scale-clip pattern of each snake, or by examination of the snake when it returned to the meadow.

The timing of these ecdysis migrations was highly variable both between and within individual snakes, with active periods in the meadows of fifteen to forty days alternating with inactive periods of ecdysis in the uplands of five to sixteen days. For all snakes the average cycling of activity and ecdysis was twenty-nine days of activity and seven days of ecdysis.

The straight-line distances travelled by the bullsnakes between their meadow positions and ecdysis sites was also highly variable, ranging from about twenty yards to six hundred yards, and averaging about two hundred yards. The actual distances are probably most closely related to the local distribution of meadows and uplands, since those snakes that resided the farthest from the meadow/upland boundary travelled the farthest to an ecdysis site while those snakes the closest to the boundary travelled the shortest distances. The critical terminus for these ecdysis migrations seems to be the meadow/upland boundary. Bullsnakes were observed to perform ecdysis at burrow locations just outside the meadows and beyond, but never within the meadows.

Once each year the bullsnakes also migrated out of the meadows for purposes of hibernation. Each fall the bullsnakes left the meadows and moved to burrows located in the uplands where they remained inactive throughout the winter. In the spring of the year the snakes emerged from hibernation and returned to the meadows.

The specific burrows that were used by the snakes as hibernacula all appeared to have been pocket gopher burrows. (Also see; BULLSNAKE DENNING.) With few exceptions the hibernaculum of each snake was also usually located very near to the burrows each snake used for ecdysis, but were never the same burrows.

The straight-line distances between the bullsnake's hibernacula and meadow positions ranged from about fifty yards to fourteen hundred yards, averaging about two hundred and fifty yards. As with the ecdysis migrations, the actual distances are probably most closely related to the local geography for the same reasons. The critical terminus for these hibernation-related migrations also seems to be the meadow/upland boundary since no bullsnakes were ever found to be denning in the meadows, but the hibernacula of the snakes were generally located farther outside the meadows than were the ecdysis sites, depending on the local topography. (Hibernacula were nearer the meadows where steep dune slopes intersected the meadows than they were where the dune slopes were more gradual.)

The timing of the migrations of the bullsnakes to and from their winter hibernacula was also variable and generally spanned a three to four week period in the spring and again in the fall. The earliest and latest dates for the spring migration that were recorded during this study were April 18 and May 22. The earliest and latest dates that were recorded for the fall migration were September 21 and October 13.

These ecdysis and hibernation-related migrations seem to be revealing a microhabitat requirement that the bullsnakes have for burrows located specifically in upland areas. Although scarce, there are some burrows located in the meadows that are available to the snakes, that the snakes do use occasionally while they are active, but these burrows were never used for ecdysis or hibernation. This apparent requirement for burrows in upland areas is undoubtedly somehow related to some physical characteristic of these sites that the burrows in the meadows do not possess, but no such data was available to this study and so this remains unexplained.

Whatever it is that the burrows in the meadows are lacking, this deficiency results in the observed migrations being evidently necessary for the bullsnakes that use meadow areas while active and foraging. These migrations are also the only predictable bullsnake movements that were discovered during this study. These migrations are predictable in that they can apparently be relied upon to cross the meadow/upland boundary. This predictability of these migrations can be exploited with bullsnake removal trapping techniques, and this is discussed in a later section of this report. (See REMOVAL TRAPPING.)

These frequent migrations of the bullsnakes and the amount of time spent in the uplands results in a sum-total utilization of the meadows by the snakes that is a surprisingly small fraction of each year. On an individual basis each bullsnake spends an average of seven months hibernating in the uplands (October- April), plus an additional seven of every thirty-six days during the activity season performing ecdysis in the uplands. This sums to a total of eight months spent inactive in the uplands each year, and only four months spent active in the meadows, on an individual basis. Considering a population of bullsnakes in any particular meadow, the snakes are only found in the meadow at all during roughly May through September, and even then only about 80% of the population that uses that meadow is ever actually in the meadow at any one time, due to the variability of migration times that staggers the activity/inactivity cycles of the snakes in that population.

There is also one last effect of these migrations that needs to be addressed here. These migrations cause the calculated home ranges of the snakes that use the meadows to become differentially inflated depending upon how far a bullsnake resides from the meadow/upland boundary while active. Because of this, rather than reporting home ranges in this final report, activity ranges are reported instead. An activity range is that area occupied by a bullsnake while it is active and foraging, exclusive of those sites used for ecdysis and hibernation. Since the occupancy of the meadows by the snakes while they are active and foraging is of greatest interest here anyway, the use of activity ranges rather than home ranges is more applicable. The activity ranges in this final report were calculated using minimum convex polygons as was done for home ranges in the preliminary report, but the sample size corrections and 90% area estimations that were used for home ranges are not used here for activity ranges. The activity ranges that were calculated for the bullsnakes in the various meadow study areas that were examined appear in the 'HABITAT MANAGEMENT' section of this report.

HABITAT MANAGEMENT

As stated in the introduction,it was of interest during this study to see what application the currently used habitat management practices may have for controlling bullsnake numbers in the waterfowl nesting meadows. The results of this investigation are as follows.

Grazing

Three study areas were used to examine the effects that grazing a meadow may have upon the subsequent use of the meadow by bullsnakes. As shown in Table 1, these three study areas represented meadow habitats during the same year grazing is applied, and during the first, second, and third years of rest from grazing. Bullsnakes were trapped and released with radio transmitters in each of these meadows. The subsequent movements of the snakes was found to be quite different in each of these units.

In the West Boyd study area used to examine same-year

Table 1. The habitat management histories of the West Boyd, East Boyd, and Island Lake management units of the Crescent Lake NWR for the years 1978-1985. The subscripts indicate the use of each unit to examine the effects of grazing during 1984 and 1985 as follows: 1. same-year grazing, 2. first year of rest from grazing, 3. second year rest, and 4. third year rest. G = Grazed, H = Hayed, B = Burned, R = Rested

	1978	1979	1980	1981	1982	1983	1984	1985
West Boyd	G	G	G	G	G/H	G/H	G_1	G/B/G
East Boyd	G	G	G	G	G/H	G	R_2	R_3
Island Lake	G	R	R	G	G	R	R_3	R_4

grazing, six bullsnakes were trapped and released with radio transmitters after the cattle were removed in 1984. None of these snakes remained in this unit longer than four days after release. These bullsnakes all dispersed from this recently grazed meadow and moved in all directions into both upland and meadow habitats. The dispersal distances of these snakes ranged from seventy-five yards to three and one-half miles from their initial capture points. Only one of these six snakes ever appeared to establish residecy in another area. This snake moved to the fringe of an adjacent meadow and remained there throughout the rest of the activity season. The other five snakes never stayed one area for very long and wandered throughout the time they were being tracked. Unfortunately all five of these snakes were lost due to transmitter failures, so the eventual fates of these animals are unknown. Because the snakes that were captured in the West Boyd unit did disperse, activity ranges and densities for bullsnakes in a recently grazed meadow could not be calculated. The West Boyd unit was grazed, burned, and grazed again during 1985, so this unit was not used during the second year of this study.

The East Boyd study area was used to examine the utilization of a meadow by bullsnakes during the first and second years of rest from grazing, in 1984 and 1985 respectively. During 1984 six bullsnakes were captured and released with trandmitters in this meadow. None of these snakes dispersed from this meadow, but they did maintain activity ranges on the fringe of the meadow rather than within it. These snakes conducted the majority of their activity in the upland areas immediately adjacent to the meadow, only going into the meadow during one to two day forays. Even though these snakes did not maintain activity ranges wholly within the meadow, their fringe-initiated forays did result in a majority of the meadow being utilized by the snakes. Indeed, waterfowl nest censuses that were conducted in the East Boyd meadow reported that bullsnakes destroyed six of the seven nests that were found in this unit. The activity ranges of the bullsnakes that used the East Boyd unit during the first year the unit was rested from grazing averaged 41.7 acres, with an average of 28% of the activity ranges encompassing the meadow.

During 1985, the second year the East Boyd unit was rested from grazing, the two bullsnakes that were still locatable from the previous year (the others were lost due to transmitter failures) maintained new activity ranges wholly within the meadow. Five additional snakes that were radiotagged in this unit during 1985 maintained their activity ranges wholly within the meadow as well. The meadow fringe oriented activities of the snakes that were so prevalent during the first year this unit was rested from grazing were completely absent during this second year of rest. The activity ranges of the bullsnakes were also much smaller during the second year of rest, averaging 22.1 acres.

The Island Lake unit was studied during the second and third years this unit was rested from grazing. During the two years this unit was examined eighteen bullsnakes were trapped and released with radio transmitters. All of the snakes that were tracked in this unit maintained activity ranges wholly within the meadow during both years. Three bullsnakes that were tracked in this unit during 1984 and 1985 used nearly identical activity ranges in both years. Also, two snakes that were initially trap-in this unit in 1984 (but were too small for transmitters) were recaptured in 1985 in the same traps, indicating similar activity range positions during both years for these snakes as well. The between-year activity range shifts that were observed in the East Boyd unit during this study were not seen in the Island Lake unit. The size of the activity ranges of the bullsnakes at the Island Lake unit also did not change much during this study, averaging 10.1 acres in 1984 and 9.6 acres in 1985.

The Island Lake unit was the only study area for which the density of the bullsnake population could be calculated, and this could only be done during the second year of this study. (Too few snakes were otherwise tracked in the study areas to give reliable density estimates.) In 1985, eleven bullsnakes were trapped and released with transmitters within a 10.2 acre portion of the Island Lake meadow. The subsequent activity ranges of these snakes covered all of this 10.2 acre area and an additional 3.7 acres of this meadow. This works out to a density of one snake per 1.3 acres. There were also three other snakes captured in this 10.2 acre area, but not radiotagged because of the interference to radio reception from already having eleven transmitters in so small an area. It cannot be known for sure, but if these three additional bullsnakes also were maintaining activity ranges in this portion of the meadow, then the resulting bullsnake density would be one snake per acre.

These results of the examination of grazing indicate that grazing has the effect of dispersing bullsnakes from a meadow the same year the grazing is done. During the first year a meadow is rested from grazing, bullsnakes do use the meadow, but maintain their activity ranges on the fringe rather than within the meadow. When a meadow is rested a second year from grazing, the bullsnakes move into the meadow proper and remain wholly within it while active. During the third year a meadow is rested from grazing the bullsnakes are well established as residents, with many of them re-using the same activity ranges that were used the previous year.

There also appears as though there may be an additional effect when a meadow is hayed as well as grazed. The East Boyd and Island Lake units were both examined during their second years of rest from grazing, but the activity ranges of the bullsnakes in the East Boyd unit were nearly double the size of those at the Island Lake unit. The major and most recent difference between the land management histories of these two units is that the East Boyd unit was hayed just two years prior to this study, while the Island Lake unit had not been hayed for at least six years prior (Table 1).

The difference in the sizes of the bullsnake's activity ranges may be due to the haying that was done in the East Boyd unit, but this would require further study to be certain.

It is suggested here that the observed dispersal of bullsnakes from a recently grazed meadow is most likely due to the loss of the matted thatch in the meadow that results from the trampling action of the grazing cattle. This thatch is important to the bullsnakes for two reasons. First, the voles (Microtus sp.) that constitute the majority of the diet of the bullsnakes in the meadows live primarily in the thatch, building nests and runway systems within it. When the thatch is flattened by grazing cattle a reduction of vole numbers, and thus bullsnake food resources, may occur. Bullsnakes may then be dispersing from grazed meadows due to a food resource shortage. A rodent census was planned for the second year of this study to test this idea, but the snap-traps that were obtained proved inadequate for this purpose.

The thatch is also important to the bullsnakes for a second, and perhaps more significant reason. The thatch in a meadow serves as a refugium to the snakes from high temperatures, and possibly predators as well. While snakes are well adapted to weathering long periods of food resource shortages (Fitch, 1949;1982; Reynolds and Scott, 1982; Pough, 1983), snakes cannot survive even a single day of the lethally-high body temperatures that would result from being continuously insolated, without a refugium of some sort as protection (Imler, 1945; Bogert and Cowles, 1947). In the uplands the bullsnakes utilize underground refugia, especially pocket gopher burrows. In the meadows, underground burrows of any kind are relatively scarce, presumably due to the high water table and frequent flooding in the meadows that would discourage burrow digging animals. The matted thatch that builds up in a rested meadow may be the only protection that is available to the bullsnakes from lethally-high temperatures. When this thatch is flattened by grazing cattle the bullsnakes may have no choice but to disperse from that meadow.

This explanation for the observed dispersal of bullsnakes from a grazed meadow is untested, but within reason. This explanation is somewhat supported by the observation that bullsnakes were not dispersed from upland areas by grazing. In the uplands the underground refugia that are used by the snakes are little affected by grazing cattle, thus no dispersal due to a loss of refugia would be necessary.

For whatever reason, grazing does produce the desired effect of dispersing bullsnakes from a meadow. Unfortunately the effect does not last long and bullsnakes begin to reinvade the meadow (and depredate waterfowl nests) the first year it is rested from grazing. Perhaps with meadows of a larger diameter than those that were examined here (ca. 600 yards), the reinvasion of bullsnakes might not reach the meadow interior so soon. Otherwise grazing does not appear to have much application for reducing bullsnake numbers in the waterfowl nesting meadows.

Prescribed Burning

As was mentioned in the preliminary report, the prescribed burning that was planned for this study did not take place (due to inclement weather), and so the potential of this practice for reducing bullsnake numbers in the meadows could not be examined. A reasonable prediction can be made however, based upon the results of the examination of grazing.

Fire does have the same general effects as grazing insomuch that any matted thatch on the ground surface is severely reduced. If the loss of the thatch when a meadow is grazed is the reason for the observed dispersal of bullsnakes, then fire is likely to have this same effect. In fact, with this same reasoning, all of the land use/management practices that are conducted upon the meadows of this region are likely to cause the dispersal of bullsnakes. Each of these practices may differ in the duration of their effect upon bullsnakes however, and should be examined specifically.

Land Use and Bullsnake Immigration

The above results of the examination of habitat management are suggestive of the possibilty that the extensive use of the meadow areas in this region (primarily by grazing and haying operations) is the reason why controlling bullsnake numbers on this refuge is such a problem, as follows.

The CLNWR is essentially a long and narrow strip of land that averages only 2-3 miles in width, with the majority of the high priority waterfowl nesting meadows located within one mile of the refuge boundary. (See map; CLNWR Predator Management Plan.) The land surrounding the refuge on all sides consists of the same upland/meadow/wetland habitat mosaic that comprises the refuge. The land surrounding the refuge is also heavily utilized by ranching operations and none of it is allowed to remain idle. The uplands are grazed and the meadows are hayed each year. Additionally, much of the refige is grazed or hayed each year as well, although to a much lesser extent than the surrounding ranchland. (Only 33% of the land area of the refuge was grazed or hayed during 1984; refuge records.)

If the conclusions of this study are correct and land use/management practices conducted within the meadows does cause bullsnakes to disperse, then a large portion of this regional bullsnake population is composed of migrants each year, dispersing in all directions from the grazed and hayed meadows on and off the refuge. With migrant bullsnakes capable of travelling three miles in less than one week, idle nesting meadows on this refuge would then be subject to a rapid reinvasion of large numbers of snakes while control of the resident snakes is being attempted. This would explain why hundreds of bullsnakes were removed from the Gimlet Lake unit during 1939-1941 and no end to the large numbers of snakes was ever reached (Imler, 1939; 1940; 1941). Currently, because such a small proportion of the refuge meadows are grazed or hayed in comparison to the surrounding ranchland, the majority of the migrant bullsnakes that now occur on the refuge probably originated in areas off the refuge. With most of the high priority nesting meadows of this refuge located within only one mile of the refuge boundary, they are within easy reach of migrant bullsnakes dispersing from the surrounding ranchland.

There are also some indications from a recent bullsnake removal effort at the Valentine NWR that controlling migrant bullsnakes may in fact be a much bigger chore than controlling the resident snakes. During 1985, about 200 bullsnakes were removed from the VNWR's management unit #21b with 40 traps placed on those 70 acres (refuge manager; pers. comm.). This works out to 2.9 bullsnakes having been removed per acre. If the VNWR has resident bullsnake densities that are similar to those at the CLNWR (one snake per 1.0-1.3 acres), then the number of migrant bullsnakes that were removed from unit #21b was nearly double the number of residents that were removed.

Because the activity of snakes, and most other reptiles, is highly variable and generally dependent upon environmental conditions (Heatwole, 1976; Reynolds, 1982), bullsnake reinvasion rates even greater than those that appear to have occurred at the VNWR in 1985 may be possible. For example, the bullsnake removal in unit #21b averaged 5 snakes captured per trap, while trap captures as high as 11.9 snakes per trap have been recorded at the CLNWR (Imler, 1945).

This discussion of land use and bullsnake immigration was included here for the purposes of stressing that immigration is a factor that cannot be overlooked when attempting to control bullsnakes. Contrary to the conclusions of Imler(1942), there is no reason to believe that the removal of bullsnakes from an area during any year will result in a carryover of reduced snake numbers in subsequent years. In fact, the information that is available indicates that this bullsnake population is probably capable of replacing itself in an area with immigration much more rapidly than what has been reported for mammalian predator populations (Balser et al., 1968; Chesness et al., 1968; Greenwood, 1986).

REMOVAL TRAPPING

Removal trapping is currently being employed at the CLNWR in an attempt to control bullsnakes, but has so far been unsuccessful. The data that was collected during this study indicates several areas where the removal trapping effort can be improved.

The first improvement concerns the placement of the funnel traps and drift fences. The radiotelemetry tracking of the bullsnakes revealed predictable movements of the snakes that can be exploited with removal trapping. These movements are the ecdysis and hibernation migrations of the snakes across the meadow/upland habitat boundary. Funnel traps and drift fences should be placed upon and parallel to the habitat boundary to intercept these bullsnake movements. With this placement the earliest possible opportunity of capturing the snakes during the waterfowl nesting season will be obtained when the snakes first emerge from hibernation in the uplands and attempt to move into the meadows. This placement will also serve to intercept the repeated ecdysis migrations of the snakes during the summer, as well as intercepting the movements of migrant snakes attempting to immigrate into the meadows from other areas. The transverse placements of the fences and traps that is currently being used should not be abandoned, but should be supplemented with placements upon and parallel to the meadow/upland boundary.

The second improvement concerns the density at which the traps are placed within the meadows. The high resident density of active bullsnakes in the meadows that was discovered during this study, combined with the information concerning immigration indicates that a far greater number of bullsnakes need to be removed from the meadows each year to attain control than what is currently being done at the CLNWR. The 1985 bullsnake removal effort at the VNWR's unit #21b is a good example of this. In this management unit satisfactory control of the bullsnakes (reflected by a 70% waterfowl nest success; refuge manager; pers. comm.) was attained only when 2.9 bullsnakes were removed per acre, as previously mentioned. The current bullsnake removal effort at the CLNWR is only removing about 0.15 bullsnakes per acre (calculated from the 1984 and 1985 trapping data).

The best way to increase the bullsnake removal rate is to simply increase the trap density. Calculated for all known bullsnake removal efforts at the CLNWR and the VNWR, the funnel traps and drift fences capture an average of six bullsnakes per trap per year. Using the above removal rate from the VNWR's unit #21b as a guide, since it is the only known successful bullsnake control effort, the funnel traps should then be placed in the meadows at a density of one trap for every two acres to achieve the removal of 2.9 snakes per acre. This is in fact very close to the trap density that was used to attain control in unit #21b (one trap per 1.8 acres). The funnel traps are currently being placed at the CLNWR at a density of about one trap per thirty acres. As can be seen from the above, this trap density has to be incraesed many-fold if bullsnake control is to be expected. A trap density of one trap for every two acres probably represents the maximum practical density that can be used. It may be possible to decrease this a bit if the above habitat boundary placements are used, but this would require further study.

The last improvements to be discussed here for increasing the efficiency of the bullsnake removal efforts concerns the drift fences that are used with the funnel traps. The drift fences that are currently being used consist of eighteen inch-wide strips of tarpaper stapled to wooden stakes upon the ground surface. During the course of this study bullsnakes were observed many times crawling over and under the drift fences rather than following along them. This bypassing of the fence by the snakes must be stopped if the maximum efficiency of this trapping system is to be expected.

Two suggestions are made here. The first is to simply increase the height of the drift fence to discourage the bullsnakes from crawling over it. A height of twenty-four inches is recommended here, but a fence of up to thirty-six inches in height would be better yet.

The second suggestion is to bury the lower edge of the drift fences below the ground surface. When the fences are just erected upon the ground surface as is being done now, gaps inevitably result beneath the fences due to the irregularities of the ground surface. These gaps, albeit small, appear as 'doorways' under the fence from a snake's perspective. The bottom 4-6 inches of the drift fences should be buried to eliminate these gaps.

Since the tarpaper that is currently being used as drift fence material is ill-suited for burial however, another material should be substituted. Metal flashing and screening have both been found to be excellent drift fence materials and far superior to tarpaper (Campbell and Christman, 1982; Vogt and Hines, 1982). The use of either of these materials may also obviate the necessity of increasing the height of the drift fences, since much of the problem with the snakes crawling over the fence stems from the drooping and sagging of the tarpaper after just a short while of it's being exposed to the elements.

Some last recommendations are made here, not so much to increase the snake captures, but to decrease the non-target captures. During the present study, forty-three species of vertebrates were captured with the currently used funnel trap design, and the mortality among the birds and mammals was quite high. Imler(1945) has also previously reported this same problem with this trap design, with bullsnakes only amounting to 5% of the total captures that Imler reported. There does not seem to be any sure solution to this problem, but two suggestions can be made here. The first is to reduce the size of the inside-end of the funnel from the current 3 x 3 inches square to a round funnel tip of

1.5-2.0 inches in diameter. The second suggestion is to install the 'drops' over the outside-end of the funnel as recommended by Brauwart (1941). Braunwart stated that drops which reduced the funnel entrance to a height of one inch would probably eliminate the capture of young pheasants altogether. Both of these suggested modifications to the funnel trap design are aimed toward reducing the trap entrance to a snake-only size, and although rodents will probably continue to be captured, the inadvertant capture of game birds will at least be severely reduced if not eliminated, if these recommendations are followed.

BULLSNAKE DENNING

As stated in the preliminary report, the bullsnakes that were tracked during this study did not appear to be denning communally. In order to further substantiate this, eight of the radiotagged bullsnakes were excavated from their dens during the winters of 1984-1985 and 1985-1986, using the transmitter signals to pinpoint their locations.

As was suspected, the bullsnakes were found to be denning in pocket gopher burrows. The specific portion of the burrows within which the snakes were located was usually a chamber at the end of a burrow that contained plant-root clippings and gopher fecal pellets. The depths at which the snakes were found ranged from three feet to seven and one-half feet, averaging five feet in depth.

Of the eight bullsnakes that were excavated, four were found together with racers (*Coluber constrictor flaviventris*), and one was found denned together with another bullsnake. This bullsnake was one that had not been previously captured or tracked during this study.

While the above discovery does technically constitute a communal bullsnake den, the numbers are obviously less than was hoped for. The large communal dens that have been found in other areas do not appear to exist here at this refuge. With this being the case, the exploitation of communal bullsnake dens does not appear to have any potential for controlling bullsnake numbers in this area of the Nebraska sandhills.

LITERATURE CITED

Balser, D.S., H.H. Dill, and H.K. Nelson, 1968. Effect of predator reduction on waterfowl nesting success. J. Wildl. Manag. 32: 669-682.

Bogert, C.M., and R.B. Cowles. 1947. Moisture loss in relation to habitat selection in some Florida reptiles. Amer. Mus. Nov. 1358:1-34.

Braunwart, R. 1941. Miscellaneous reports from the Crescent Lake National Wildlife Refuge for the summer of 1941. unpubl. rep. to R.S.F.W.S.

Campbell, H.W., and S.P. Christman. 1982. Field techniques for herpetofaunal analysis. p. 193-200. In N.J. Scott, Jr., ed. Herpetological communities. U.S.F.W.S. Wildl. Res. Rep. 13. Washington, D.C. 239 p.

Chesness, R.A., M.M. Nelson, and W.H. Longley. 1968. The effect of predator removal on pheasant reporductive success. J. Wildl. Manage. 32:683-697.

Cowardin, L.M., A.B. Sargeant, and H.F. Duebbert. 1983. Problems and potentials for prairie ducks. Naturalist 34:4-11.

Cowardin, L.M., D. S. Gilmer, and C.W. Shaiffer, 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monagr. 92:1-37.

Fitch, H.S. 1949. Study of snake populations in central California. Am. Midl, Nat. 41:513-579.

Fitch, H.S. 1960. Autecology of the copperhead. Publ. Mus. Nat. Hist., Univ. Kansas 13:85-288.

Fitch, H.S. 1982. Resources of a snake community in prairie-woodland habitat of northeastern Kansas. p. 83-97. In N.J. Scott, ed. Herpetological communities. U.S.F.W.S. Wildl. Res. Rep. 13. Washington, D.C. 239 p.

Greenwood, R.J., and P.M. Arnold. 1984. Evaluation of predicides for controlling mammalian egg predators inside electric fence exclosures. Abstract. Arrowwood WMD Narrative Report.

Greenwood, R.J. 1986. Influence of striped skunk removal on upland duck nest success in North Dakota. Wildl. Soc. Bull. 14:6-11.

Imler, R.H. 1938. Waterfowl nesting studies on Crescent Lake Refuge, Nebraska in 1938. unpubl. rep. to U.S.F.W.S.

Imler, R.H. 1939. Waterfowl nesting studies and experimental bull-snake control, Crescent Lake Refuge, Nebraska, and LaCreek Refuge, South Dakota, in 1939, unpubl. rep. to U.S.F.W.S.

Imler, R.H. 1940. Waterfowl nesting studies and experimental bull-snake control, Crescent Lake Refuge, Nebraska, and LaCreek Refuge, South Dakota, in 1940. unpubl. rep. to U.S.F.W.S.

Imler, R.H. 1942 Waterfowl nesting studies and experimental bull-snake control, Crescent Lake Refuge, Nebraska in 1942. unpubl. rep. to U.S.F.W.S.

Kalmbach, E.R. 1939. Nesting success: Its significance in waterfowl reproduction. Fourth North Amer. Wildl. Conf. p. 591-604.

Pough, F.H. 1983. Amphibians and reptiles as low-energy systems. p. 141-188. In Aspey, W.P., and S. Lustick eds. Behavioral energetics: vertebrate costs of survival. Ohio State Univ. Press., Columbus, Ohio.

Reynolds, R.P., and N.J. Scott, Jr. 1982. Use of a mammalian resource by a Chihuahua snake community. p.99-118. In N.J. Scott,Jr., ed. Herpetological communities. U.S.F.W.S. Wildl. Res. Rep. 13. Washington, D.C. 239 p.

Sargeant,A.B., and P.M. Arnold.1984. Predator management for ducks on waterfowl production areas on the northern plains. Proc. Vertebr. Pest Conf. 11:161-167

Vogt, R.C., and R.L. Hine. 1982. Evaluation of techniques for assessment of amphibian and reptile populations in Wisconsin. p.201-217., In N.J. Scott, Jr., ed. Herpeto-logical Communities. U.S.F.W.S. Wildl. Res. Rep. 13 Washington, D.C. 239 p.