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Estimating Population Structure in Two Species of Turtle Using the Mark-Recapture Method

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ABSTRACT

Populations of eastern painted turtles, *Chrysemys picta picta*, and snapping turtles, *Chelydra serpentina*, in five ponds in southern New York State are studied in a mark-recapture experiment. Using a linear regression model based on the Lincoln index, population estimates are made of each pond and compared with estimates made by a computer using the usual two sample Lincoln index method. The validity of the population estimates are questioned on the basis of the three basic assumptions necessary for populations in a mark-recapture study, and how turtle populations match these assumptions. Turtle populations appear to meet these idealistic assumptions as best as can be expected when dealing with such a stochastic system. With careful planning and an intensive trapping regimen, painted and snapping turtle populations of even modest size may be accurately estimated. Such demographic studies are the stepping stone to future research on turtle biology and conservation efforts.

INTRODUCTION

Our environmental resources are continually coming under threat from the activity of mankind. We have little knowledge of where this current trend will lead and how severely our destructive habits will affect many species and ecosystems. Loss of habitat, over harvesting and pollution are likely contributors to the serious worldwide decline of turtle populations in recent years (Ernst and Barbour 1989). Gaining a more thorough knowledge of turtle biology, particularly acquiring information on the life cycle and habitat requirements of threatened species, may help in the design of conservation projects focused on the prevention of further population deterioration. The contribution of freshwater turtles to the trophic and energy structure of pond ecosystems is not well studied. Nor are the habitat requirements and density limits of various species well documented. This void of information is most likely due to a lack of biomass data for turtles (Iverson 1982). Estimates of population size and structure by several authors have shown considerable degrees of variation (Ream and Ream 1966; Sexton 1959; Wilbur 1975), and may be affected by trapping method (Ream and Ream 1966) and by the method of statistical analysis used. In order to examine the populations of animals in the wild, scientists can either observe or collect specimens. A common method of analyzing population size and structure is the mark-recapture method.

The mark-recapture method was originally developed by Peterson (1889) for use in fisheries, but he never actually used the technique for estimating population size. The theory was first put to such a use by Lincoln (1930) to estimate the number of wildfowl in the United States. Jackson (1933) used the method to estimate the number of tsetse-flies in a small quadrant of land in Africa. By then the technique was already referred to as the Lincoln index. That name has generally stuck, although some texts refer to it as the Peterson index or the Lincoln-Peterson index. In theory the process is quite simple. First, a sample of the population is taken by trapping individuals. These individuals are marked by some means and then released back into their habitat. After a period of time long enough to allow the marked individuals to mix back in with the rest of the population, another sample is taken. By comparing the number of marked individuals to unmarked individuals in the second sample, an estimate of the population can be made. In order for this method to provide an accurate estimation, certain assumptions must be made about the population in question.

1. The individuals in the population must intermingle sufficiently so that after the first sample the marked

individuals mix evenly into the unmarked population.

2. The marking must have no affect on the behavior of the animals that would cause the marked animals to reenter the traps more or less frequently than the unmarked animals.
3. The population must not increase in size during the time of the experiment due to birth or immigration since the fraction of marked to unmarked individuals would change.

These assumptions are admittedly difficult to keep. Several authors have developed new methods, or at least modifications of the old method, for estimating population information. These methods (Cormack 1966; Eberhardt 1969; Manly and Parr 1968; Orians and Leslie 1958; Seber 1965) are mainly directed towards the third assumptions. Births, deaths, immigration and emigration are inevitable occurrences in all populations, making the third assumption invalid. However, turtles have a number of characteristics which allow us to assume, to a reasonable degree, that the third assumption is accurate.

1) Juvenile and adult turtles are not likely to die within a short period of time. Turtles, in the order Testudines, are believed by many to be the oldest living group of vertebrates (Fisher 1958). In a captive study of 56 species representing 8 families of turtles, at least one species in each family had individuals lasting 20 years and half the families contained species in which individuals lived over 50 years. Gibbons

(1987), believes that the reason for such longevity is a combination of low metabolic activity, a lack of physiological and anatomical deterioration over time, a long maturation period, and a large investment in the shell. Whatever the reason, turtles seem to survive. One study by Wilbur (1975) estimated the annual mortality rate of juveniles and adults in a population of painted turtles to be 0.15 for males and 0.18 for females. Some deaths occur during the winter months, so the mortality rate for the summer would be somewhat lower

2) Immigration and emigration of freshwater turtles from their ponds is thought to be quite low based on several studies, particularly those on painted turtles (Bayless 1975; Gibbons, 1968; Wilbur 1975). Turtles seem to leave the ponds only to lay eggs and to bask on rocks or logs, and then they return quickly to the water. Thus the ratio of marked to unmarked turtles in a pond is unlikely to change due to movement.

3) The catchable population will not include new hatchlings because they are too small (Aengenheyster, personal observation) to be caught by our trapping method (see Methods and Material). Thus the adult population will not be affected by new recruitment within a particular season.

Using the Lincoln index, it should be possible to make a reasonable estimate of the population size of painted and snapping turtles (*Chrysemys picta* and *Chelydra serpentina* respectively) in the five ponds we studied at Black Rock Forest. This will allow us to analyze the mark-recapture process in and of itself as well as gather information useful to other studies on turtle ecology and conservation in the future.

Painted turtles are the most widespread turtle in the United States. They have a smooth, oval carapace colored olive to black. Usually the carapace is decorated with red and yellow marking in the form of bars or crescents. The skin is olive to black, like the carapace, and the legs, neck and tail are striped with red and yellow. One or two yellow stripes on the face extend from under the eye to the neck, and two more yellow bands are found on the chin. The underside, or plastron, of the painted turtle is usually yellow but may have brown or red markings. There are twelve scutes on each side of the carapace. The eastern painted turtle, *Chrysemys picta picta,* one of four subspecies of painted turtle, is distinguished from the other three subspecies by the light borders found along the carapacial seams and the alignment of the vertebral and pleural carapacial seams. Its range extends from southeastern Canada to Georgia and westward from the Atlantic coast to eastern Alabama. (Ernst and Barbour 1989) Males can be distinguished from females by the presence of a longer third claw on their forefeet and a greater preanal tail length than females.

Chelydra serpentina is one of the largest and most viscous of the freshwater turtles. They can grow in excess of 20 kg and 30 cm in plastron length. The carapace of *Chelydra* can range in color from tan, brown, or olive to black and it is rough with large knobs or keels on the scutes. The rear scutes are highly serrated. Skin ranges in color from gray to brown and is rough and scaly. The head is large with a slightly protruding snout and a hooked upper jaw. A breathing hole is visible on the tongue. Males grow larger than females and as with the painted turtle have a longer preanal tail length than females. Snapping turtles have a range that extends east of the Rocky Mountains from southern Alberta south through the United States, Mexico and Central America all the way to Ecuador.(Ernst and Barbour 1989)

Painted and snapping turtles are far from rare and therefore are not the top priority for conservation efforts. However they are among the most studied turtles in the world and thus a demographic study will offer a look into the effectiveness of the mark-recapture method and allow comparison with other studies. The goal of this study is the beginning of a comprehensive demographic and ecological study of the painted and snapping turtles in Black Rock Forest. The first step in this study must be the review of its methodology so that in the continuation of the study, all efforts will be focused in the proper direction.

METHODS and MATERIALS

STUDY AREA

This study took place in the Black Rock Forest, located in Cornwall NY. in the Hudson Highlands. The turtle populations in five ponds are examined in this study. These ponds range in size from 3-7.3 acres and in elevation from 314-398m (Adirondack Lake Survey). Sutherland Pond, the only natural pond is estimated to be 12,000 years old and likely the original source of turtles in the area. The other ponds, Tamarack, Sphagnum, Arthurs and Aleck Meadow are all reservoirs used for drinking water by the town of Cornwall. Aleck Meadow, the oldest of the four was built from 1910-1915 and Sphagnum, the youngest built from 1926-1927. Runoff from Tamarack runs into Sphagnum which in turn runs into Aleck Meadow. Aleck Meadow also receives runoff from Arthurs (See Figure 1). During the course of the summer the three upper reservoirs, Tamarack, Sphagnum and Arthurs experience a drop in the water level as they drain into Aleck Meadow (John Brady, personal communication; Aengenheyster, personal observation).

TRAPPING

Trapping occurred from June 5 until August 7, interrupted by a period of no trapping from July 3 to July 10. Hoop nets three feet in diameter were set in water with the upper portion of the trap above water, allowing trapped turtles to breath as described in Ream and Ream (1966). Traps were anchored in place at the closed end using wooden stakes. Often, rocks were placed in the trap at the opening to keep the opening against the bottom of the pond. Traps were set in areas of the pond that were near vegetation or basking areas and had murky bottoms in which the turtles could hide. Attempts to trap in areas where the water was clear and the pond bottom was gravelly resulted in little or no trapping success. Each pond had either three or four large hoop traps distributed in suitable areas. The traps were baited predominantly with canned sardines. Experimenting with other baits such as canned tuna fish or cat food showed no noticeable increase in captures, so we decided to stick with sardines. Holes were punched in each can and the can was placed in the trap at the end farthest from the opening. Every trap was checked for turtles every day except for the period from July3 to July 10 when the traps were removed, cleaned and then reset in different locations with fresh bait.

MEASUREMENTS

Each captured turtle was aged, sexed, measured and weighed. Age was determined by counting the growth rings on the carapace as described by Sexton (1959). When the number of rings was indeterminable, it was recorded as "worn".

Tail measurements were taken in order to determine the sex of each turtle. Each turtle was flipped over on its back. Using a clear plastic ruler, we measured the distance from the plastron to the anus, or cloaca, and from the cloaca to the tail tip. In the case of the painted turtles, we used dial calipers to measure the length of the third claw on the front feet. As an indicator of size, we measured the plastron length, again using a clear plastic ruler. Weight was determined by placing the turtle in a bag or bucket and weighing them with a fishing scale. A 1 kg and a 10 kg scale were used depending on the size of the turtle.

During June, when we found an adult turtle that appeared female we checked for the presence of eggs. This is accomplished by holding the turtle upside down and placing the index finger between the plastron and carapace directly in front of the hind legs. If eggs are present they can be felt as hard round objects under the skin.

BLOOD SAMPLES

Blood samples were taken from both the painted turtles and the snappers in order to catalogue the genetic diversity of the turtle population at Black Rock. The collection of blood samples from the turtles is part of a larger project being done by Michael Forester, University of Florida, attempting to index samples of turtle DNA from across the country. Since the turtles are cold blooded, they have no turgor in their blood vessels. This means that in order to extract blood from an artery, the tip of the needle must be exactly inside the artery (Forester, personal communication). We used 10cc syringes to extract the blood. The safest place to take blood was the femoral artery because of the size of the blood vessel and its location away from any sensitive organs. If we could not obtain blood from the femoral artery, we extracted it from the tail. Blood samples were placed in small collecting vials along with a buffer that prevented clotting.

MARKING

Marking was done using two methods. The first method involved cutting notches in the shell as described by Cagle (1939). A hacksaw was used to cut the notches in the scutes of the adult turtles. A nail clipper was used to mark any small turtles whose carapace was too soft to withstand the hacksaw. The hacksaw and nail clippers were sterilized using a lighter between each notching. The pieces of shell were kept in small collecting vials and preserved in alcohol. These in turn were collected by Michael Forester as part of his genetic study. The other method of marking involved the use of a magnetic marker called a PIT tag (AVID, 10mm in length), injected under the skin as described by Camper and Dixon (1988). The tagged turtles could then be identified using a hand held scanner. We injected the tags behind their back legs, where turtles have large folds of loose thick skin tissue and the tags do not affect the turtles muscle tissue. On turtles which were too small to PIT tag (Plastron smaller than 10 cm), we marked them with notches so that in a few years, if they are recaptured, they can then be Pit tagged.

STATISTICAL METHOD

The Lincoln index is based on a simple two sample experiment. In the first sample all the individuals are marked and in the second sample the marked to unmarked ratio is used to estimate the population. Because we trapped and marked turtles everyday for several weeks I used calculations that are in essence a linear regression of the Lincoln index developed by Schnable (1938) for instances when the marked to unmarked ratio in a population continually increases over the duration of the experiment.

As an illustration of a population estimate under the three assumptions required for the analysis of mark-recapture data, consider an ideal case in which 100 turtles are captured each day representing 10 percent of the population (this is unknown to the researcher). Let denote the number of turtles in each sample that are recaptures and let be the number of new, unmarked turtles in each sample. Also let equal the number of turtles marked previous to each sample. This information should be gathered in a table to assist calculation (see Table 1). In this ideal situation, the true size of the population, , can be determined by the observed ratio, , and the known value using the equation

after the first sample and whenever and are not zero.

However, the number of turtles in each sample may very a great deal from sample to sample and the observed ratio is subject to sampling error. Therefore,

is an estimate of

and is not an appropriate equation in cases where is small for each sample. Given that the marked turtles are randomly distributed among the population and are as likely to be caught as unmarked turtles, then the value as an estimate for the population size, can be derived by least squares analysis from the observed ratio .

Since the weight of each individual observed ratio varies directly with the number of turtles in the sample, the formula for estimating the size of a population is given as,

and the mean square of the residuals is therefore

where equals the number of samples used in the calculation, and the standard error of the estimate is

This information is easiest to work with on a spreadsheet (Table 2). For a more in depth look at how to derive the formula for and for standard error, see Schnabel (1938) and Hayne (1949).

RESULTS

CAPTURE DATA

In total we captured and tagged 158 painted turtles, 48 snappers and 2 red eared sliders, a species widely sold as pets and which does not naturally occur in the region. A group of New York City seventh graders who were taking a class at Black Rock also found a box turtle, a rare land species, but it was not tagged because I was unsure how to properly tag a box turtle. Out of the 158 painted turtles we caught, 122 were adults, and of those 82 were females. Thus the adult male:female sex ratio is 1 : 2.05. Out of 48 snappers, 37 were adults and 16 were female and therefore the adult male:female sex ratio is 1.3 : 1. Aleck Meadow had the greatest number of captures followed by Sutherland, Tamarack, Sphagnum and finally Arthurs (see Tables 3 and 4).

POPULATION SIZE

The total estimated population for the 5 ponds studied in Black Rock Forest is 291.16 painted turtles and 63.63 snapping turtles. Broken down by pond, the population estimates corresponded with the actual capture numbers per pond, Aleck Meadow's population being the largest and Arthurs being the smallest (see Table 5). The size of each pond was also factored in, resulting in a calculated population density for each population (see Table 6).

DISCUSSION

TURTLE POPULATIONS

Over 75 percent of the painted turtles captured live in two ponds, Sutherland Pond and Aleck's Meadow. Sutherland is about 12,000 yr. old and the only natural pond in the study. Aleck's Meadow has the most turtles and is at the lowest elevation of all the ponds studied. Unlike the painteds, there are a very small number of snapping turtles in Aleck's Meadow. Aleck's is the most isolated pond from the others and large snapping turtles are much more cumbersome on land than painted turtles (Aengenheyster, personal observation), so they are less likely to move from pond to pond. It seems likely that the turtle population originated in Sutherland and the turtles very slowly spread into the reservoirs. Movement between ponds in general however is probably very infrequent. There only one observed migration between ponds during the entire study.

These populations are all at different levels of activity. Some seem to be healthy and will hopefully grow, while others may be on the decline. Wilbur (1975) has suggested that turtles in the northern part of the range tend to lay only one clutch per year due to the shorter breeding period. Also Wilbur (1975) indicates that there can be a 90% or higher mortality rate during the incubation period due mainly to nest predation by raccoons. This type of scenario would likely favor a high ratio of females to males, who can fertilize many females in one season. Indeed the two largest populations of *C. picta* in Aleck Meadow and Sutherland also have the highest ratio of females per male turtle. Small populations of *C. picta* in New York and Minnesota (under 100 turtles each) show male:female ratios of 2.21:1(Raney and Lachner 1942) and 1.45:1 (Bayless 1975). Some larger populations however, show a more even ratio between males and females (Ernst 1971; Gibbons 1968) and one 600+ population even had a 0.66:1 male:female ratio (Sexton 1959). Perhaps male skewed populations are in a rapid state of growth or recovery. Turtles are one of the few groups of organisms in which sex is determined by the temperature of the nest. Nest incubated at a temperature greater than 27C produce females and those incubated at a temperature less than 27C produce males. It has been suggested (Chris Raxworthy, personal communication) that turtles may use this strange phenomenon in order to control the sex ratio in a population. This would allow for rapid growth if a low number of one sex was a limiting factor in reproductive success. It is difficult to tell exactly how a change in sex ratio affects a population of *C. picta.* without looking at a change in population structure over a number of years. The populations of *Chelydra serpentina* seem to follow a different trend when it comes to sex ratios. The largest populations had more males than females.

Other factors must have a serious role in the health of these 10 populations. Density factors into the health of a population. Scarcity of food, nesting sites, and basking sites can all affect a population of turtles. Also predation can have a large influence on population size. Interestingly Aleck Meadow not only has the largest population of painted turtles, but also the smallest population of snappers. It may be that a deficit of snappers in Aleck Meadow allows for a larger population of painted turtles. For the snappers themselves, territorial behavior may limit the number of snappers in a pond. When density, rather than population size is considered, the 5 populations of snappers are quite similar. Only Sutherland has a considerably higher population density than the other ponds. Of course these density figures were calculated using the surface area of the ponds. It is likely that certain areas of each pond are turtle free due to lack of food or shelter, or the depth of the water. Our trapping experience indicates that some areas of each pond had little or no turtle activity, thereby reducing the effective area for feeding and mating. Density calculations from other studies reveal a wide range of population densities for various populations, from 5-233 turtles per acre for *C. picta* (Bayless 1975; Sexton 1959; Gibbons 1968) and up to 48 snappers per acre (Froese and Burghardt 1975). Apparently density is not an overwhelming factor, assuming that resources are available.

There is evidence that these populations have been affected by acid rain in the area (McKinsey 1998). Aleck Meadow has the most neutral water and Tamarack the most acidic. However Arthurs, the least acidic after Aleck Meadow, with an average pH of 5.8, has virtually no turtles (Adirondack Lake Survey 1987) This may be the result of severe drainage experienced by Arthurs in order to supply Cornwall NY with drinking water (John Brady, personal communication). Unstable environments caused by drastic change in water level may cause turtles to migrate to less threatening locales.

METHODOLOGY

This study illustrates both several faults and weaknesses in using the Lincoln index or a linear regression model to estimate populations with mark-recapture data. First, the linear regression method seems to work the best when there is a need for many samples due to large fluctuations in the results of individual samples. The Lincoln index results obtained by McKinsey (1998) using the program CAPTURE gives several estimations which must be averaged. This means that one estimate may skew the average either high or low. In this specific case, averaging the Lincoln index results provided some obvious errors. The estimate for the Aleck Meadow snapper population was lower than the number of snappers actually caught. The Lincoln index was not designed to deal with the slow accumulation of recaptures over several samples.

On the other hand, the turtle populations seem to have fit the assumptions necessary for population estimation very well. With the exception of one snapping turtle, the turtles appeared to be confined to their ponds. While some individuals were caught more often than others, the actual number of total recapture events in each population were so small that it is difficult to determine if there is a statistical imbalance in individual catchability. A study by Ream and Ream (1966) suggests that the hoop trap method of trapping used in this study attracts turtles once one is caught, due to visibility through the net, and perhaps creates data that is male skewed. However, due to some of the low recapture rates in some of the ponds, it doesn't appear that just the marked turtles were attracted to the traps. In addition the turtles seemed to move around a lot and recaptures were usually in a different trap than the one in which they were originally caught. For the Black Rock Forest populations at least, *C. picta* and *C. serpentina* populations appear to meet the assumptions of mark-recapture theory.

The main problem with this mark-recapture study was its scope. It seems that not enough data was collected to provide a clear picture of the demography of each population. Trapping was not as successful as was hoped and age was often difficult to estimate. Thus it is impossible to create a complete life table for each population. In order to estimate survivorship, fecundity and the sex ratio of hatchlings, mark-recapture studies must be done annually for several years. It seems clear from this study that there is not one main factor, such as acid rain, limiting the populations. Rather the ponds with the healthiest populations seem to have the most going for them, while the most depraved populations have all the strikes against them. To better understand to what degree population density, sex ratios, topography, vegetative biomass, predation and several other factors influence turtle populations, a solid understanding of the population in question must be acquired. This means more traps per pond in order to learn exactly the movement patterns of the turtles. Also, trapping earlier in the summer and into September, when sexual activity is at its peak, may result in more captures (Ream and Ream 1966). Mark-recapture studies involving *C. picta* and *C. serpentina* have the potential to teach us a great deal about turtle ecology.

FUTURE STUDIES

This study only scratches the surface of what we can learn from demographic studies. A well planned, long term study of the turtles in Black Rock Forest could lead to a greater understanding of the turtles role in the ecosystem. Future studies at Black Rock need to focus on the relationship between sex ratios and population growth;

continued research into the affects of acid rain, and the availability of nest sites. Perhaps building artificial beaches on some of the less productive ponds would bolster nest survivorship.

Turtles are well adapted to their natural environment, but are also susceptible to drastic changes that offset the natural balance. Perhaps turtles may even be used one day as an indicator species to determine pollution levels in freshwater ecosystems. The turtles of Black Rock are an educational asset and need to be used appropriately. Hopefully the small headway made in this study will continue in years to come, continuing the tagging of turtles every summer. In a few years, the majority of turtles in Black Rock could be tagged electronically and Black Rock could become a leading center in turtle ecology. This goal is quite feasible if more in depth demographic studies based on mark-recapture data take place.

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