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Charles H. Lobdell
Virginia Polytechnic Institute and State University

Robert H. Giles Jr.
Virginia Polytechnic Institute and State University

A MODEL FOR DETERMINING LEAST-COST QUAIL STOCKING PROGRAMS

Charles H. Lobdell and Robert H. Giles, Jr., Division of Forestry and Wildlife Sciences, Virginia Polytechnic Institute & State University, Blacksburg

Abstract:

A model is presented to allow the calculation of the minimum cost of providing an acceptable level of quail hunter success expressed as kill per day. The model is based on a Poisson distribution for hunter kill per day, the number of hunters, their success rates, quail survival rates, various costs of quail production and release, stocking levels, and frequency of stocking. An example is given.

Game farm quail (*Colinus virginianus*) have been used primarily to provide hunting opportunity in areas having low populations of game birds and a high level of hunting pressure. Secondarily, these birds have been used to replenish areas where wild birds vanished due to temporary habitat losses or other factors.

In some highly populated urban areas, it may be desirable to stock birds to provide hunting opportunity for the urban hunter on a stock-shoot basis. Although superficially expensive, it can be demonstrated, in areas of high hunter demand and limited habitat, that (A) it is impossible to satisfy hunter demands from natural stocks, and (B) the cost per bird harvested or the mean cost per unit of hunter satisfaction is less under the stock-shoot program than under a natural habitat production program. All evidence indicates that to get the most out of a stock-shoot program, large numbers of birds should be released on limited areas that are heavily hunted. This procedure ensures that a high proportion of the birds will be harvested before the birds die of other causes or before they disperse from hunting areas. Game managers recognize that stocking will not insure increased game populations or even increased harvest levels if the birds are stocked too many months prior to the hunting season. Yet such stocking programs continue.

It is not the purpose of this paper to discuss the biological shortcomings of the use of pen-reared birds to achieve the second objective. Numerous accounts in the literature point out these deficiencies (1,2,3,4).

It is recognized that the percent of the released birds eventually killed by a hunter is inversely proportional to the length of time between the stocking date and the opening date of the hunting season.

Under such a system of intensive management it is important to minimize costs and increase efficiency. A model has been developed to achieve such efficiency. It is based on the previous concept and utilizes the knowledge of game managers about the size and temporal distribution of the kill, cost of raising quail or other game birds, the extent of natural mortality on released birds, the temporal and spatial distribution of the hunting pressure, and the effect of success on the total hunting effort. The model allows a priori assessment of the cost of stocking programs with various rates and replenishment schedules and, thus, the least cost solution for providing satisfactory stock-shoot quail hunting. It is the purpose of this paper to develop such a model and to present its theoretical basis. It is demonstrated that a computer is not required, but the problem could be formulated for computer solution.

Hopefully, this paper will stimulate further use of mathematical models in analyzing biological processes to increase the efficiency of wildlife management.

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Development

Through use of mail surveys and other means, the size of the kill, number of days hunted, and the temporal distribution of the kill is known by most state agencies. Marking released birds with leg bands had provided estimates of the natural mortality of these birds as well as the percentage of the birds released that are killed by hunters. Field studies have provided information on behavioral habits of wild birds, such as average covey size at the start of the hunting season. These parameters, with some qualifying assumptions, provide sufficient information to analyze stock-shoot programs. From such analysis a model can be developed. The objective of the model is to minimize the cost of providing an acceptable level of hunter success expressed in terms of the kill-per-day.

Assume that the probability of x kills per day by a hunter follows a Poisson distribution having a mean m, where

$$m = N/C \tag{1}$$

and

N = the size of the stocked population

C = the number of birds that must be stocked per harvested bird.

Thus, the probability that a hunter bags x birds in 1 day is

$$\frac{m^x e^{-m}}{x!} \ ; \ x = 0,1,2,... \tag{2}$$

which is the mass function for the Poisson distribution.

The goal of the manager is to provide a sufficient population of stocked birds such that a predetermined percentage of hunters, S, harvests at least x birds per day. The probability that the kill per hunter is equal to or greater than x is

$$p(X \geq x) = P(x,m) = \sum_{\chi=x}^{\infty} \frac{m^x e^{-m}}{x!}$$

The complementary cumulative distribution function, $P(x,m)$, for the Poisson distribution is tabulated in many statistics and mathematics handbooks. To use these tables to determine the number of birds that must be present to ensure with probability S that a single hunter bags at least x birds, one simply searches the table in the rth row or column until he finds a value greater than or equal to S in the column or row corresponding to a particular m. Then from (1),

$$N = m \cdot C. \tag{4}$$

With most stocking programs, birds released to the wild have poor survival. Assume the number of birds dying from causes other than hunting in a given period is proportional to the size of the population. The simplest functional relationship is

$$M = K \cdot N \tag{5}$$

where

M = the number of birds dying of causes other than hunting, and

K = a constant mortality rate per week.

Let P_t represent the number of hunters hunting in a given time period t. P_t is a function of the number of hunters in the population and the success of the previous hunt. This relationship is formulated as

$$P_t = H \cdot S^t; \quad t = 0,1,2,\ldots \tag{6}$$

where

H = the number of hunters that hunt the area on opening weekend, and

S = the percent of hunters bagging at least x birds per day.

The number of hunters is assumed to decrease at a rate proportional to declining success rate, S, between replenishment stockings during the season. It is further assumed that a hunter ceases to hunt in any year as soon as he fails to bag at least x birds in a single hunt.

Due to the leisure patterns of the average citizen, most hunting takes place on the weekends. It is assumed that the amount of hunting during the week (except on opening days) is insignificant. That is, from a total quail population management point of view, the effect of this hunting mortality is completely substitutable with natural losses and is, therefore, included in the constant K in (5).

Each time birds are released, the cost of the effort can be represented by equation 7.

$$TC = F + V \cdot N \tag{7}$$

where

F = the fixed costs independent of the number of birds released (N)

V = the cost per bird.

In most instances, the size of the stocking programs is sufficiently large so that the fixed costs are negligible and can be ignored. Thus the problem of minimizing cost reduces to one of maximizing the utilization of the released birds. To do so, it is assumed that birds will be released immediately prior to the weekend when most hunting activity takes place.

Define r_t as the stocking level prior to each weekend t, $t = 1,2,\ldots,$ w where w is the length of the hunting season in weeks. The number of birds released prior to the opening weekend is

$$r_1 = P_o N \tag{8}$$

If Q_t, $t = 1,2,\ldots,$ w is the residual population at the end of the t<u>th</u> week, the replenishment stocking level (r_t) becomes

$$r_t = \begin{cases} 0 \text{ if } Q_t > P_t N \\ P_t N - Q_t \text{ otherwise} \end{cases} \tag{9}$$

where

$$Q_t = \begin{cases} P_o(N-m)\ (1-K) \text{ if } t = 1 \\ \sum\limits_{i=o}^{t-1} (r_i - P_i m)(1-K) \text{ if } t > 1 \end{cases}$$

The total number of birds released throughout the season is $R = \sum\limits_{t=o}^{w} r_t$.

Example

Assume it desirable to stock enough birds so that 95% of the hunters bag at least 1 bird per day ($S = 0.95$). From cumulative Poisson tables we read across the row corresponding to $x' = 1$ until we find a value greater than or equal to 0.95. This value is found in the column corresponding to $m = 3.0$, the mean kill per day per hunter.

Assume that 1.5 birds must be released per quail harvested ($C = 1.5$). Thus the number of birds to be stocked so that a single hunter will have a 95% chance of bagging at least 1 bird is

$$N = mC = 3.0(1.5) = 4.5$$

If 20% of the population dies each week from nonweekend hunting causes (K = 0.20), if the hunting season is 4 weeks long and starts on a weekend, and if the expected hunting pressure on the first weekend (P_o) is 1000, then the size of the initial stocking, r_1, will be 4,500 birds.

Using (6); t = 0,1,2,...,4, then the hunting pressure on subsequent weekends is

$$P_0 = 1000$$
$$P_1 = 950$$
$$P_2 = 900$$
$$P_3 = 855$$
$$P_4 = 812$$

The total hunting pressure, P, is 4,517 hunter days. The residual population (Q_o = 0) is

$$Q_1 = P_o(N-m)(1-k) = 1000(4.5 - 3.0)(1-0.2) = 1200$$

The replenishment stocking level for the end of the first week is

$$r_1 = P_1\,N - Q_1$$
$$950(4.5) - 1200 = 3075$$

The residual population and the replenishment stocking level after the second week is

$$Q_1 = P_1\,(N-m)(1-K) = 950(4.5 - 3.0)(.8) = 1140$$

$$r_2 = P_2\,N - Q_2 = 900(4.5) - 1140 = 2910$$

In a similar manner, we obtain

$$Q_3 = 900(1.5)(.8) = 1080$$

$$r_3 = 2768$$

and

$$Q_4 = 855(1.5)(.8) = 1026$$

$$r_4 = 2628$$

$$R = \sum_{t=o}^{4} r_t = 15,881$$

The total cost of this effort is

$$TC = 5(F) + 15{,}881\ (V)$$

if $F = \$100.00$ and $V = 1.00$, then

$$TC = 500.00 + 15{,}881 = \$16{,}381$$

The total weekend kill ($P \cdot m$) is ($4517 \cdot 3.0$) = 13,551 quail.

This example demonstrates the use of the model, resulting in a calculation of 4,517 hunter days of quail-based recreation being produced for a minimum total cost of $16,381, or about $3.60 per hunter day.

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FORMULATION OF AN OPTIMUM WINTER FOOD-PATCH MIX FOR BOBWHITE QUAIL

Charles W. Smart, Edward B. Rayburn, Oscar T. Sanders, Division of Forestry and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg

Abstract:

Many state game agencies are seeking to improve winter quail food and habitat by means of artificial food-patch plantings. The objective of such plantings is to increase the limited supplies of nutrients available to quail in late winter. Desirable qualities of food species included in the seeding mixture are: low seeding cost, high nutrient and energy content, persistent seeds, and cultivation ease.

Presently used mixtures have been formulated in the absence of detailed nutritional analysis and cost-minimization techniques. This paper seeks to demonstrate the utility of modern operations-research technology in such decisions by outlining the procedures for determining the composition of an optimum food-patch mix. This mix will meet nutrient and cultivation requirements at a least-possible cost per acre of food planting. Although a solution is presented, the emphasis of the paper is on the method for obtaining such a solution.

In many states, the establishment of artificial food-patch plantings is a major activity in bobwhite quail management programs. The