A Bountiful Harvest for Science

HOW CONSERVATION SCIENCE BENEFITS FROM THE STUDY OF GAME SPECIES

By Gary C. White, Ph.D., and Chad J. Bishop, Ph.D.

Courtesy of Gary C. White

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Credit: Margie Michaels

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The Dust Bowl days of the "Dirty Thirties" were a disaster for settlers in North America's Great Plains and for waterfowl populations. The extreme drought of this period depressed populations of both farmers and ducks. Yet the devastation to game bird populations led to a breakthrough in the science of estimating wildlife populations—just one illustration of how the study of game species can benefit conservation.

In the 1930s, Jay "Ding" Darling was a political cartoonist for the *Des Moines Register* and an avid hunter. Alarmed by the decline in duck numbers, he published multiple cartoons illustrating the plight of waterfowl during the extended drought. Appointed in 1934 to head the Bureau of Biological Survey (forerunner of the U.S. Fish and Wildlife Service), Darling wanted to learn how the drought had affected duck populations.

To the rescue came Frederick Lincoln, who ran the Bureau's bird banding program. Bird banding was primarily a private enterprise at the time, but Lincoln recognized that the recovery of waterfowl bands could provide a method to estimate waterfowl populations. He realized that bands placed on waterfowl prior to the hunting season represented the first sample of a mark-recapture survey, and that hunter recoveries of banded and un-banded birds represented the second sample. Based on the probability that a harvested bird was banded, Lincoln demonstrated how to compute an estimate of the North American waterfowl population (Lincoln 1930). Wildlife professionals now know this mark-recapture estimator as the Lincoln-Petersen index (see box on page 45).

Known as a careful scientist, Lincoln understood the assumptions required to generate a valid estimate, yet he faced two problems: Bands were not uniformly dispersed throughout the waterfowl population, and the estimates of harvest were likely biased. To improve estimate accuracy, Lincoln encouraged hunter cooperation. "American sportsmen who are vitally interested in the perpetuation of an abundant stock of wild fowl and in the American sport of free shooting," wrote Lincoln, "should be willing to do all in their power to see that all banded birds are reported to the Bureau of Biological Survey and to furnish reports concerning their seasonal bags, and other information, when requested to do so" (Lincoln 1930).

Waterfowl harvest brought about the development of Lincoln's method, demonstrating how game hunting has played a critical role in monitoring waterfowl for the benefit of conservation. Likewise, many other scientific advancements have sprung from the study of game populations, including the estimation of survival rates, understanding density dependence, balancing predators and prey, insights into survival variation, adaptive management, marking techniques, and habitat enhancement.

Estimating Survival Rates

In 1970, renowned statistician George Seber published a very technical mathematical paper on how recoveries of dead animals could be used to estimate survival (Seber 1970). Yet the paper appeared in *Biometrika*, a journal that most wildlife professionals would not have read or even known about, with a level of mathematics far beyond what was familiar to most wildlifers of the day. Fortunately David Anderson, a U.S. Fish and Wildlife Service (FWS) biologist working at the Patuxent Wildlife Research Center, *did* recognize the significance of the Seber study. Anderson has said that he couldn't believe his luck at finding a method that would do exactly what he wanted—estimate survival rates. It was one of those eureka moments.

With paper in hand, Anderson assembled a team that greatly extended the theory of how survival rates were estimated. He hired biometrician Ken Burnham and established a connection to Doug Robson, a statistician at Cornell University. Robson recruited graduate student Cavell Brownie, and the rest, as they say, is history—at least for wildlife professionals. The team produced some of the first specialized computer software to estimate survival rates of waterfowl banded as adults (the ESTIMATE

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program) and banded as both juveniles and adults (the BROWNIE program). The analyses produced by these software packages included goodness-of-fit tests, a broad set of models, and likelihood ratio tests between models. A major scientific report documenting the team's theory and software was published in 1978 (Brownie *et al.* 1978) and revised in 1985 (Brownie *et al.* 1985).

Game harvest enabled the development of these survival estimation methods, which are still routinely used worldwide to manage waterfowl populations. These methods have been extended to analyze data from encounters with both live and dead animals, and thus are useful for the study of many species that are not hunted. They have also been extended to apply to animals marked by other means, such as live recaptures and re-sightings. For example, survival rates of albatrosses might be estimated from data collected on recaptures and re-sightings at the breeding colony and from band returns from albatrosses accidently killed in commercial fishing activities. Ultimately, defensible management of wildlife species—hunted or not—depends on reliable estimates of survival. Anderson and his colleagues provided that foundation.

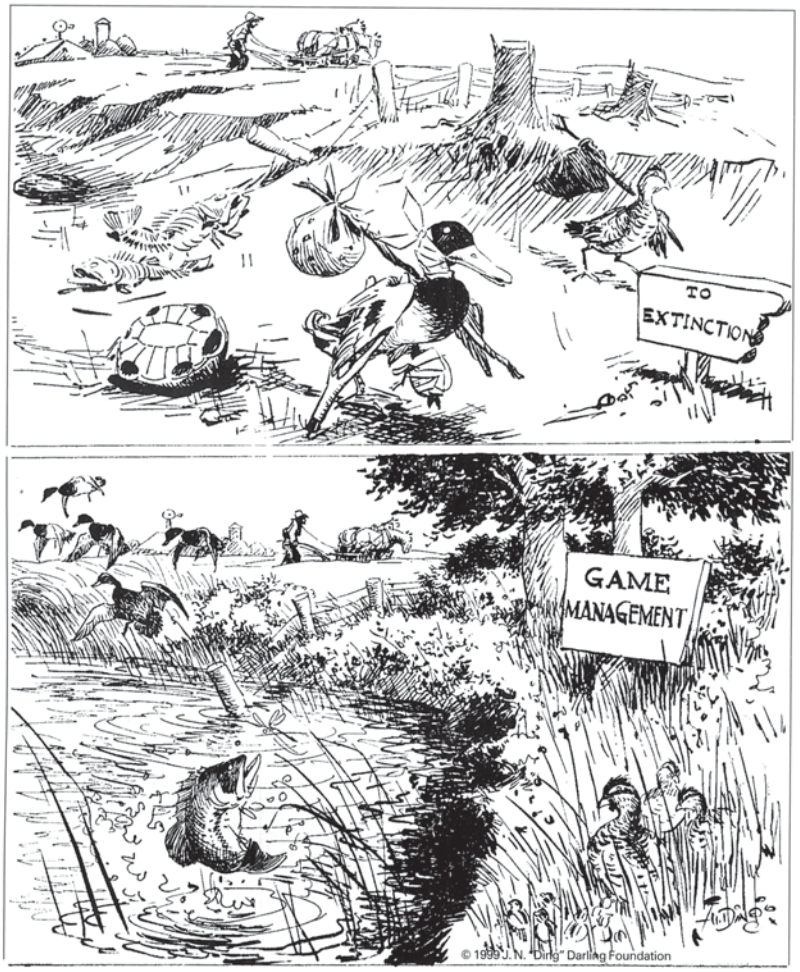
Understanding Density Dependence

Manipulating game populations through harvest has contributed to the scientific rigor of wildlife management. To study the effects of density dependence on population regulation, population size must be manipulated to obtain cause-and-effect results. Biologist Dale McCullough's work with white-tailed deer on the George Reserve of southeastern Michigan offers a classic case in point (McCullough 1979). McCullough manipulated deer populations within the fenced reserve to measure fawn recruitment to the reproductive population. His work clearly showed how fawn recruitment responded to the density of deer within the Reserve, and thus supported density-dependent population models.

As part of our own research in Colorado, we have had sport hunters manipulate populations of mule deer to evaluate the impact of density on fawn survival (White and Bartmann 1998). We estimated fawn survival in two areas using radio-tracking, and then reduced the deer population in the treatment area through sport hunting. Each hunter was allowed to take two antlerless deer. The results demonstrated that over-winter

Credit: Michelle Gallagher/Colorado Division of Wildlife

Doing its part for science, a young mallard in Colorado receives a leg band from Kammie Kruse of the U.S. Fish and Wildlife Service. Part of the Migratory Bird Management project, banding helps determine survival and reproduction of resident ducks, a game species often used for scientific research of waterfowl.



Courtesy of the J. N. "Ding" Darling Foundation

The cartoons of avid hunter and conservationist Jay "Ding" Darling spoke powerfully of the need for active game management to ensure the health of species and habitats. A Pulitzer Prize-winning cartoonist, Darling designed the first Federal Duck Stamp in 1934.

Credit: Ken Logan/Colorado Division of Wildlife

Wildlife veterinarian Lisa Wolfe assesses a captive mule deer (above) and other colleagues weigh a fawn (below) during studies of density dependence in Colorado. Hunting has been used to manipulate wildlife populations to advance scientific understanding of density dependence, predator-prey relationships, and other issues.

Courtesy of the Colorado Division of Wildlife

fawn survival increased with decreasing density (i.e., increased harvest). This finding supports the compensatory mortality model, which describes how increased mortality from one source (such as hunting) results in decreased mortality rates from other sources (such as predation or disease) and a survival rate that remains constant. In contrast, the term additive mortality describes how an increase in a mortality source is additive to existing mortality, and thus the resulting survival rate declines. An increase in a source of mortality can be completely additive, with the survival rate dropping by the amount of increase in this mortality, to full compensation of this increase mortality whereby the survival rate remains unchanged.

Balancing Predators and Prey

Hunting and trapping can inform science about predator-prey relationships by manipulating predator populations. In Idaho, for example, biologist Mark Hurley and colleagues recently reduced coyote and puma populations to measure the impact on mule deer survival and population levels (Hurley *et al.* in review). Extensive coyote removal did not influence overwinter survival of six-month-old fawns or annual survival of adult females, which was consistent with past findings in Colorado (Bartmann *et al.* 1992). Coyote removal had a positive effect on newborn fawn survival, but only when small mammal abundance declined and coyotes became dependent on deer fawns as alternate prey. Puma removal increased survival of adult female deer during winter, although weather had the most influence on winter survival. Extensive predator removal did not have a detectable effect on population change, whereas winter weather severity did. These results demonstrate that increased predator harvest is not a particularly effective means of increasing mule deer populations in southeast Idaho.

In Alaska, wolf control through hunting has led to a deeper understanding of wolf-moose and wolf-caribou dynamics (Boertje *et al.* 1996). In contrast to Hurley *et al.*'s work, Rodney Boertje and colleagues studied historical data and concluded that controlling wolf populations in combination with favorable weather can increase long-term abundance of wolf, moose, and caribou populations. Initial reduction of the wolf population allowed moose and caribou populations to grow, and thus support a larger wolf population after wolf control stopped. Benefits to humans from wolf control included enjoyment of more wolves, moose, and caribou and harvests of several thousand more moose and caribou than would have been possible if wolf control had not occurred.

These sorts of studies contribute to our understanding of population dynamics and are possible because of the ability to manipulate populations through controlled harvest. Without manipulation, we cannot evaluate whether observed predation is actually having an impact on prey populations, and therefore whether predation or some other factor is ultimately limiting population growth. Such studies reveal the complex relationships between predators and their

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prey and how other factors such as weather and alternate prey influence those relationships.

Enhanced understanding of density dependence and predator limitation in harvested populations can be extended to non-hunted species. Identifying and understanding potential limiting factors of population growth is fundamental to management of sensitive or declining species, many of which are not conducive to large-scale experimentation. Population models and subsequent management decisions for sensitive species are directly influenced by our understanding of population dynamics gleaned from studies of more abundant hunted species.

Insights to Survival Variation

Long-term research and monitoring efforts on game species have also contributed to our understanding of population dynamics by quantifying how survival rates vary over time (i.e., process variance). Because of the economic importance of game species, wildlife management agencies are willing to conduct costly long-term survival monitoring efforts. For example, the Colorado Division of Wildlife estimates annual survival rates of mule deer via radio-tracking of fawns and adult females on five intensively studied populations. These survival data enable improved population models to set harvest levels. The variation in annual survival rates is a critical piece of information required to estimate the probability of population decline or extinction. This information is typically lacking for endangered species, yet is necessary for any realistic population viability analysis.

Game species can be used as surrogates to construct realistic population viability models for endangered species because scientists can monitor game species over a time period long enough to achieve more precise estimates of the process variance of critical parameters (White 2000). For example, sex- and age-specific survival rates of North American mallards have been estimated for over 50 years with the band recovery models described above. In contrast, most endangered species completely lack any information on the variance of the survival process, which typically isn't possible to obtain given so few individuals available for study.

An Adaptive Approach

Analysis of game species has recently become more sophisticated through the use of adaptive harvest management, or AHM, which involves collaboration of wildlife managers and scientists in making management decisions and adjusting those decisions as circumstances change. "Key elements of this process are objectives, alternative management actions, models permitting prediction of system responses, and a monitoring program," writes USGS biologist James Nichols. "The iterative process produces optimal management decisions and leads to reduction in uncertainty about response of populations to management." This adaptive approach represents the most modern theory of harvest management to date.

An Enduring Tool

In 1896, Danish fisheries biologist Carl Petersen developed an innovative mark-recapture method to estimate fish populations. Some three decades later, Frederick Lincoln adapted the method for a bird-banding program to estimate waterfowl populations. In use ever since, the Lincoln-Petersen estimator provides a simple ratio for determining population size as follows:

$$\hat{N} = \frac{n_1 n_2}{m_2}$$

where $\hat{N}$ is the estimated population size, n_1 is the number of ducks banded, n_2 is the number of ducks harvested (both banded and unbanded), and m_2 is the number of banded ducks harvested.

(*As an aside, note the correct spelling of Petersen, which reflects his Danish heritage. Incorrect spelling of his name is likely one of the most common errors in wildlife literature.*)

Credit: Jake Ivan/Colorado State University

A newly re-collared snowshoe hare pops free of a handling bag during a study on hare density and demography in Colorado's Gunnison National Forest. Snowshoe hares are a primary food source for Canada lynx, reintroduced into the state in 1999. To ensure lynx survival, researchers study hare distribution and potential impacts on populations.

Since 1995, for example, FWS has implemented AHM to set hunting seasons for mid-continent North American mallards (Nichols *et al.* 2007). Scientific analysis has shown that recruitment in the population is weakly density-dependent, but that almost equal weight is assigned to additive versus compensatory mortality (Nichols *et al.* 2007). These results make biological sense. In years where good water conditions result in elevated production of young, hunting mortality is additive, because more ducks returning to the breeding grounds would result in larger population increases. Conversely, in years with poor water conditions, the excess of breeders relative to the conditions do not produce young, and therefore can be harvested with no impact on the population.

This case illustrates one of the major benefits of AHM—that we learn about the system in the process of making and adjusting management decisions. Adaptive management may not be as focused on learning as traditionally manipulative experiments (such as agricultural plot experiments analyzed with analysis-of-variance procedures), but it does foster new knowledge while enabling optimal decisions about management. Such approaches are therefore beginning to be used to manage non-game species and to facilitate science-based management within a structured stakeholder decision process.

Catch, Mark, and Release Techniques

Research on abundant game populations such as deer, elk, and waterfowl has helped scientists to evaluate and refine a number of animal capture, handling, and marking techniques, which can then be used safely on rare species. In fact, the Animal Care and Use Committee would not give researchers approval to handle threatened or endangered species with any technique that has not been extensively tested on abundant species. This includes techniques involving drop nets, Clover traps, helicopter darting, helicopter net capture, cannon-netting, and a wide array of sedation drugs and methods of delivery. Such techniques can be refined and adapted for use on less-plentiful species with reduced risk of harming or killing the individuals. Cannon nets used to capture abundant gulls or crows, for example, have been refined for capture of waterfowl and turkeys.

Habitat Enrichment

Scientific advancements stemming from research and management of hunted species have only been possible because of the large amount of funding provided by sportsmen. As decades of experience have clearly shown, habitat protections that were funded for particular game species have benefitted myriad non-hunted species and helped keep ecosystems intact. Waterfowl production areas in the Rainwater Basin of south-central Nebraska, for example, were funded to increase waterfowl production for hunters, yet these areas also provide excellent habitat for endangered whooping cranes during spring migrations.

Just as the management of habitat for hunted species benefits many others, the wildlife profession's scientific evolution has benefitted enormously from sportsmen's dollars. The management of hunted populations requires sound information, and this quest for information has lead to many scientific advancements. In a very real sense, those who harvest wildlife have helped generate new management techniques, theory, software, methodologies, and basic scientific knowledge that will help our profession meet the challenges facing numerous wildlife species, now and into the future. ■

This article has been reviewed by subject-matter experts.

For a full bibliography, go to *www.wildlife.org*.

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