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# SEARCHING THE INTERNET TO ESTIMATE DEER POPULATION TRENDS IN THE U.S., CALIFORNIA, AND CONNECTICUT

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## ABSTRACT

*Information for decision making may be publicly available, but costly to obtain. As an experiment in environmental scanning, the internet was searched on a daily basis over several years to collect information and provide analysis related to decisions on deer management. The process discovered that, contrary to common assumptions, the U.S. deer population has apparently been falling since about the year 2000 based on analysis of available state data that had not been aggregated. In some cases, state population estimates were created using standard procedures on available data. Results indicate that differences in survey methods appear to be relatively constant over time as does the ratio of hunting data to official state population estimates. While reliability intervals for population estimates are wide, population trend reliability is relatively high. An analysis of Connecticut and California illustrate problems with the population estimates. In Connecticut, an independent group that financed some local surveys assert the state has overestimated the population. In California, some population estimates reported to the public are inconsistent with historic information, masking the dramatic decline of the deer population in the state.*

**Keywords:** Environmental Scanning, Data Analysis, Deer Management, Knowledge Base

## INTRODUCTION

Recent advancements in information systems have lowered the cost of acquiring information relevant to decision making. Public availability of information on the internet has reduced acquisition costs and dramatically expanded the amount of information available. Easy access to analytical tools have enhanced the ability to organize information in a form useful to decision makers. For this project, information related to deer management has been collected from a daily internet search and from targeted searches. A website knowledge base was created to allow users to find relevant information and to provide analysis of relevant issues.

Deer belong to the people of each state. To support public input into the management decision process, each state has some kind of information system to distribute information to the citizens and to help manage the deer herd, allowing for public input. Wisconsin has recently revised its process, greatly increasing citizen input. With the rise of the internet, information related to deer management has been provided on each state's website. Many states have given up the old method of selling deer hunting licenses through stores, moving to their website and apps that hunters can take with them to the field on their smart phones. Although this saves time for the hunters and money for the states, rural businesses have suffered as hunters often no longer come into rural stores to buy their deer licenses. Data from deer hunting, the deer harvest, are commonly used estimate deer population trends which are widely considered to be important an input into deer management (Artelle, et al., 2018; Callcutt & Smith, 2018).

Wildlife agencies generally have authority to change the number of hunting licenses sold, but not to change the price. Prices for hunting on public land are generally well below prices on private land. This economic disequilibrium creates an incentive for overhunting on public land and for manipulation of sex ratios to increase deer populations (Webb, 2016). Also, an incentive to overstate the deer population. A careful analysis of Idaho's historic data concludes that a wildlife manager "inserted the exaggerated 1960s harvests back into Idaho's deer harvest history to hide the evidence of the biologists 1960s destruction of the mule deer herds" (Dovel, 2004, p. 4).

As part of the search process it was discovered that the national U.S. deer population trend was a significant decision issue. However, there were no recent available population estimates and the consensus speculation on the current direction of the population trend appeared to be incorrect. The last figure in this paper provides a population estimate for the U.S. deer population from 1450 to 2016 created by aggregating and doing analysis on information from a wide combination of public sources, including websites of state wildlife agencies. Population estimates are also provided for Connecticut and California as an illustration of issues related to the estimation process and the reliability of the estimates.

In Connecticut there is evidence the state's population estimates may be too high, supported by some independent surveys in areas that are particularly important because they are where a Center for Disease Control study is evaluating the relationship between Lyme disease risk and the deer population. In California, a graph of the historic deer population was removed from the wildlife agency's website after a presentation to a local wildlife conference (Webb, 2015) demonstrated the population estimate was not consistent with historical information, based on information collected in the environmental scanning process. A comparison of this graph to a population estimate based on harvest data appears in the section about California. Collected data indicate that California has experienced the largest decline in the deer population for any state over the past 100 years (Webb, 2016).

**Environmental Scanning**

Choo (2001) defines environmental scanning as "the acquisition and use of information about events, trends, and relationships in an organization's external environment" (p. 1). Soniewicki (2017) reports that environmental scanning is the first step in the strategic management process. An early field study of environmental scanning found that among a variety of information sources (including company library, databases, internal documents, and consultants) that usage was positively related to accessibility (Culnan 1983). Choudhury and Sampler (1997) provide a theoretical construct for the cost of information in decision making based on transactions cost and agency theory. Cost was found to be a critical success factor in the implementation of a data warehouse among business enterprises (Ojeda-Castro, Ramaswamy, Rivera-Collazo, & Jumah, 2011). Ebersold and Glass (2016) note that the Internet of Things is likely to further reduce transmission and information cost.

For this project, the primary scanning approach was to search the internet on a daily basis using the Google Alerts search tool and Microsoft's Bing. Deer harvest data, population estimates, and information on other factors affecting the population estimates were collected. The information was organized by state in a web-based knowledge base.

## THE DATA

When possible, official estimates of deer populations were used. Estimates by public officials reported in the press were also used to fill in gaps in the data. In years when no population estimates were available, the population was estimated from harvest data using the approach described in the following section. Populations were estimated at the state level then summed to get the national population estimate. A nearly complete set of U.S. data was collected back to the year 2000. Detailed data for many states was discovered dating back to the early 1900's.

One general reliability issue related to how data are reported is a result of the significant seasonal deer population change, the population may vary by as much as half over a year. Agencies sometimes specify that they are referring to the pre-hunt or post-hunt populations when they provide annual population estimates, but often no distinction is made. The population number is quite different depending on the time of the year. For a region with winter habitat, minimum populations occur around early April at the end of winter when food is still scarce. Maximum population occurs around May and June when fawns are born. All fawns are born around the same time in part to reduce the number that can be taken by predators.

As Figure 1 illustrates, deer populations that are hunted less come into the winter with a higher population because the hunt generally starts in the fall, continuing into the early part of the next winter. Fawn season begins in late April extending into July. The number of fawns born per doe is density dependent, so the hunted population will have a higher fertility rate restoring some of the numbers lost in the hunt. Fawn survival rates over the summer vary depending on the weather and pressure from predators and other factors. Other mortality such as disease and predation are present throughout the year but may also have a seasonal element.

A deer fertility feedback control system balances the population (Keyser, Guynn, & Hill, 2005; Richter & Labisky, 1985). When deer are not hunted, more deer are eating and using their habitat through the late winter into fawning.

That leaves less available habitat per deer so the doe fertility rate is lower, reducing the spring population increase. This kind of feedback system has been reported in other mammals such as rabbits (Davis & Pech, 2002), mountain goats (Swenson, 1985), and feral horses (Kirkpatrick & Turner, 1991).

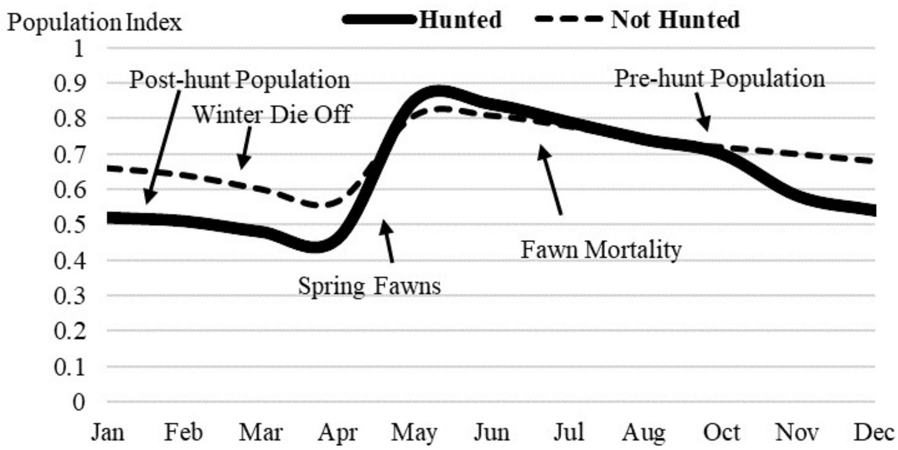


**Figure 1.** Representative Seasonal Pattern of Annual Deer Population with Winter Habitat

**Deer Harvest Data**

For many years the number of deer taken by hunters was called the deer kill. In the last decade or two the term has generally been changed to the "deer harvest" although there is controversy about this change. Except for a few years when a state did not report the harvest, a nearly complete set of harvest data was assembled for all states back to the year 2000. A continuing goal of this project is to provide easy public access to as complete a set of historical data as possible.

Each state conducts its own data collection process so there are many variations in how data is collected that significantly affect the values that are reported. For example, some states estimate from different types of hunter surveys, some states ask hunters to report their kill and some states make that mandatory. California has used several approaches so provides a good example of differences in how data are collected. These issues are discussed in a following section explaining a long-term deer population estimate for the state.

## POPULATION ESTIMATION

The results of the annual deer hunt, the deer harvest, are an important source of information to estimate deer populations (Roseberry & Woolf, 1991; Wade & McDonald, 2010). States such as New Hampshire, New York, and West Virginia have used a multiple of the two-year moving average of the buck harvest as a basis for the population estimate. The buck harvest is used since the doe harvest is more variable because it is routinely managed by the states to control the population. One hypothesis that proved to be significant when tested using data from California is that the state's population estimate is a statistically significant multiple of the buck harvest.

To estimate population, harvest data may be supplemented with surveys, including aerial surveys with new technology such as advanced infrared imagery (Kissell R.E. Jr., & Nimmo, S.K., 2011) and increasing use of drones (Linchant J., et al., 2015). Surveys are a major input to the population estimate in states like Connecticut. Also, collection of data relevant to deer survival supports estimates, including winter severity, precipitation, and mast crop. Data on deer-vehicle collisions are also used.

State deer populations estimates are routinely controversial. Hunters are often concerned that population estimates are too high while farmers and auto insurers tend to be concerned that estimates are too low. To avoid controversy or to reduce management costs, some states have stopped making formal estimates, but will sometimes give rough estimates to the press. For example, the new deer management plan for Maine (Remington, 2018) shifts from estimating population densities to a focus on deer health, a change that has garnered skepticism from the public.

**The Add Factor**

In many cases, qualitative information was available relevant to the population estimate. This type of information was entered into the model by judgement, a positive or negative adjustment to the population estimate created from the harvest data. Olsen and Wulfsberg (2001) discuss the common use of add factors in computer models. For example, where there is a large acorn crop, deer will not move around as much for food and so the deer kill will go down. It would be possible to create quantitative estimates of this effect, but obtaining the data is costly and the data are often spotty and lack standardization. So while the long term trend is determined by the harvest data, year to year adjustments are made qualitatively to reflect whatever extra information is discovered through the environmental scanning process. Examples of add factors used in population estimates are described with the following results.

## RESULTS

In this section estimates for the Connecticut deer population, 2000 to 2016, the California deer population, 1911 to 2017, and the U.S. deer population, 1450 to 2016, are provided. Harvest data for 2017 was not yet available for all states. Hypotheses are tested for the relationship between two methods for gathering harvest data, reported and surveyed, and for the stability of the multiple relating harvest data to the population estimate. Formal tests were done for California where there is enough data to make a relatively large sample.

**Connecticut Deer Population Estimation Issues**

Figure 2 illustrates the population estimate for Connecticut created by combining data from three sources: an official population estimate in 2006 (Hladky, 2015), estimates reported to the press by the state for 2000 and 2016 (Miller, 2016), and deer harvest data reported by the state. In this case, the total harvest was used because the buck harvest data was incomplete.

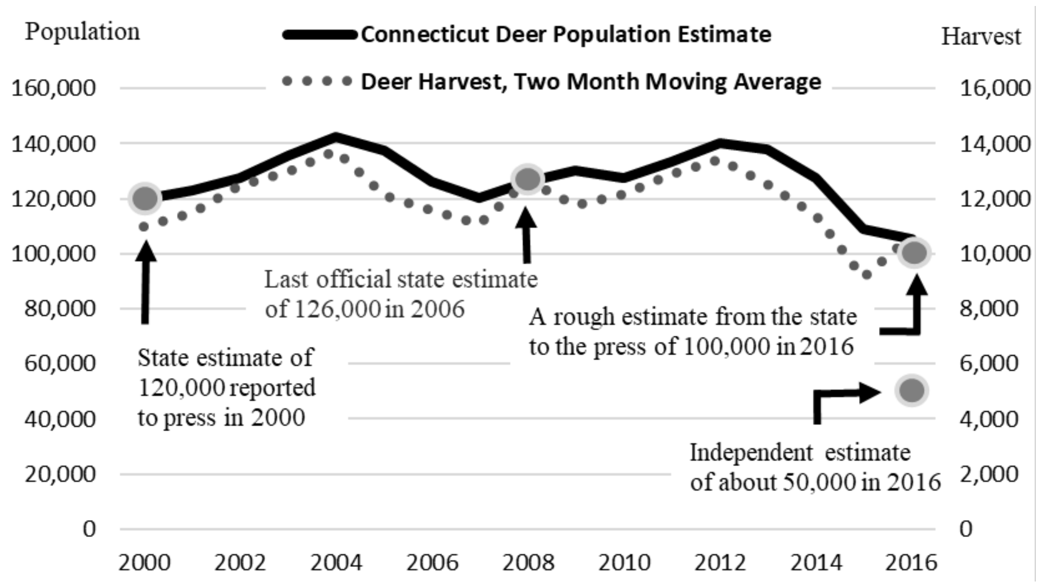


**Figure 2**. Estimated Connecticut Deer Population and Reported Deer Harvest
Harvest data from the Connecticut Department of Energy and Environmental Protection.
Harvest data from 2000 to 2003 is estimated from a graph in the 2013 Deer Program Summary.

The 2016 population estimate provided by a state official as a rough estimate reported to the press was about 100,000. A similar number of 105,2013, illustrated in Figure 2, was based on the two year moving average of the deer harvest, extrapolating the 2006 official estimate forward. The state's official 2006 population estimate was 10.62 times the two year moving average of the total harvest so this multiple was used.

The 2006 official estimate was also extrapolated backwards to the year 2000, giving an estimate for that year of just under 120,000, similar to the rough estimate for the year 2000 provided by a state official to the press, also 120,000. A small add factor was used for the following year, 2001, since the harvest data indicated a slight increase in the population above the state's rough estimate of 120,000 for year 2000. The similarity of the rough and formal population estimates from the state and the estimates based on harvest data indicates that the harvest data can be used to provide reasonable estimates of population trends. The state used harvest data and aerial surveys for their population estimates. However, these numbers were not without controversy.

At issue in Connecticut is the multiple used to convert survey or harvest data to the population estimate. A group of hunters looking at the state population estimate of 120,000 reported to the press for the year 2000 provide copies of an aerial survey conducted by the state in 1999-2000 that put the population at 76,344 (Ekstrom, 2016) and a 2006-2007 aerial survey estimate of 62,189. The hunters estimate the 2016 population at about 50,000, the independent estimate in Figure 2, noting that the 2015 harvest was just 66.2 percent of the peak in 2004. They conclude the increase in the 2016 harvest was partially attributable to a poor acorn crop, forcing deer to move more to find food and making them more likely to be taken in the hunt – a common add factor included in deer population estimates. They argue that the multiple used by the state to infer the deer population from survey is too high, that the state routinely multiplies its survey data by 2 to account for deer not observed.

Support from other sources for the declining population comes from the decline in deer-vehicle collisions, dropping by 76 percent from 2000 to 2015 (Connecticut Bureau of Natural Resources, 2015) and comments to the press from a wildlife official that the deer population has plunged, but that population estimates are so difficult that the state has quite trying to make them ("Helicopter surveys, deer", 2014).

Given their personal observations of a declining deer population, they hired an aerial survey company using FLIR (Forward Looking Infrared Radar) to conduct surveys in their area. Their survey results were the subject of several newspaper articles since the results showed a much lower population than estimated by the state in the areas of Redding, Ridgefield and Newton, Connecticut, where a large study is underway by the Center for Disease Control (CDC) to investigate the relationship between deer and Lyme disease ("Deer Survey is Flawed", 2015; "Hunters, scientists dispute deer count", 2015). Deer in the area were killed by sharpshooters to test the impact of reducing the deer population on Lyme disease risk. The FLIR survey scanned about 90 percent of area while the state used transect surveys, a sampling procedure on a small fraction of the area.

The study managers argue that they were prevented by the hunters from reducing the deer population enough to meet their study targets, while the hunters argue that targets for reducing deer populations were actually exceeded. Deer population information in this case is particularly valuable given the rising concern about how to deal with Lyme disease.

**California Deer Population Estimation Issues and Stability of Estimation Ratios**

This research project began to focus on deer population estimates when the environmental scanning of information on the internet turned up conflicting estimates for the peak California deer population. A graph from the "1998 Assessment of Mule and Black-tailed Deer Habitats and Populations in California" (California Department of Fish and Game, 1998) had been given a page on the California Department Fish and Wildlife's website. It put the peak population at around 800,000, extrapolated from the graph. For many years, a Google search on "California deer population" listed this page near or at the top of the search results. An article in the San Francisco Chronicle (Stienstra, 2013) put the number at about 2 million, a big difference. Research from this project contributed to the removal of this population graph from the department website, but the 1998 Assessment that contains the graph is still available on the internet, providing confusion for this issue.

The California Department of Fish and Wildlife (2018) currently provides numerical population estimates back to 1990 on its website. Both estimated and reported deer harvest data are available for that time, allowing for some analysis of the relationship between these different approaches to data collection. Most states only report one set of harvest data. Also, California changed from voluntary to mandatory reporting in 2015, the effect on the harvest numbers with more hunters reporting is clear in the large increase in the reported harvest for 2015 and 2016. Two assumptions of the deer population estimates for this study are that differences in reporting methods are approximately a stable ratio and that the population is a relatively stable multiple of the harvest.

The research hypotheses tested in Table 1 are that the ratios used to estimate deer populations are relatively stable:

$H_1$: The reported deer harvest is approximately a constant ratio of the estimated deer harvest
$H_2$: The estimated deer population is approximately a constant ratio of the reported buck harvest

**Table 1.** Results of Hypothesis Tests for California

| $H_1$: Relationship of Reported Deer Harvest (Dependent Variable) to Estimated Deer Harvest (Independent Variable). **Conclusion**: Strong statistical significance | | | | | |
|---|---|---|---|---|---|
| Independent Variable | Estimated Coefficient | R-square | p-Value | Lower 95% | Upper 95% |
| Estimated Deer Harvest | 0.519 | 0.982 | 0.00000 | 0.481 | 0.556 |
| $H_2$: Relationship of Estimated Deer Population (Dependent Variable) to Reported Buck Harvest (Independent Variable) **Conclusion**: Strong Statistical Significance | | | | | |
| Independent Variable | Estimated Coefficient | R-square | p-Value | Lower 95% | Upper 95% |
| Reported Buck Harvest | 28.367 | 0.975 | 0.00000 | 26.44 | 30.30 |

As Table 1 reports, both hypotheses are supported by strong statistical significance. The following analysis explains how these relationships were used to create a long-term population estimate for California

Data from the deer hunt in California were available back to 1911, about when many states started keeping records. No hunt was held from 1917 to 1926 in an effort to protect the herd whose numbers had fallen to very low levels due to overhunting. The state had a long, consistent data collection process from 1911 to 2014 that relied on voluntary reporting by hunters. The state has also more recently made an estimate based on a hunter survey. Typically the estimate from the voluntary reporting is about half that from the hunter survey (0.519 is the estimated coefficient from Table 1). In 2015, California changed its data collection process from voluntary to mandatory reporting, so there is a significant increase in reported harvest. In order to maintain a consistent base for estimating population, the relationship between the survey data and voluntarily reported data was analyzed and the reported data was adjusted using the 0.519 ratio for 2015 and 2016. The population estimate for California in Figure 3 relies on a two month moving average of the reported buck harvest multiplied by the estimated coefficient, 28.367 from Table 1.

Figure 3 shows some comparisons of this population estimate with other sources. The model overestimates an historical estimate done for 1947 ((Longhurst, Leopold, Dasmann, 1952) by about 24 percent, however, the authors indicate their estimate is 1.1 million or more, so the actual number may be higher. The estimate for 1992 is about 18 percent above the 1992 estimate by the California Department of Fish and Wildlife (2018). Estimates are about the same for 2012, and about 24 percent below their 2013 estimate. These differences give a sense of the reliability intervals for the population numbers. Although point estimates are provided to the public, the agency gave a 2016 estimate to a professional group of plus or minus 10 percent (Mule Deer Working Group, 2016). Georgia recently revised its recent state deer population estimates by about 20 percent. California also made recent revisions, changing the state estimate for 2015 upwards by about 27 percent, showing a significant population increase in a year of extreme drought. Data from the U.C. Davis Roadkill project point to a "troubling decline" in deer numbers for 2015, consistent with the expected outcome of prolonged drought from 2011 to 2015 (Little, 2015, p.1).

The estimates taken from the 1998 Population Assessment, the gray line in Figure 3, are more problematic. The peak population estimate of about two million around 1960 from the press and this project is about 250 percent above the estimated peak from the state's 1998 Population Assessment which doesn't track with the harvest data.

This relationship is discussed more thoroughly using some basic simulations by Webb (2013). The extensive survey done by Longhurst and Leopold to get the 1947 population estimate for the state puts the number at least 50 percent above the 1998 Population Assessment. A notable problem with the 1998 Population Assessment is that it identifies the period beginning in 1925 as a "period in which deer populations are clearly exceeding the carrying capacity of the range" (p. 14), but deer were not hunted in California from 1917 to 1926 to protect the remaining deer populations. The current state estimate for the deer population is below the estimate from the 1998 Population Assessment when hunting was banned to conserve the deer.

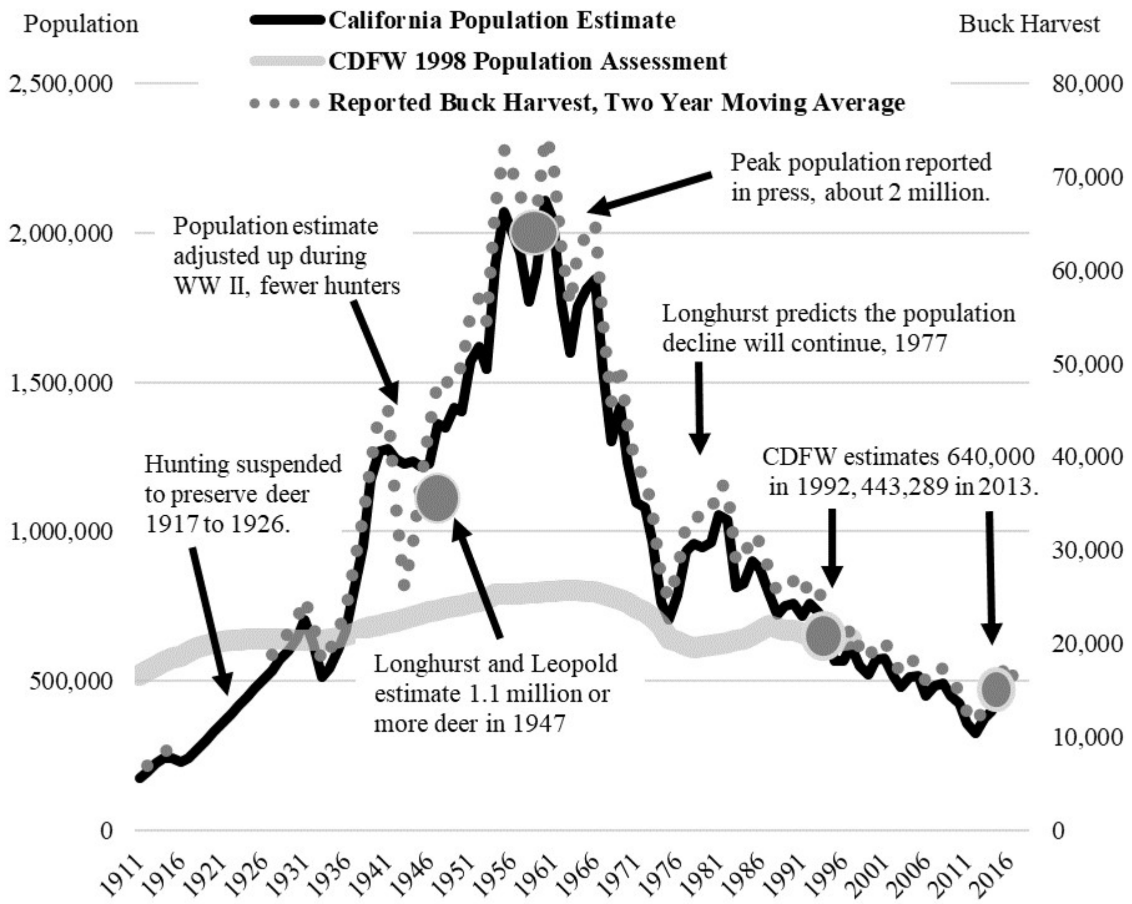


**Figure 3.** Estimated California Deer Population (1911 to 2017), Reported Buck Harvest, and the Population Estimate from the CDFW 1998 Deer Population Assessment. Source of buck harvest data: California Department of Fish and Wildlife (CDFW).

A goal of this project is continue to collect information in addition to harvest data to improve the population estimates. For example, the population estimate in Figure 3 during World War II in California has been adjusted upward to account for the reduced number of hunters during that period, lowering the deer harvest. No historic data was found suggesting a population decline during World War II.

**United States Deer Population Estimate**

The environmental scanning process discovered numerous public news articles describing what is thought to be the continuing increase in the U.S. deer population (David, 2013; Sun, 2018), described as an explosion over the past 100 years. In order to put the recovery of the deer population in historical perspective, Figure 4 was created. It shows that the white-tailed population is currently at about the level of pre-colonization, year 1450, although their range has expanded. For deer of the west, mule deer and black-tailed deer, the total population appears to be below pre-colonization levels. As Figure 4 illustrates, presenting just the information over just the last 100 years significantly distorts the historic perception of the deer population to members of the public who may be involved in decision making.

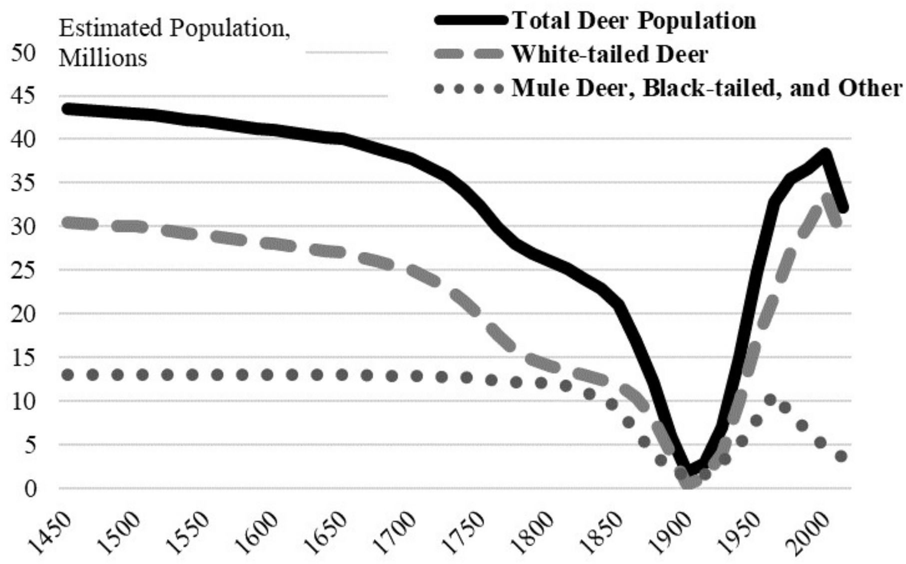


**Figure 4**. Estimated U.S. Deer Population, 1450 to 2016
Year 2000 to 2016 estimated from combined sources from state agencies.
Year 1450 to 1999 white-tailed based on VerCauteren (2003) and McCabe & McCabe (1984).
Year 1911 to 1999 mule deer, black-tailed, and other from state population and harvest data.
Year 1450 to 1910 mule deer, black-tailed, and other from historical sources.

VerCauteren (2003) and other sources put the deer population at about 30 million around the year 2000, but based on the data collected from state agencies, this estimate is about 34 million. Adjusted for this difference, the 1450 to 1999 white-tailed estimate follows the trend of VerCauteren (2003) and McCabe & McCabe (1984, p. 60). The mule, black-tailed and other deer estimate from 2000 to 2016 is based on harvest data and population estimates collected from various state agencies in the western United State where these deer are found. The 1911 to 1999 estimate is also based on the state data, although all western states did not provide data over the entire time span so missing data was estimated. The 1450 to 1910 estimate for mule, black-tailed, and other deer is based on historical writing and research, including Carpenter (1997), Messmer (2012), Mother Earth News (2014), Rue (2004, p. 4), and Seton (1953).

## CONCLUSIONS

Although reasonable estimates of the current trend in the deer population can be derived from publicly available data, the cost of collecting and analyzing this information is significant. The trend of the U.S. deer population has been a topic often discussed in media and research, but no estimates had been created from data for the period from about the year 2000 to the current year. Yet, the public debate on management of deer has typically assumed a continuing, rapid increase in their population. Since 2000, the population trend appears to be down. Problems with population estimates for Connecticut and California suggest the magnitude of the decline may be underestimated.

As Artelle et al. (2018, p. 1) concludes in a survey of big game management among states and provinces in the U.S. and Canada, while wildlife agencies "defend controversial policy by claiming adherence to science-based approaches" their "results raise doubt about the purported scientific basis of hunt management across the United States and Canada." More than half of the agencies were lacking in "measurable objectives, evidence, transparency, and independent review." While a state like Wisconsin has made significant efforts to improve their system for support of public decision making, these examples of Connecticut and California illustrate some of the problems.

The precise level of the deer population by state is not known. Reliability of the estimates on the order of plus or minus 20 percent is common. Repeated annual sampling of deer by hunting appears to give a somewhat reliable picture of the deer population trend. The ratio of the deer population to the harvest appears to be relatively constant as does the proportional difference in the deer harvest as estimated by alternative methods.

By searching the internet for information relevant to decision-making, looking for discrepancies in the discovered information, research for this project focused on an effort to make a comprehensive estimate of the U.S. deer population trend. Population estimates were not considered to be a goal at this project's inception, rather the environmental scanning process led in this direction. Improved search and analysis tools could reduce the cost and time required for this approach. This application of environmental scanning illustrates how the approach can be usefully employed by organizations wanting to better understand their external environment.

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