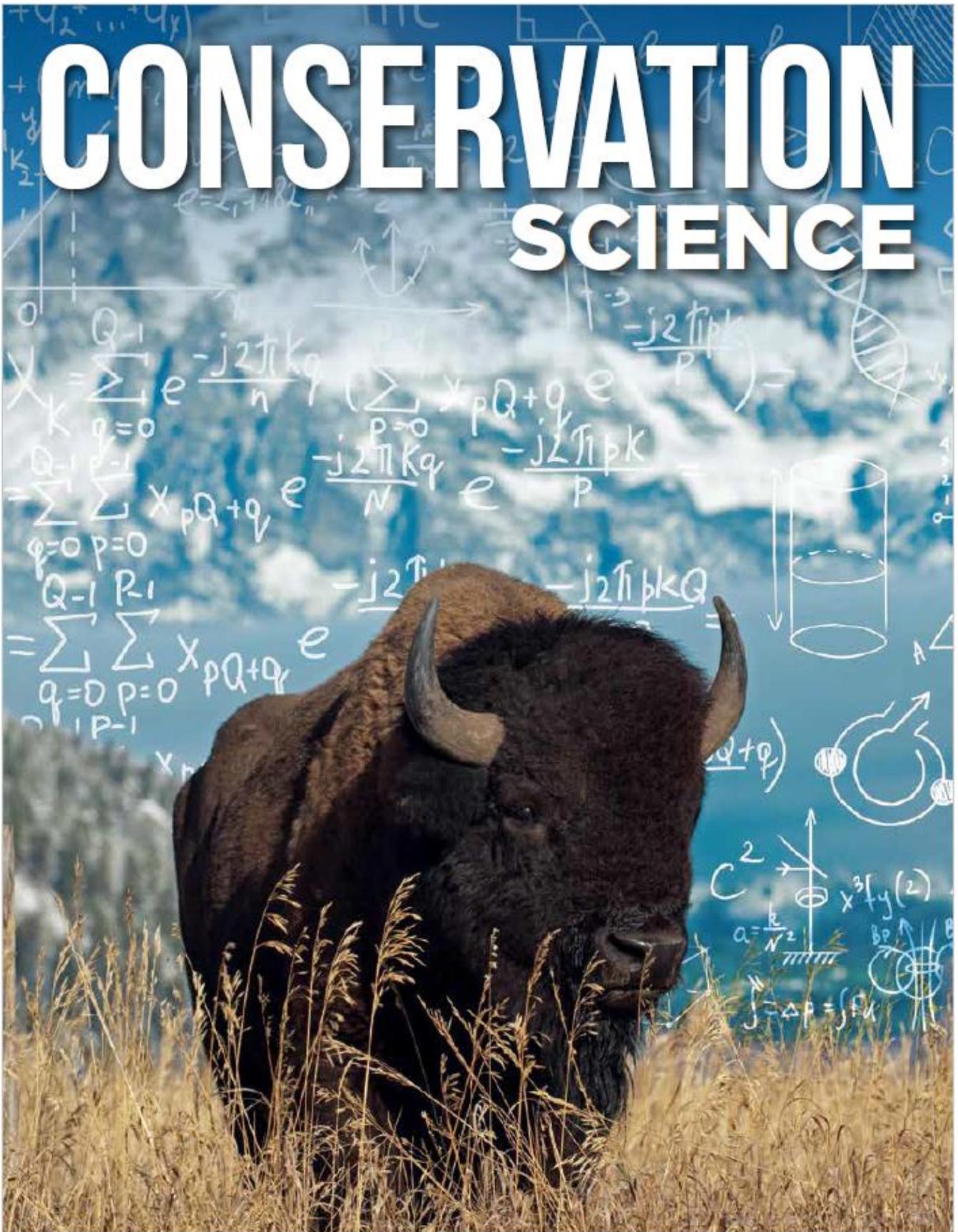


CONSERVATION SCIENCE



Conservation Science

An introduction to the science behind the North American Model of Wildlife Conservation and how it continues to save wildlife and their ecosystems.

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First Edition

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Why Conservation?

Humans always have been, and always will be, an integral cog in the natural resources wheel. The challenge we face today is: how do we best use and conserve those resources in a society that drifts further away from their connection to them.

For the vast majority of recorded history, humans existed as hunters and gatherers. However, with advancements in technology, agricultural practices and the advent of modern society, that connection and understanding of how wild places, animals and humans interacted has largely been lost. In the process, little attention was paid to the sustainable use of our wildlife, leaving many populations across North America on a perilous pathway towards extirpation, if not outright extinction.

This crisis, which manifested itself at the turn of the 20th century, brought a new ethos for how we manage our natural surroundings and the wildlife living within them. Known as the North American Model of Wildlife Conservation, the movement, led by the forefathers of conservation, men like Theodore Roosevelt and Aldo Leopold, changed the course of wildlife sustainability, management and natural history.

What took hold was a belief that we can ensure a future not bereft of wildlife, but one with sustainable and thriving populations for generations to come simply by regulating hunting and fishing activities and using the tax revenue to fund conservation efforts.

This was a radical and progressive departure from the commercialized approach in practice that allowed the vast destruction of bison herds in the west, the market hunting principles that threatened waterfowl species and the unregulated taking of ungulates that pushed even whitetail deer to the brink of extinction. Today, the North American Model is widely accepted as the greatest conservation success in history.

“The Ohio Division of Wildlife is excited to see conservation education brought directly to students across Ohio. Project based learning is critical to the future of both our kids, wildlife and wild places.”

Kendra Wecker, Ohio Division of Wildlife

“Because we live in a time of abundant wildlife and natural resources, it is easy to take them for granted. But the future of wildlife conservation begins with good understanding of Conservation Science, the Pennsylvania Game Commission is thrilled to support this vital education in the classroom.”

Bryan Burhans, Pennsylvania Game Commission.

Support for this project was made available through a partnership with the Ohio Division of Wildlife utilizing funds from the Wildlife Restoration program and the Pennsylvania Game Commission.



2.2: The North American Model - Pillars 4-7

NAMWC Pillar 4: Scientific Management

Pillar 4 states that science is the proper tool to discharge wildlife policy. This pillar was established to ensure that hunting regulations allow for sustainable use of resources based on science and not political pressure or personal opinions. The use of scientific studies and data gives state game agencies the knowledge they need to objectively and fairly manage wildlife. The game agencies employ staff and researchers to collect and analyze this data when making management decisions.

Application: At a public hearing, the state game agency receives feedback from citizens regarding new wildlife regulations. Daniela voices her concern over the high population of turkeys in her part of the state and recommends an increase in the bag limit to help reduce the population. James speaks next and presents his case for why killing animals is inhumane and hunting should be banned altogether. The state game agency manages the wildlife on behalf of all citizens. Therefore, they consider all public input, but must ultimately make their decisions based on sound science.

NAMWC Pillar 5: Harvest for a Legitimate Purpose

Pillar 5 states that wildlife is a shared resource that should not be wasted by killing for frivolous reasons. There are many legitimate reasons wildlife needs to be harvested, even if they are not going to be consumed. Reasons include: human safety, nuisance animals, preventing or controlling the spread of diseases, reducing population density, crop damage, predation of livestock, erosion control, etc.

Application: A couple moves into a house in Florida and notices that almost every day their neighbor Liam is killing iguanas and just throwing them into the trash. Eventually they get upset with this waste and call the Florida Fish and Wildlife Conservation Commission to report their neighbor for poaching. When the wildlife officer arrives and investigates, he tells the couple that the neighbor is not breaking any laws and is in fact helping to reduce the tremendous number of iguanas, which are an invasive species that impact native wildlife, damage habitat and transmit diseases to humans and other animals.

NAMWC Pillar 6: International Resource

This pillar was developed to acknowledge that many wildlife species travel great distances and through multiple countries. Pillar 6 states that many wildlife species are considered an international resource and treaties such as the Convention on International Trade in Endangered Species (also known as [CITES](#) – “sight-ees”) and the [Migratory Bird Treaty Act](#) are a recognition of the responsibility that all countries share in managing the wildlife that cross national borders.

Application: Many North American waterfowl species travel north to Canada during the summer and south into the U.S. and Central America during the winter. Harvest and development practices in all involved countries needs to be coordinated to put an effective and cohesive management plan in place.

**Links to additional information on that topic.
Videos, articles, research, websites, etc**

NAMWC Pillar 7: Democracy of Hunting

This pillar is also a reflection of the European culture where the nobility owned the wildlife, and therefore the common person was not allowed to harvest it. Pillar 7 states that government will use democratic principles when allocating access to wildlife, regardless of wealth, prestige or land ownership. This means that since all citizens of a state own the wildlife, they all will have an equal opportunity to harvest wildlife under the same set of regulations that all others must follow.

Application: A group of hunters from Pennsylvania wants to hunt mule deer on public land in New Mexico. When they investigate buying a license, they find that New Mexico uses a lottery system to issue permits. This means that they have to apply for a license, but are not guaranteed to get one. Further research reveals that only 6% of licenses are awarded to non-residents. Coming from a state where they can buy a hunting license over the counter they are upset. Eventually they talk to staff at the New Mexico Department of Game and Fish who explains that there is more demand for hunting licenses than they have available. In an effort to give equal access, they utilize a lottery system.

Demonstrate Your Understanding

1. While there are statewide hunting regulations, the bag limit for a species may vary depending on where in the state you hunt. Based on the idea of scientific management, name some reasons why the bag limit for a species may vary depending on what part of the state you are hunting in.
2. Research and identify at least two invasive or native species in your state that do not have a bag limit and provide a reason why the state wants to reduce or maintain their numbers.
3. If you have enough money you can go to private property that is managed for wildlife and you will have an exceptional opportunity to harvest an animal. Explain why this does not violate the “Democracy of Hunting” pillar of the NAMWC. (Hint: Opportunity to hunt vs access to property).

Section questions engage students with the content requiring them to think, give opinions, summarize, predict, calculate, etc.

2.5: Funding Conservation

Need for Funding

For the first two centuries of existence, the U.S. exploited natural resources without any centralized thought for future sustainability. Recovering wildlife and habitat would require regulation, enforcement, time and financial resources. The NAMWC is funded by revenue generated from the sustainable use of our natural resources. The funding maintains stable wildlife populations, improves at-risk wildlife populations, restores damaged habitats, sustains healthy habitats, provides enforcement for game laws and pays for biological studies of wildlife and ecosystems. The NAMWC removes much of the funding burden from taxpayers, and instead relies on revenue collected from those who use the natural resources: hunters, anglers, trappers and boaters.

License Sales

According to data from the [2020 National Hunting License Data report](#) released by the U.S. Fish and Wildlife Service, there were 15,158,443 individuals who spent \$902,356,898 on hunting licenses, tags, permits and stamps during 2020. Using data from the [2020 National Fishing License Data report](#), there were 29,286,854 individuals who spent \$752,108,909 on fishing licenses, tags, permits and stamps during 2019.

Excise Taxes and Use Fees

According to a [report](#) released by the Congressional Research Service, from 2015 to 2020, the Pittman-Robertson Act generated more than \$800,000,000 per year from excise taxes on firearms, ammunition and archery equipment.

According to a [report](#) from the Department of the Interior, for fiscal year 2019, the Dingell-Johnson Act allocated \$347,304,235 to the Sportfish Restoration Fund for distribution to states. Based on the [information](#) provided by the Fish and Wildlife Service, the Sport Fish Restoration Fund receives around 57% of the total revenue collected by the Dingell-Johnson Act, which means that in 2019 about \$610,000,000 was generated from excise taxes and import duties on boats, boat fuel and fishing equipment.

According to the [2018 Annual Report](#) released by the Migratory Bird Conservation Commission, there was \$37,836,931 generated from the sale of duck stamps the prior fiscal year. The Duck Stamp Act requires all migratory bird hunters 16 or older to buy an annual duck stamp. The current price is \$25 per stamp, which means around 1,500,000 stamps were sold that year.

Total Annual Impact

This means that in recent years hunting, fishing, trapping, shooting sports and boating have generated a total of \$3.1 billion per year for conservation, an average of \$62 million per state each year. The majority of the annual budget for state game agencies comes from these funding sources, so the NAMWC is heavily dependent on people who hunt, fish, trap, shoot and boat to fund conservation. The decline in participation in these activities by younger generations is a concern for state agencies and future conservation-funding efforts across the country.

Demonstrate Your Understanding

1. Use the data from the FWS [2020 National Hunting License Data](#) report to answer the following:
 - a. Which state had the highest number of paid hunting license holders?
 - b. Which state generated the highest gross revenue from the sale of hunting licenses?
 - c. How many paid hunting license holders were in your state in 2020?
 - d. How much revenue was generated in your state from the sale of resident hunting licenses, tags, permits and stamps?
 - e. How much revenue was generated in your state from the sale of non-resident hunting licenses, tags, permits and stamps?

2. Use the data from the FWS [2020 National Fishing License Data](#) report to answer the following:
 - a. Which state had the highest number of paid fishing license holders?
 - b. Which state generated the highest gross revenue from the sale of fishing licenses?
 - c. How many paid fishing license holders were in your state in 2020?
 - d. How much revenue was generated in your state from the sale of resident fishing licenses, tags, permits and stamps?
 - e. How much revenue was generated in your state from the sale of non-resident fishing licenses, tags, permits and stamps?

2.7: A Benefit to All

The revenue generated by hunting, fishing, trapping, boating and the shooting sports (the funding five) provides a tremendous benefit to habitat and wildlife conservation efforts. Additionally, these recreational activities benefit those participating in other, non-consumptive outdoor activities like hiking and wildlife or bird watching. This design is often referred to as a “User-Pay, Everyone Benefits” model because the impact provided by the “funding five” applies to both game and non-game species. Habitat and water quality critical for healthy wildlife populations and areas enjoyed by people who do not hunt, fish or trap all benefit from the funding provided by NAMWC. For example, it’s not uncommon for boardwalks in popular birding areas, campsites, maintained hiking trails, state parks and wildlife sanctuaries to receive some funding from the “funding five.” Beyond direct funding, however, hunters, anglers and shooting sports participants also provide helpful data and countless volunteer hours that further conservation and the enjoyment of wild places across the country.

Dollars at Work

The revenue generated by the “funding five” is used in a [variety of ways](#), including:

- Fish and wildlife population management
- Habitat management
- Research and studies
- Surveys
- Acquisition of land
- Maintenance and construction of facilities and access to public lands and waters
- Technical assistance programs
- Aquatic education programs
- Grants

During [2020](#), PR revenue provided:

- \$8,000,000 for the Multi-State Conservation Grant Program
- \$51,713,469 for the North American Wetlands Conservation Account
- \$3,582,618 for the Migratory Bird Conservation Fund
- \$678,894,449 for the wildlife agencies in each state

Habitat Acquisition and Restoration

This biggest threat today to maintaining or recovering wildlife populations is loss and fragmentation of habitat. As of 2009, PR dollars had been used to acquire [68 million acres](#) of land, which is larger than the state of Colorado. Sixty percent of PR dollars are used to purchase, restore and operate these lands. One example includes the [Magee Marsh Wildlife Area](#) located in northwest Ohio, which is one of the most popular sites in the country for [birdwatching](#). The annual [birding festival](#) with over [300 species of birds](#) observed in this 2,200 acre property draws more than 90,000 visitors each year, including people from every state and more than 22 countries. This is just one example of the many wetland conservation projects, funded by hunting license sales and/or the purchase of ammunition and firearms, that have contributed to the [restoration](#) and [conservation](#) of millions of acres of wetlands across the country.

Many plants and animals depend on [pollinators](#) to help plant reproduction and to provide food, such as the fruits and nuts that form as a result of pollination. Habitat loss, disease and pollution have all contributed to the decline of many [pollinator species](#).

This is problematic in many ways:

- For plants: 75 percent of flowering plants (including 35 percent of the world's crops) depend on pollinators to reproduce
- For pollinators: loss of habitat has reduced the number of flowering plants and also increased the seasonal availability of flowering plants.
- For upper trophic levels: both humans and animals rely on pollinators to allow plants to successfully reproduce and to produce fruits and nuts.

One effort to help pollinators has been to plant [pollinator plots](#) with native flowering plants that provide flowers throughout multiple seasons while also providing food and cover for many wildlife species. The natural partnership formed with the [Conservation Reserve Program](#) has provided millions of acres of pollinator habitat, although the efforts of many individuals to establish [pollinator gardens](#) has also provided a significant amount of additional habitat.

Research

An average of 26 percent of PR dollars are spent annually to conduct research and surveys. The data and information gathered from these efforts enhance the scientific management of all fish and wildlife populations. [Monarch butterflies](#), [Kirtland's warbler](#), [blue-spotted salamanders](#), [desert tortoise](#), [slickspot peppergrass](#), [Topeka shiners](#) and [Florida panthers](#) are just a few examples of plant and wildlife species that benefit from the research that conservation dollars fund. State wildlife agencies commonly partner with non-profit groups and universities to help conduct the research.

Demonstrate Your Understanding

1. Birding, camping, hiking, rock-climbing and biking are a few examples of outdoor recreation that benefits from conservation efforts without directly contributing funding back into the system. Describe how individuals that participate in these activities could benefit conservation:
 - a. Funding (Two ways to fund conservation voluntarily):
 - b. Effort (Two examples of ways to volunteer):
2. Do your own research and find at least one parcel of land and three non-game species that benefit from the "funding five."

4.4: Urbanization and Waterways

Impermeable Surfaces and Runoff

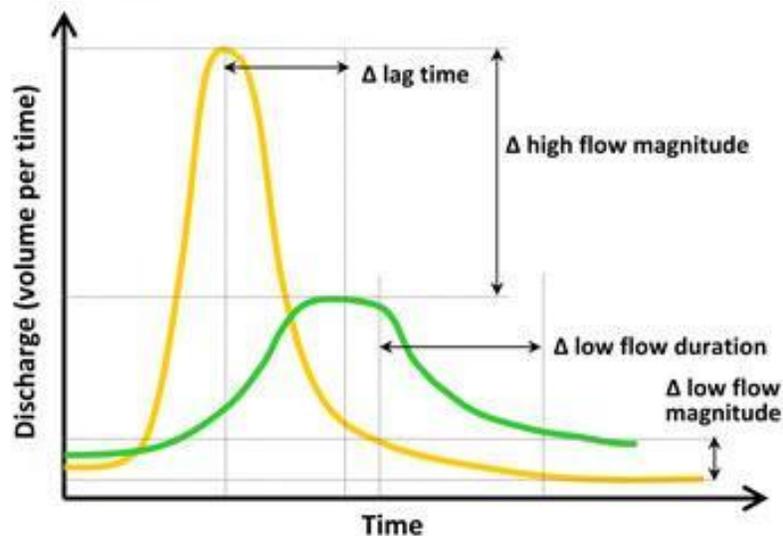
The sustainable use of natural resources includes recognizing the affects that development and urbanization have on the ecosystem, the water cycle and water quality. In areas with natural groundcover, most of the precipitation will infiltrate into groundwater or back into the atmosphere through evapotranspiration. Precipitation not absorbed by the ground or plants becomes runoff and eventually makes its way into nearby surface waters.

In heavily developed areas, many artificial impermeable surfaces, such as roads, roofs and parking lots, prevents the precipitation from infiltrating the groundwater. Instead, much of this precipitation runs into storm drains, which often empty directly into nearby waterways. The large volumes of water carrying debris, chemicals and dirt from the impermeable surfaces have many affects, including causing flooding, erosion, less recharge of groundwater, increased water pollution, increased erosion, higher sediment loads, warmer water and less dissolved oxygen.

Peak Discharge

Each waterway has a watershed, which is the surface area of land that drains into that waterway. As the percent of impermeable surfaces in a watershed increases, the runoff volume will increase and the lag time will decrease. Lag time is defined as the amount of time that elapses between peak rainfall and peak discharge. Peak discharge is the point in time when a river or stream is moving the highest volume of water downstream during a period of time (gal/min or m³/s are common units).

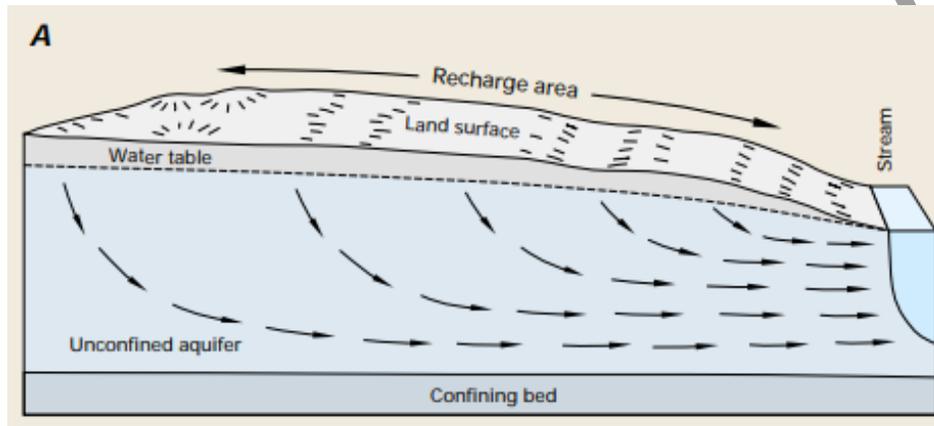
A good analogy would be pouring a jug of water through a funnel. The water coming out of the funnel represents runoff, the highest volume of water per second that is poured into the funnel is the peak rainfall and the highest volume of water per second coming out of the funnel is the peak discharge. If the funnel cannot discharge the water fast enough, the water will pour over the sides of the funnel, much like a stream will flood its banks. In a rural watershed, most of the precipitation would be absorbed into the ground or by plants so only a small percentage of the water makes it into the waterway as runoff. In an urban watershed a small portion of the precipitation would get absorbed into the ground or by plants and a majority will become runoff and quickly enter the waterway.



Source: [U.S. EPA](#)

Recharging Groundwater

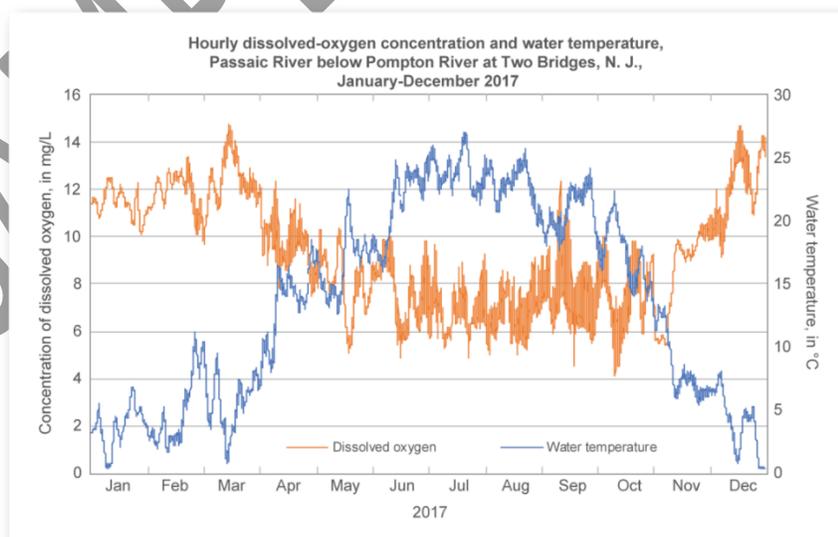
Watersheds with less impermeable surfaces provide a more consistent stream flow even during periods between rainfall because the rain that gets absorbed into the ground water will continue to contribute water flow to the stream. Many streams and lakes are simply exposed ground water; the ground is low enough at that point in the terrain to expose it. Groundwater levels will rise if more water is absorbed into the ground, which will also increase the water level in the streams and lakes. Runoff does not recharge the groundwater, so the level of the stream or lake will drop and, in some cases, cause the stream to dry up when the ground water level drops below the bottom of the stream.



Source: U.S. Geological Survey

Sediment, Temperature and Dissolved Oxygen

Increases in runoff volume and decreases in lag time means that warm runoff water will move into streams faster and cause flooding. When there is more warm runoff water, the temperature of the stream tends to rise since less of the stream water is coming from cooler groundwater. Warmer water holds less dissolved oxygen, which makes it harder for aquatic organisms to breathe, and many organisms, such as trout, cannot survive in warm water. A common example of the relationship between temperature and dissolved gasses is: If you open a carbonated drink when it is warm, it will quickly go flat (lose the dissolved CO₂).



Source: [U.S. Geological Society](#)

The higher velocity of flood water moving downstream also causes more erosion of streambanks and can dislodge aquatic organisms, such as fish, insects and eggs, from the streambed and deposit them downstream. The sediment eroded by the floodwater can also bury the aquatic organisms in the streambed causing death.

Reducing the Impact

Many methods can minimize the effects of urbanization on the health and hydrology of waterways. Restoration of wetlands, using permeable road surfaces, creating retention ponds to store stormwater and collecting rainwater to use for irrigation can reduce the impact of urbanization on a watershed.

Demonstrate Your Understanding

1. Many houses in the U.S. have a total of 3,000 square feet of horizontal impermeable surface, including the roof and driveway. The average annual rainfall in the U.S. is 38 inches per year and 1 gallon is equal to 0.13 cubic feet. Use this information to calculate the total number of gallons of rainwater that fall on these impermeable surfaces annually. (Show your work)
2. You simultaneously pour out two five-gallon buckets of water on a slope. One of the buckets gets poured onto a cement driveway with curbs on both sides and the other gets poured onto the lawn next to the driveway. Predict which surface will allow the water to reach the bottom of the hill first, and also predict which surface will allow the highest volume of water to be absorbed into the ground. Be sure to provide the reasoning for your predictions.
3. Describe at least three different chemicals that commonly end up being washed into storm drains and are harmful for aquatic life.

6.1: Upland Birds

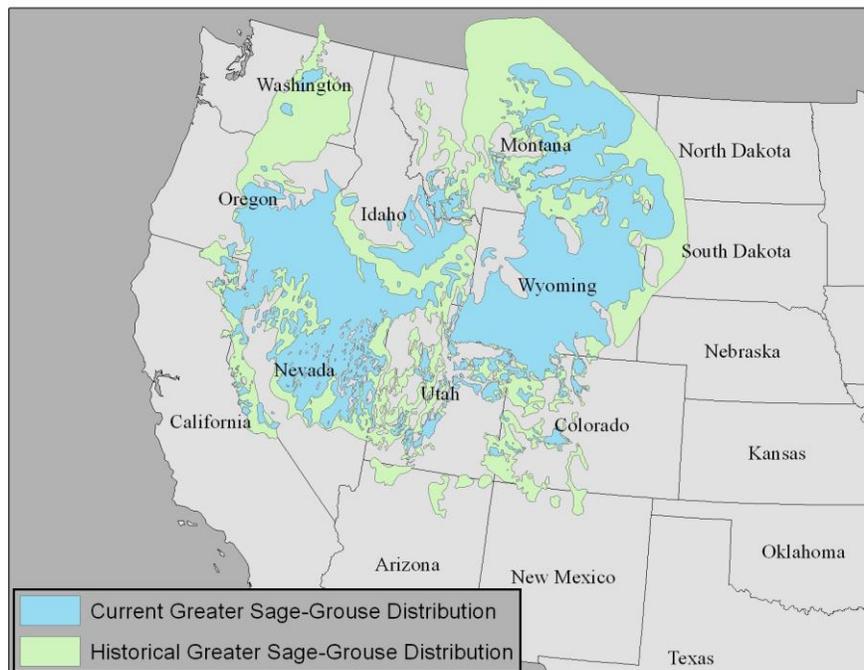
Passenger Pigeons

Passenger pigeons were once the most abundant bird in North America with a total population estimated in the billions. The flocks of migrating passenger pigeons were so large that the sky would be darkened for days as they flew overhead. The sound of millions of wings was reportedly as loud as a freight train and a cool downdraft of air from their wings could be felt below. When they landed in trees, the weight of the birds would bend the branches and even uproot the trees so that it looked like a tornado had gone through the forest.

Deforestation, disease and unregulated hunting of the tasty and abundant bird led to the extinction of this gregarious species. The last passenger pigeon died in the Cincinnati Zoo in 1914. In less than a hundred years the passenger pigeon had gone from one of the most abundant animals in North America to extinct. The stark reality of their demise was a key influence on the conservation movement and helped lead to the development of the modern NAMWC so that the story would not play out in another species in the future.

Greater Sage Grouse

The greater sage grouse is the largest native grouse species in North America and currently exists in 11 U.S. states and two Canadian provinces. They are a ground-dwelling bird up to 30 inches long with males weighing up to 5 pounds. Although they can live up to 10 years, most live for less than two years. Sage grouse depend on sagebrush habitat for cover and food and cannot survive in areas without it. The males display on dancing grounds called *leks* and the females gather at these locations to select a mate, breed and then raise the chicks on their own. The annual home range of an individual sage grouse can cover 230 square miles and the species exist across 165 million acres of sagebrush, which represents a 56 percent loss of their historic range.



Source: [U.S. Fish and Wildlife Service](#)

Currently there is not a consistent range-wide survey method to accurately pinpoint sage grouse numbers, but there is an estimated total population of 200,000 to 500,000. Since 1985, the population has declined an estimated 30 percent due to habitat loss. Since sage grouse are dependent on sagebrush, the loss and fragmentation of suitable habitat are the biggest threat to the species. Where sufficient habitat still exists, the local sage grouse populations are doing well enough to support hunting opportunities while maintaining stable populations. While agricultural conversion, infrastructure and urbanization have caused the loss of sagebrush, the largest threat to habitat is invasive cheatgrass and pinyon-juniper.

Historically, periodic fires naturally cleansed sagebrush habitats and spurred new growth, but with the arrival of cheatgrass that all changed. The invasive plant has outcompeted the native sagebrush, slowly taking up more land in the ecosystem. Because of this, when fires occur now, they burn hotter and spread faster, devastating the sagebrush habitat and allowing the cheatgrass to thrive even more. There are currently more than 100 million acres of private and public lands infested with cheatgrass.

In 2010, the greater sage grouse was considered as a candidate for listing as threatened under the Endangered Species Act. In 2011, the Sage Grouse Task force was started by the governors of Colorado and Wyoming to help the bird and its habitat. Current sage grouse range is 64 percent federally owned, 31 percent privately owned and 5 percent state owned land. In 2015, FWS determined that listing of sage grouse under the ESA was no longer warranted and worked with states to implement plans to reduce cheatgrass and range fires to reduce further loss of habitat.

North American Wild Turkey

The pre-Columbian population of wild turkeys in the U.S. is estimated to have been 10 million birds. Unregulated market hunting and habitat loss due to clearcutting reduced the population to 200,000 birds in 18 states by 1920. Through regulations, habitat restoration and the relocation of captured birds, the wild turkey population has recovered to more than 6 million birds today. This recovery is due to the efforts and cooperation between state agencies and organizations like the National Wild Turkey Federation (NWTf).

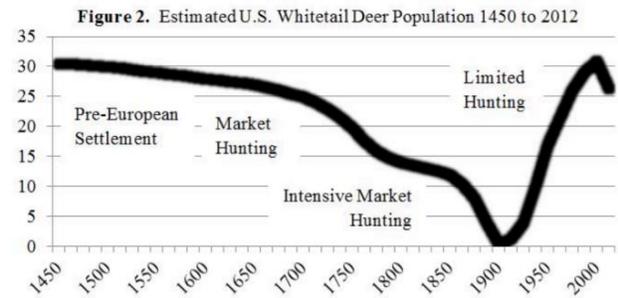
Demonstrate Your Understanding

1. Passenger pigeons are considered a *gregarious* species. Provide a definition of “gregarious.”
2. When considering the decline of overall sage grouse populations, explain why state agencies would still allow sage grouse hunting in specific areas.
3. Do your own research or use this [document](#) to explain the Weed and Wildland Fire Cycle and how it is causing the loss of sagebrush habitat.

8.1: Population Management Tool

Abundant Wildlife

Many wildlife populations thrive today due to the development and implementation of the NAMWC, as well as the efforts of many wildlife agencies, organizations and individuals. Today, many people don't know the exploitation of our natural resources that drove many animal populations to precariously low numbers. Abundant animal populations did not happen by accident, but rather through deliberate and often sacrificial efforts. Many animal populations have recovered to levels equal to or higher than those estimated prior to European colonization. Loss of habitat, and not hunting, is the greatest challenge facing wildlife today.



Maintaining Healthy Populations

Since many animal populations are thriving, preventing a species from becoming overpopulated in an ecosystem is a major concern. Exceeding the carrying capacity of an ecosystem not only jeopardizes the health of that species through starvation and spreading of diseases but also threatens other animal populations and the habitat of that ecosystem. For example, the browsing pressure of an overpopulation of deer can remove almost all of the lower canopy which depletes the habitat that other species rely on for food and cover.

Table 1. Deer Permits Issued, 2007 - 2019.

| Year | Permit | | | Total |
|---------|--------|------------|------------------------------|---------|
| | Youth | Either-Sex | Antlerless-only ² | |
| 2007-08 | 65,647 | 411,522 | 101,197 | 578,366 |
| 2008-09 | 67,338 | 396,704 | 147,400 | 611,442 |
| 2009-10 | 67,828 | 394,620 | 162,460 | 624,908 |
| 2010-11 | 66,300 | 380,462 | 162,655 | 609,417 |
| 2011-12 | 62,864 | 377,302 | 163,383 | 603,549 |
| 2012-13 | 64,634 | 397,333 | 126,918 ² | 588,885 |
| 2013-14 | 60,961 | 373,315 | 101,400 | 535,676 |
| 2014-15 | 58,227 | 378,921 | 57,230 | 494,378 |
| 2015-16 | 58,055 | 392,533 | 15,514 | 466,102 |
| 2016-17 | 52,706 | 373,791 | 18,669 | 445,166 |
| 2017-18 | 49,529 | 367,753 | 11,724 | 429,006 |
| 2018-19 | 42,781 | 345,408 | 11,117 | 399,306 |
| 2019-20 | 45,755 | 339,077 | 8,535 | 393,367 |

¹Antlerless-only permits were renamed "Deer Management Permit" in 2019.
²Restrictions on the use of the antlerless permit began in 2012 and continued through 2019.

Hunting as the Primary Management Tool

It is up to the state wildlife agency to manage the population of all animals for the benefit of its' citizens (NAMWC Pillar: Held in Trust). The state wildlife agencies use data-based decisions (NAMWC Pillar: Scientific Management) to create hunting regulations (NAMWC Pillar: Allocation by Law) that prioritize the maintenance of healthy populations of game animals. Hunting is the primary tool used by state agencies to maintain their population objectives (NAMWC Pillar: Equal opportunity for all) not only to offer equal opportunity but also because it is impractical to use other methods because of the time, cost and access that would be required. For example, Ohio has a whitetail population of around 700,000 whitetail deer and during the 2019-20 deer season the ODNR issued 393,367 deer permits which resulted in the harvest of 180,155 deer (or roughly 26% of the population)._ This harvest amount allows the deer

Table 2. Buck, doe, button buck, and total harvests by season, 2019-20 and three-year average¹.

| | Bucks ² | | Does | | Buttons | | Total | | Diff. (%) |
|---------------------|--------------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|------------|
| | 2019 | 3yr avg. | 2019 | 3yr avg. | 2019 | 3yr avg. | 2019 | 3yr avg. | |
| Gun | | | | | | | | | |
| Traditional (7-day) | 23,147 | 25,313 | 33,522 | 33,463 | 6,898 | 7,853 | 63,567 | 66,629 | -4.6 |
| Bonus (2-day) | 4,036 | 3,455 | 8,164 | 6,140 | 1,503 | 1,373 | 13,703 | 10,969 | 24.9 |
| Youth | 3,133 | 3,228 | 2,419 | 1,916 | 697 | 658 | 6,249 | 5,802 | 7.7 |
| Total | 30,316 | 31,996 | 44,105 | 41,520 | 9,098 | 9,884 | 83,519 | 83,401 | 0.1 |
| Archery | | | | | | | | | |
| Crossbow | 31,256 | 25,665 | 23,777 | 21,087 | 4,483 | 4,429 | 59,516 | 51,181 | 16.3 |
| Vertical Bow | 14,564 | 14,313 | 12,280 | 12,755 | 1,746 | 2,065 | 28,590 | 29,132 | -1.9 |
| Total | 45,820 | 39,977 | 36,057 | 33,842 | 6,229 | 6,493 | 88,106 | 80,313 | 9.7 |
| Muzzleloader | | | | | | | | | |
| | 3,160 | 4,200 | 6,322 | 8,630 | 1,139 | 1,606 | 10,621 | 14,436 | -26.4 |
| Total | 80,138 | 76,916 | 87,578 | 84,990 | 16,752 | 18,249 | 184,468 | 180,155 | 2.4 |

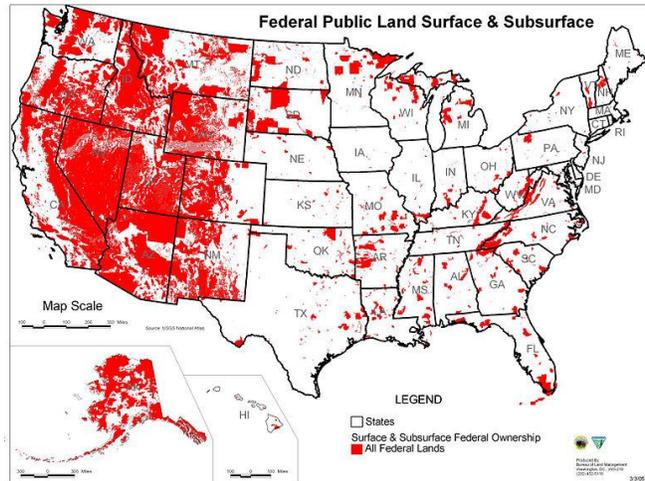
¹Average of 2016-17, 2017-18, and 2018-19 seasons.

²Includes bucks at least 1.5 years old with antlers less than three inches in length (2,282), and bucks with shed antlers (829).

Visuals, tables and graphs help students understand the big picture and provide information from source documents.

population to stay at the management objective. Without hunting the deer population would quickly swell beyond the carrying capacity of the ecosystem.

In 2019 a resident, either-sex permit cost \$31.20. Using this value (youth permits are cheaper, non-resident permits are more expensive) the ODNR would generate around \$12.3 million dollars just from selling deer permits alone. In contrast, if hunting was not the primary population control mechanism the ODNR would have to spend money to use alternative population management techniques. Even if other population management techniques were practical and taxpayers funded their implementation the success of their use would depend on the ability of the ODNR to access private property. In Ohio, only 4% of the land area is public land and only 6.4% of the deer harvest in 2019 came from public land.



Demonstrate Your Understanding

1. Figure 2 on the previous page demonstrates how unregulated market hunting devastated the whitetail deer population in the United States. How does the NAMWC ensure that hunting today will not allow the same thing to happen again?
2. Table 1 on the previous page provides the total number of deer permits issued from 2007-2020. Find the deer season that sold the highest total number of deer permits and use that value in “a” and “b” below.
 - a. How much revenue would that have generated assuming each permit cost \$31.20? Show your work.
 - b. How does a decrease in revenue from deer permit sales have a negative impact on conservation efforts in Ohio?
3. Some cities have banned hunting and are trying alternative management techniques. Research an example of this and use the space below to summarize the techniques being used, the cost to use them and the effectiveness in managing the targeted animal population.

14.1: Wildlife as a Sustainable Food Source

Healthy Food Movement

A growing number of people in the U.S. and other countries have realized the importance of clean, healthy foods in their overall health. Formal and informal movements and labels have started over the years, such as locavores, free range, sustainable, environmentally friendly, non-GMO, farm to table, organic, natural, hormone free and whole food. In general, people want to know more about the food they consume and to play more of a direct role in the food chain. They find value in eating locally sourced food that uses fewer chemicals and is raised with a natural diet. While many farms have changed their agricultural practices to produce higher quality and more natural foods, wild game meat is the ultimate example of the food followers of these movements seek. Animals harvested following science-based hunting regulations provide a superior food system, especially in regard to ecological maintenance and environmental impact.

Wild animals have a much more diverse diet and move much more than confined animals, producing leaner, more nutritionally dense meat. The body requires roughly equal amounts of saturated, monounsaturated and polyunsaturated fatty acids, and the fatty acid ratio found in wild game is much more balanced than grain-fed animals. Hunting can also improve the physical fitness, mental health and emotional wellbeing of participants.

By the Numbers

The Wild Harvest Initiative is an international study that is quantifying the amount of wild foods harvested each year and the contribution of those foods to the diet of people, as well as the economies of various countries. Hunting in the U.S. alone provides more than 970 million pounds of meat each year, which equates to more than 3.8 billion meals assuming a 4-ounce serving. The game meat provided by hunters feeds millions of Americans without disrupting the biodiversity and wild spaces that are under increasing human pressures. Below are some specific numbers related to wild game meat.

- 25,210,605 ducks were taken in the U.S. and Canada during the 2014-15 and 2015-16 hunting seasons with an estimated live mass of 45,678,548 pounds and 14,273,457 pounds of consumable meat. This meat is valued at \$194,979,199 based on minimum retail pricing.
- During the same 2014-16 seasons mentioned above, U.S. and Canadian hunters also harvested 86 million pounds of squirrel (31.43 million meals) and 96 million pounds of doves and pigeons (13.23 million meals).
- Around 6 million whitetail deer are successfully hunted each year in the U.S. and produce an average of 50 pounds of meat per deer. This means that U.S. hunters harvest around 300 million pounds of meat each year. This does not include the meat from deer killed in over one million car-deer collisions each year or those that are culled from parks by sharpshooters.
- The Tennessee chapter of Hunters for the Hungry donated 140,401 pounds of venison to food banks and emergency shelters in 2019, which helped to combat the food insecurity of over 45 million people in the U.S.
- A 2019 study by the National Shooting Sports Foundation found that 43 percent of Americans ate wild-caught deer, boar, wild turkey, duck or buffalo in the previous year.

The Personal Economics of Wild Game

For many hunters, wild game makes up a large portion or almost the entirety of their family's meat consumption. The satisfaction of acquiring their own food, the confidence in the quality of what they are feeding their family, the enjoyment of their time outdoors and the challenge of pursuing wary game are common motivations for why people hunt wild game. While hunting produces high-quality protein, many examine the cost per pound to see if hunting is "worth it." If you calculate the cost of fuel, equipment and tags and divide it by the number of pounds of meat a hunter secures each year, it will likely be cheaper to buy meat from the store. That said, meat from the store is not as high quality. Since hunting is often the main hobby for many people, it would be more fair to compare the cost of hunting to other recreational activities, such as skiing, golfing and vacation. People spend money on trips and equipment, but for hunters these expenses happen to be spent on hunting and also provides high quality food.

Demonstrate Your Understanding

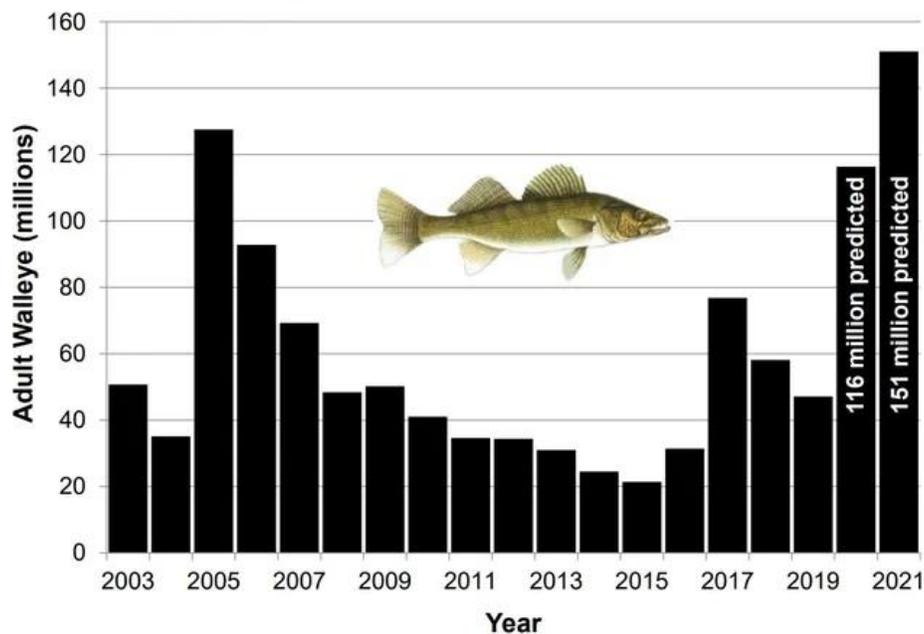
1. Hunting in the U.S. produces over 3.8 billion 4-ounce servings of meat per year. How many meals could hunting have provided to each of the 328.2 million people in the U.S. in 2019? (Show your work).
2. Survey at least 10 people (not in this class) and ask them what wild game animals they have eaten in the past year, if any. Record the results of each person below and calculate the percent that ate wild game and how many different wild game species were consumed. You may include yourself as one of the 10.
3. Do you support the science-based taking and consumption of wild game animals? Describe and explain your answer.

15.1: Fishing as a Population Management Tool

Peaks and Valleys

Like most wildlife, fish populations often rise and fall in response to food, habitat and predation. State wildlife agencies use fishing to manage the population of different species by changing the number and size of fish that can be kept, which are referred to as “limits”. For example, the fish agencies in Michigan, Ohio and Pennsylvania cooperate with Canada to collect population and age class data to help determine daily limits on walleye. The walleye hatch was exceptionally high in 2018-19, so the daily limit on walleye was increased. By increasing the daily walleye limit, the exceptionally high walleye population could be lowered, which could help prevent the walleye population from crashing due to lack of food (smaller fish) later. When hatches are smaller, the daily limit can be lowered to help maintain a higher population of walleye. This allows biologists to use fishing as a way to maintain a more consistent population of walleye and other fish in the ecosystem.

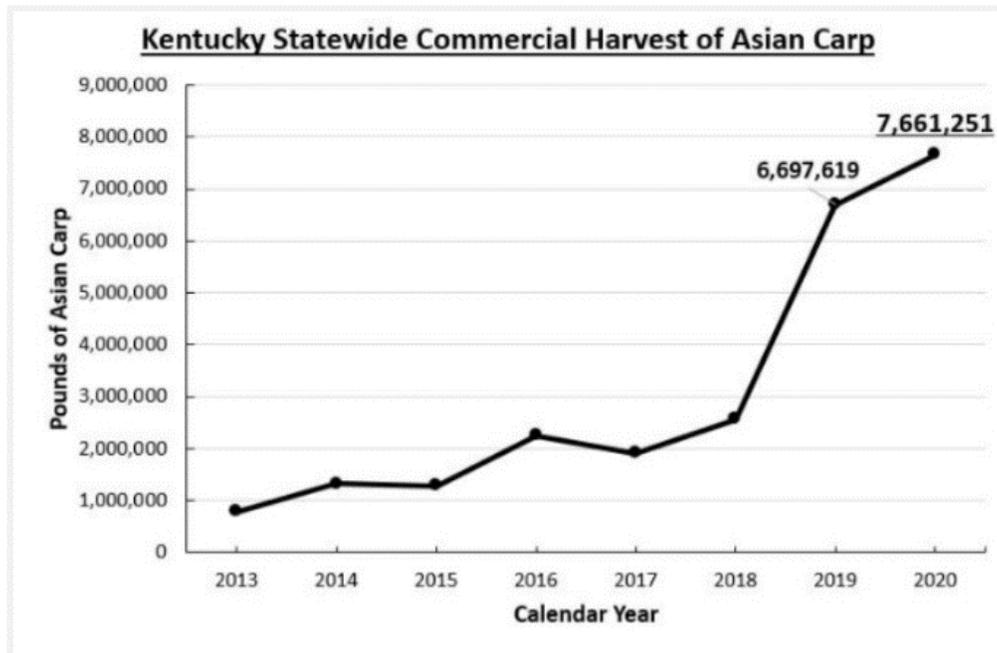
Walleye Population Estimate



Source: Ohio Department of Natural Resources

Eliminating the Competition

Many invasive fish negatively impact native fish populations. Commercial and recreational fisheries play an important role in removing these species. For example, Invasive Carp (commonly referred to as Asian carp) are found in most U.S. states, grow up to 60 pounds and eat so much that they reduce the population of native fish species. In the state of Kentucky, commercial fisherman removed 7.6 million pounds of invasive carp in a single year. Lionfish, an invasive species taking over ocean reefs in many states, have venomous spines that prevent most predation. Spearfishing for these tasty fish has become quite popular, which has helped to reduce their impact. Snakeheads, an invasive freshwater fish, will eat anything and can breathe and move on land, which allows them to move into other bodies of water, are sought by anglers for sport and to eat. Northern pike, largemouth bass and lake trout are examples of popular fish that are native to one area of the U.S. but are injurious in another body of water if introduced because they out-compete the native fish for resources or habitat.



Tracking Tags

The use of tracking devices to map fish locations has been very helpful for biologists in providing information about fish movements, migrations and how they use the habitat. Common tags include coded wire tags (CWT), Floy (anchor tags), Passive Integrated Transponder (PIT) and acoustic telemetry systems. Each of these systems have advantages and disadvantages.

The CWT are magnetized stainless steel wire that is about the width of human hair and have a numeric code etched into the wire. The CWT is cheap, and since it is so small it can be inserted into juvenile fish when they are only a few inches long. These tags have been put into 2 billion coho and chinook salmon by fish managers on the west coast and over 10 million tags have been recovered, often by commercial or recreational fishing.

The acoustic telemetry system requires that a tag be surgically implanted or attached to a fish, which will then give off a signal. This signal is then used to determine the location of the fish as it swims past receivers. This system is more expensive since it requires a network of receivers, but it gives much more data for researchers. The Great Lakes Acoustic Telemetry Observation System (GLATOS) maintains a growing number of receivers that collects data from fish tagged by researchers. This has provided biologists with a lot of valuable information about fish movement.

Demonstrate Your Understanding

1. The total allowable catch (TAC) for Lake Erie walleye went from 7.109 million fish in 2018 to 10.237 million fish in 2020. The Lake Erie perch TAC went from 10.498 million pounds in 2018 to 7.805 million pounds in 2020. Use this information to answer the following questions:
 - a. Calculate the percent increase in the Lake Erie walleye TAC from 2018-20. (Show your work).
 - b. Calculate the percent decrease in the Lake Erie perch TAC from 2018-20. (Show your work).
 - c. How might the walleye population affect the perch population in Lake Erie?
2. Do your own research and described at least three ways that invasive carp are being used after they are removed.
3. Watch this video (or find your own) showing telemetry data of walleye movement on Lake Erie. Record at least three things that you found interesting about the walleye movement patterns.

21.1: Salmon in the Great Lakes

Setting the Stage

There were a number of human-caused issues that led to the introduction of salmon in the Great Lakes. Through the early 1800s, the Great Lakes had abundant populations of whitefish, lake trout, pike, walleye and lake sturgeon. A combination of water pollution from the Industrial Revolution and unregulated commercial fishing took a toll on fish stocks. During the late 1800s, around 80 million pounds of fish were being harvested from the Great Lakes annually, including 24 million pounds of whitefish and 8 million pounds of sturgeon. This eventually led to Atlantic salmon being extirpated from Lake Ontario and the extinction of blue pike from Lake Erie.

Many canals were built to connect bodies of water or to bypass shipping barriers, such as the Niagara Falls between Lake Ontario and Lake Erie. Alewives, an invasive plankton-eating fish native to the Atlantic Ocean entered Lake Ontario in 1873 through canals but was blocked from entering the other Great Lakes by Niagara Falls. After improvements to the Welland Canal, they gained access to the other four Great Lakes and became widespread by 1960. A similar story occurred when the invasive sea lamprey was discovered in Lake Ontario in 1835 and, following the same path as the alewives, found their way into the other Great Lakes from between 1921 and 1938.

The Great Lakes provided both alewives and sea lamprey with suitable food and spawning areas, allowing them to reproduce. The native lake trout were the only significant predator of the invasive alewives, but they were also the preferred host for the parasitic sea lamprey. The lake trout were already struggling due to overfishing and the additional mortality by sea lampreys caused the extirpation of lake trout from most areas of the Great Lakes. This allowed the alewife populations to soar and by the 1960s there were huge annual die-offs that caused hundreds of millions of these fish to wash up on beaches around the Great Lakes. One report from a Michigan DNR employee reported a mass of dead alewives along Beaver Island that was estimated to be seven-miles long and half-a-mile wide. Heavy equipment such as backhoes and bulldozers were used to bury the dead fish, but the stench significantly affected the large tourism industry in the Great Lakes area and the citizens demanded action.

Introduction of Salmon

In 1964 there was little recreational fishing on Lake Michigan, and conservation officials estimated that 95 percent of the biomass in Lake Michigan was alewives. Howard Tanner was the chief of fisheries for the Michigan DNR at this time and he made the bold move of releasing some young salmon in Lake Michigan tributaries. Salmon are a natural predator of the alewives and Tanner wanted to use salmon to control the alewife population and provide a recreational fishing opportunity at the same time. An attempt at introducing kokanee salmon in 1965 failed, but a 1966 stocking of Coho salmon in the Platte River and Bear Creek was successful. The Coho salmon gorged on alewives and by late summer of 1967 there were 12- to 20-pound fish that quickly became popular targets of recreational anglers. Later chinook (king) salmon and steelhead were added to the stocking program. Today, the total value of fishing on the Great Lakes is more than \$7 billion annually and supports over 75,000 jobs.

Restoring the Native Fish

Although salmon are still stocked in the Great Lakes, far fewer are released today than during the 1980s when 25 million were stocked annually. While new invasive species like round gobies plague the Great Lakes, alewives have been greatly reduced or eliminated from portions of the lakes. Chemical treatments have reduced sea lamprey populations, which has helped the native lake trout to form sustainable populations in Lake Superior and parts of the other Great Lakes. Fisheries managers have reduced the

salmon stocking and increased efforts to restore native fish species, such as lake trout, walleye, cisco, bloater and emerald shiners. The fisheries managers are trying to balance the salmon fishery with the restoration of native species since salmon has become such a key part of the Great Lakes culture and economy.

Demonstrate Your Understanding

1. Assume the average alewife is 10-inches long and 3-inches wide. Use the dimensions of the mass of dead alewives provided in this section to estimate the number of fish in that mass. For the ease of calculation, you can assume each alewife is a 10-inch by 3-inch rectangle and they are all lined up side by side floating on the water. (Show your work)

2. Do your own research or use this [link](#) to learn about sea lamprey. Describe in detail how a sea lamprey attaches to and parasitizes its victim.

3. Salmon are not a native species to the Great Lakes but there is an economic and social pressure to maintain a salmon fishery. Name at least two reasons why:
 - a. Citizens of the Great Lakes states would want to keep stocking salmon species.

 - b. State fish agencies might want to reduce or eliminate salmon stockings.

22.1: A Vital Management Tool

The Trapping Niche

Trapping fills an important niche in wildlife management as it provides a way to manage species that are difficult or impossible to manage in other ways. As a biology term, niche refers to the role that an organism plays in an ecosystem. Beavers play a unique role in their ecosystems by building dams that create ponds and wetlands. Many aquatic animals could technically be hunted instead of trapped, but safety and recovery are problematic. Bullets tend to skip off water, which is a safety concern, and a beaver or muskrat that are shot in the water tend to sink, which makes recovery difficult. Trapping is also important for certain terrestrial (land) animals that are nocturnal, hard to locate or so abundant that they cannot be effectively controlled by other means. Trapping provides state wildlife agencies with a very specialized but important management tool.

How Trapping is Used to Manage Wildlife

Heavily regulated by state wildlife agencies, trapping provides a critical wildlife management technique used to:

- **Harvest wildlife for sustainable use:** The leather, fur, meat and other products that trapping provides are an important source of renewable raw materials. Many people are looking for eco-friendly, organic, biodegradable products, which is exactly what trapping provides.
- **Prevent or respond to animals causing property damage:** Houses flooded by beaver, electrical wires chewed by mice, calves killed by coyotes, raccoons spreading rabies and muskrats causing erosion problems are just a few examples of how wildlife can impact humans and society negatively.
- **Help recover or protect endangered and threatened species:** Raccoons, skunks, opossums and coyotes pose significant threats to the recovery of various endangered species due to their consumption of eggs and juvenile offspring. Trapping allows state wildlife agencies to reduce predation of and competition with the struggling species.
- **Manage the population levels of abundant or invasive wildlife:** Trapping is an essential tool for the removal of invasive species, such as feral hogs, feral cats and nutria. There are also many animals such as raccoons, coyotes and muskrat that thrive in developed areas and the only practical means of management is trapping.
- **Capture animals for scientific research and relocation:** Trapping is used to reintroduce native animals, such as wolves and river otters, to parts of their native range from which they have been extirpated (regionally eliminated). Important ecological information, such as wildlife diseases and the current range of a species, is also collected using trapping.

Sustainability of Trapping

Just like hunting and fishing, state wildlife agencies use scientific management to create and enforce trapping regulations to ensure sustainable populations of wildlife. Trapper education courses help to ensure that trappers know and follow trapping laws, such as seasons, species that can be trapped, bag limits and the types of traps allowed. State and federal agencies have conducted exhaustive research to determine Best Management Practices, which are recommendations that ensure animals are humanely captured. Trapping helps control the population of the animals being trapped, and it also helps to

conserve struggling species by removing predators or competition. Raccoons, for example, are one of the largest threats to restoring sea turtle and spiny softshell turtles due to their ability to find and eat the eggs. Raccoons, opossum, fox and coyotes are also a significant threat to ground-nesting birds like turkey and quail. High populations of these nest-destroying predators will prevent the successful management of these prey species. Trapping is an important tool used by wildlife managers to reduce predator populations.

Demonstrate Your Understanding

1. Describe a scenario where trapping would be the only practical solution to managing a specific wildlife species. Be sure to identify the species, the problem it is causing, why other management options, such as hunting, are not an option and how trapping would be used to solve the problem.
2. Do your own research and explain how trapping is used to control an invasive species.
3. Some states, such as California, have banned trapping. Name at least one way that you think trapping bans would affect wildlife management.

30.1: Firearm Safety

Why Firearm Safety Matters

Over 70 million people in the U.S. own firearms. According to a 2017 Pew Research Center Survey, 30% of American adults personally own a firearm and an additional 11% live with someone who does. Nearly half of American adults grew up in a household with at least one firearm and 72% have fired one at some point in their life. Recent data indicates that firearm ownership continues to increase. During 2020 alone, the National Shooting Sports Foundation (NSSF) reported that the FBI conducted 21 million background checks for firearm transfers, which includes 8.4 million first-time firearm purchases. The large amount of people who own firearms makes it vitally important for people to learn how to use them safely.

Safe Use

Whether driving a car, operating a chainsaw or using a firearm it is important to follow basic safety protocols to ensure that a useful tool does not cause unintended injury or damage. Never use any of these items without proper training, and this includes firearms.

Five basic firearm safety rules include:

1. Treat every firearm as if it were loaded.
2. Never point a firearm at anything you do not intend to shoot.
3. Do not touch the trigger until you are ready to fire.
4. Keep firearms on “safe” until you are ready to fire.
5. Know your target and what is beyond it.

Safe Storage

Every firearm owner has an obligation to prevent unauthorized use of their firearms. Properly securing firearms prevents accidental discharge, unauthorized use and theft.

Three ways to safely store a firearm include:

1. **Trigger Locks:** These locking devices typically use a key or combination lock to prevent the trigger from operating. Most firearms manufacturers provide a locking device with each new firearm purchase. Additionally, many police departments also provide free locks.
2. **Gun Cases:** These portable storage options are designed to allow one or more firearms to be transported safely and can be locked with padlocks.
3. **Gun Cabinets and Safes:** Both options are typically used at home to store firearms in a locked metal box. Safes tend to be constructed in a sturdier manner and therefore provide additional safety by preventing unauthorized access and some have robust fire damage capabilities. Cabinets and safes are secured by keys, combination locks or in some cases utilizing biometric/fingerprint technology.

Firearm Safety Courses

While many people learn to shoot a firearm from a family member or friend, others also take a course to reinforce firearms safety, training and proficiency. There are tens of thousands of Hunter Education and firearm safety courses conducted across the U.S. and online each year. Experienced instructors provide hands-on training to ensure that firearm users and owners know how to safely operate and store firearms. These courses may also include information about firearm laws in your state. In addition to hunting safety, course topics may include marksmanship, handgun shooting, defensive shooting, and more.

Demonstrate Your Understanding

1. Explain what steps a responsible firearm owner should take to prevent unauthorized use of their firearm(s)?
2. List the five basic firearm safety rules outlined in this chapter and explain why each of these rules are important.
3. Even if you do not plan to own or use a firearm, explain at least one reason why you might benefit from taking a firearm safety course.

SAMPLE USE ONLY

34.2: Eutrophication

Eutrophication

Eutrophication is a natural process that results from a body of water becoming over-enriched with nutrients. Excess nutrients can cause a sudden increase in algae growth, which feed on the nutrients. This is especially problematic when algae covers the surface of the water since it blocks sunlight from reaching sub surface plants. Without sunlight these plants can no longer do photosynthesis which means they will die and no longer produce oxygen. As these plants and algae decay, oxygen is consumed from the water. Without dissolved oxygen, aquatic animals, such as fish, clams, and crustaceans will also die. Although a natural process, eutrophication can be accelerated by human activities that add excess nutrients to the water. This process is more likely to occur in water bodies that have a high input of nutrients but are relatively stagnant (little current or movement of water), such as ponds, lakes and shallow parts of the ocean, like river mouths and bays. A fast-moving waterway will wash the nutrients downstream, which prevents eutrophication of the stream but can still cause it in areas downstream.

Harmful Algae Blooms

A symptom of severe eutrophication includes harmful algae bloom (HAB) events, which have increased in recent years. Excess nutrients can cause the rapid growth of a cyanobacteria, which eventually decay and remove oxygen in the water, and in turn threaten the health of the entire aquatic ecosystem. Also known as "*blue-green algae*", cyanobacteria have chlorophyll similar to actual algae and are known for producing a variety of toxins that range from skin irritants to neurotoxins. Exposure to these toxins by humans is greatest when drinking or swimming in the water, which often leads to the closure of municipal water supplies and beaches.

Because it is relatively shallow, the western basin of Lake Erie has had many HAB events due to excessive runoff of nutrients, specifically phosphorus and nitrogen.

Limiting Nutrients

The limiting nutrients for most aquatic ecosystems are nitrogen and phosphorus. Both nitrogen and phosphorus are vital nutrients for plant growth and their relative scarcity is usually what limits their growth. Nitrogen is widely recognized as the most limiting nutrient for plant growth and is an essential component of many proteins necessary to produce chlorophyll. A lack of nitrogen limits the amount of photosynthesis of a plant, which in turn limits plant growth. Although the atmosphere is nearly 80-percent nitrogen gas (N_2), this form of nitrogen is unreactive and not usable by most organisms. Lightning and nitrogen fixing bacteria can convert nitrogen gas into useable forms of nitrogen like ammonia and nitrate.

Similarly, phosphorus is also a vital limiting nutrient necessary for the formation of nucleic acids in DNA and RNA, as well as a key element in ATP (adenosine tri-phosphate). A lack of phosphorus results in stunted growth of plants and a reduction of flowering and fruiting.

Human Caused Sources of Nitrogen and Phosphorus

Fertilizers, phosphate-based detergents (soaps) and human waste are the largest sources of nitrogen and phosphorus. Fertilizers used on lawns and agricultural fields are identified by their N/P/K (nitrogen/phosphorus/potassium) content since these three elements are usually what are missing for optimum plant growth. Rain will often carry dissolved fertilizer with it as runoff into nearby streams, ditches or storm drains before it can be absorbed by plants. Phosphate-based detergents and human waste end up in wastewater that is supposed to be treated before being released. However, there are still many combined sewage systems (CSO) that cannot process the water quick enough during large rainfall

events. This results in untreated wastewater being dumped directly into nearby lakes and rivers. These nutrient sources play a significant role in causing more frequent and severe HAB events.

Controls

There have been extensive efforts to reduce the phosphorus and nitrogen sources that cause HAB events. Many communities with CSOs have spent millions of dollars to separate the stormwater and sewage pipes, which helped reduce raw sewage ending up in surface waters. No new CSOs have been built since the 1950s and the EPA's 1994 CSO Control Policy reduced the annual discharge of untreated waste from 1,070 billion gallons (pre CSO Control Policy) to 850 billion gallons. The use of fertilizers has also become more controlled by reducing the nitrogen and phosphorus content and limiting the amount that is used in areas next to lakes and streams. Agricultural practices have also adapted to help reduce the amount of fertilizer runoff by changing the timing of fertilizer applications and using soil analysis to apply the correct N/P/K levels. No-till farming, the use of cover crops and creating buffer zones along water bodies has helped to increase groundwater infiltration and reduce runoff, which reduces the amount of fertilizer in the water.

Demonstrate Your Understanding

1. Explain how blue-green algae can cause the death of other aquatic organisms. You may use a labeled drawing as part of your answer if you would like.
2. There are 2.5 million liters of water in an Olympic swimming pool (50m x 25m x 2m). Using the post-CSO control policy numbers provided in this section, how many of these pools could be filled up with the annual discharge of untreated sewage. 1 gal = 3.78 liters (Show Your Work)
3. Explain how the discharge of untreated sewage can cause a HAB event.