BY DESIGN

THE CENTER FOR CONSERVATION BIOLOGY

Annual Report 2023

CCB's
ONGOING MISSION

The mission of The Center for Conservation Biology, through all of its diverse programs, is to provide the global community with the information needed to drive thoughtful, science-based conservation, to educate and train the next generation of conservation scientists, and to make lasting contributions to the natural world through critical thinking, innovation and ground-breaking research.

THE CENTER FOR CONSERVATION BIOLOGY

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Annual Report 2023
Content by Bryan Watts
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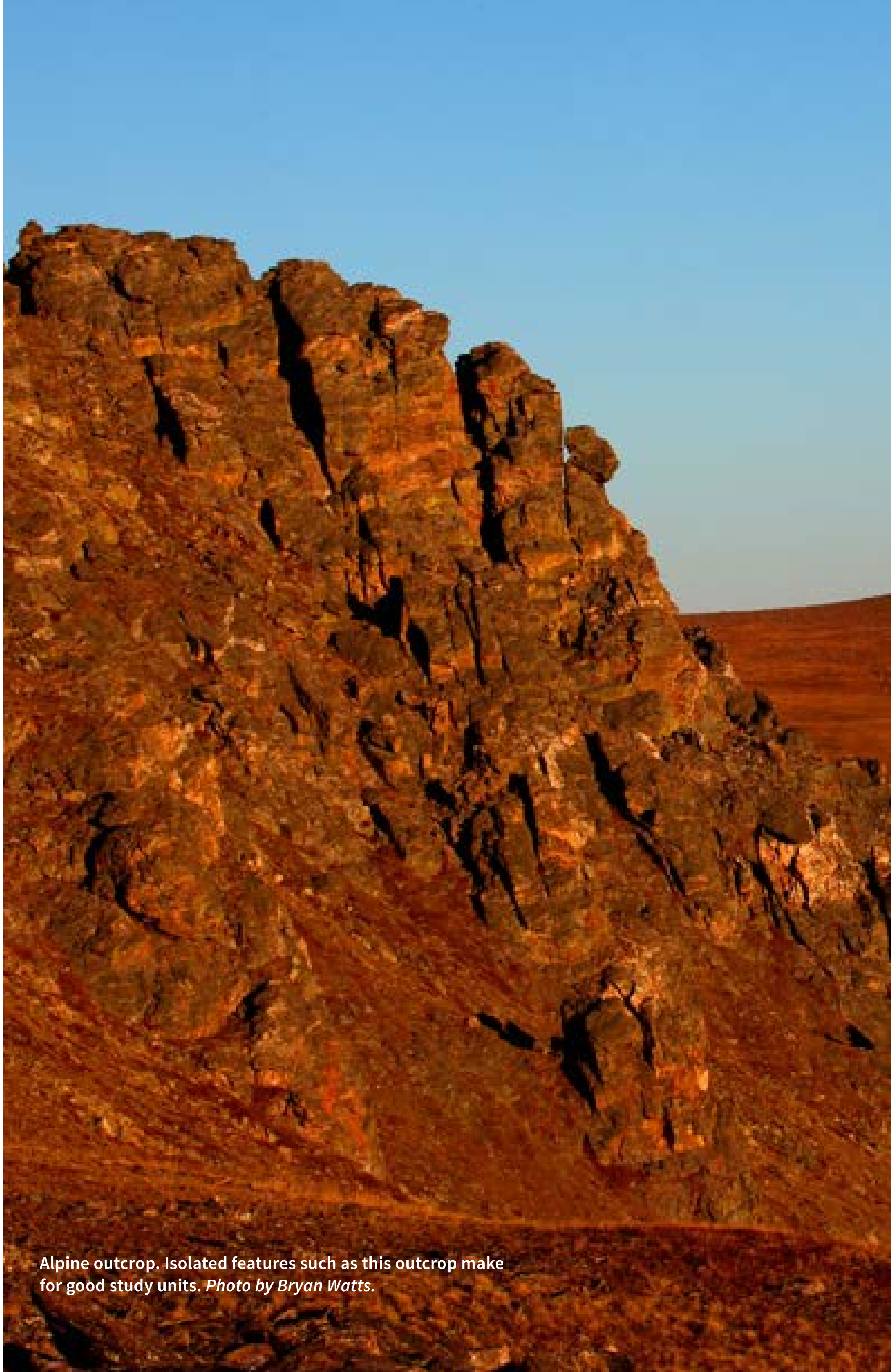
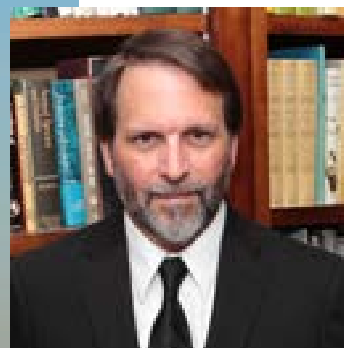
(Front cover) Adult bald eagle catches a blue catfish on the upper James River. Investigating changes in diet across the salinity gradient within the Chesapeake Bay allows us to better understand which prey populations eagles depend on and where. This natural history information informs management. *Photo by Bryan Watts.*



Alpine outcrop. Isolated features such as this outcrop make for good study units. *Photo by Bryan Watts.*

a MESSAGE *from the* DIRECTOR



There is something inspirational about walking through a Frank Lloyd Wright house or inspecting a George Nakashima bench. The organic lines and wholeness of design instill an intended sense of peace. Both masters designed from nature and believed that design was developed from within outwards seeking harmony between the materials, place and user. Each believed that design emanated from an intimate understanding of the material.

Great research design flows from the interdependence of statistical design and natural design. Statistical design allows us to interpret results with a known degree of confidence. This confidence is what gives science the footing to move forward. However, in order to effectively work with a species, we must know them as ourselves, understand the place where they live and understand the constraints under which they evolved. Working with a species without appropriate statistical design leaves us with little confidence in the outcome and applying statistical design without understanding the species may lead to meaningless results.

Beyond the statistics and natural history is the underlying purpose that a design is intended to fulfill. Wright was famous for stating “form follows function,” meaning that design begins with an intended purpose. Within conservation biology, we practice a form of backward design. We begin with a clearly defined objective and work backward using knowledge of natural history to inform statistical design and develop a methodology in service of the design. Within this annual report I highlight the relationship between natural design, statistical design and the process of backward design.

Join us in learning more about the species that need our help to persist.

Sincerely,

Bryan Watts

Bryan D. Watts
Mitchell A. Byrd Professor of Conservation Biology
Director, The Center for Conservation Biology

A clapper rail swims across a tidepool in a coastal marsh. Clappers are on the front line of sea-level rise. The Center has monitored them within a series of reference marshes for many years. So far, clappers have held up better than many other marsh species. *Photo by Bryan Watts.*

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Marsh grass at flood tide. Tidal marshes support a unique community of nesting birds that are threatened by sea-level rise. The Center established a set of reference marshes and we have monitored key species for more than thirty years to evaluate how populations are coping with rising seas. *Photo by Bryan Watts.*

NATURAL DESIGN

Species are marvels of design. Eons of time have shaped and reshaped form to function. The closer we look, the more beautiful the design and the more we appreciate how the many pieces of life dovetail together. Each element is essential to the whole and each fits hand in glove with the others. We refer to the general makeup of a species such as body size, clutch size, habitat use, diet, breeding strategy and others to be the species' natural history. Although descriptive in nature, natural history provides the foundation for designing research and the more we understand a species the more effective the design. Without a full understanding of natural history, we are designing blind and we lack the context needed to clearly interpret results.

Because we believe that natural history is an essential element of design, The Center has invested heavily in investigating the natural history of dozens of birds of conservation concern. These investments have resulted in more effective research and the development of comprehensive conservation programs that are tailored to individual species. Over time, The Center has become a reservoir of expertise that is used by agencies and organizations throughout the Western Hemisphere.

Northern gannet forages over the North Atlantic. As with other species, the design of this bird is exquisite. Their wing and body design allow them to migrate long distances and forage on the wing for hours. Their streamlined form allows them to plunge from height like a torpedo deep into the water for fish. *Photo by Bryan Watts.*

A THOUSAND FACES

As young naturalists we are fascinated and overwhelmed by the complex tapestry of life – the seemingly endless variety of forms, colors and behaviors. We can sit for hours watching a single individual as it reveals its natural history layer after layer. As ecologists we recognize that the number of ways that life can persist is not infinite. All species are bound by the same laws of thermodynamics, economics, motion and demography. The expressions that we see as species, though unique and endlessly fascinating, are actually riffs on the same basic melody.

Understanding the limits of the box in which populations may persist gives us insight into how we may design research on a wide variety of ecological and conservation issues. What level of harvest is a population able to absorb and how may we better design harvest studies? What is the threshold in prey density below which a population will collapse and how should we design research focused on prey management? What consumption rate is needed to fuel a migrant bird and how should we design human disturbance studies?

(Top) A juvenile yellow-crowned night heron in Panama. Although a brother to the race found in North America, the resident race in Panama has noticeably different juvenile plumage and body form. *Photo by Bryan Watts.*

(Bottom) The eared dove has a form and natural history typical of the family. This species is widespread throughout South America and is considered one of the most numerous doves in the world. The species reaches tremendous densities and is the focus of a large destination hunting industry. *Photo by Bryan Watts.*

(Opposite page) Purple gallinule sneaks through the shadows of a southern swamp. Birds come in a wide variety of shapes and colors but the foundations of their lives are remarkably similar because they all operate under the same constraints. Understanding these constraints provides researchers insights about how to better design projects. *Photo by Bryan Watts.*

Eastern willet fitted with a transmitter. Tracking is being used to better undestand space use on the breeding grounds and throughout the annual cycle. Understanding how species use space is an important component of designing projects to answer other questions. ***Photo by Bryan Watts.***

USE OF SPACE

Whether we are considering an eagle or a sparrow, one of the most amazing traits of wild birds is their ability to move. Flight has made birds the most mobile animal group on earth. Birds move in three ways including 1) around their home range where they move to perform daily activities, 2) when they are dispersing from where they were hatched to where they will breed themselves and 3) when they migrate to and from places that they use during different seasons. Distances traveled and the size and shape of the space they use vary dramatically between species and depends on factors such as body size and how essential resources are distributed.

For many ecological and conservation questions, understanding patterns of space use is an essential piece of information that allows us to define sampling units and to develop appropriate field designs. Once we determine the number of sampling units required, patterns of space use inform the required size of study areas, the logistics of fieldwork and the manpower needed to collect appropriate data. The Center has been interested in all aspects of bird movement for decades. For many species, The Center has invested considerably in quantifying space use. This information has contributed to what we know about the natural history of these species but has also allowed us to be more effective in designing fieldwork to answer pressing management questions.

(Top) Plants on primary dune along the Virginia Barrier Islands. These plants help form and stabilize the dune but also provide the primary food for the Ipswich sparrow during winter. Seed crops are patchy and vary across years. The distribution of seed crops determine space use by the sparrow. *Photo by Bryan Watts.*

(Bottom) Little blue heron. Banding work by Mitchell Byrd during the 1970s and 1980s in Virginia demonstrated that this species and other small herons dispersed widely throughout the mid-Atlantic and beyond shortly after leaving the natal colony. *Photo by Bryan Watts.*

ACTIVITY PERIODS

The great conservation biologist Aldo Leopold would rise before dawn, sit out in a chair, record the time when he first heard different bird species singing and then later the time when the singing rate began to decline. Bird species vary in their time of peak activity throughout their daily cycle. In addition to light levels and time of day, activity periods for many bird species also respond to other rhythms like tide stage, moon phase or rainfall. Many species also depend on seasonal resources and must migrate away when resources begin to decline. Understanding the temporal rhythms that constrain bird activity is a key piece of natural history that informs the design of field projects and the timing of data collection.

When the rate of bird activity varies with time, we must either control for time (constrain data collection to periods of known activity) or consider time as a separate factor (collect data across a range of activities) when investigating most ecological and conservation questions. When we know more about activity periods, we are able to increase field efficiency and isolate the factors of interest by targeting periods of high activity. The Center has conducted many studies focused on understanding activity periods in order to use this information to refine field designs and improve efficiency.

(Top) Purple sandpipers forage in an algae patch on the rocks of a bridge in the Chesapeake Bay. Like virtually all arctic-nesting shorebirds, purple sandpipers must migrate south to escape the cold winter months. Although species differ in specific winter grounds and prey, their annual cycles are similar and driven by the arctic winter. *Photo by Bart Paxton.*

(Bottom) The village of Willis Wharf during low tide. Many species of waterbirds feed on invertebrates accessible only when mudflats are exposed during the low tide. The foraging patterns of these species are centered around low tide. As the tide returns they move out to roost sites. *Photo by Bryan Watts.*

Chuck-will's-widow on nest. Work by The Center has established that their nesting cycle is aligned with the lunar cycle. This information has been used to design survey and breeding work with this species. *Photo by Bart Paxton.*

DEMOGRAPHY

Whenever we have a mortality event like a disease outbreak or an oil spill or a storm, we wonder how the event may impact the broader population. The same is true for large episodes of nest failure due to starvation or some other factor. Of course, changes in deaths and births are not always abrupt, showy events but are more often slow downturns that persist. The relationship between births and deaths is what drives population change and their study is demography. Because population change is a central focus of conservation biology, we often investigate demographic rates to better understand the underlying causes of population change. Understanding the basic framework of population biology and demography is critical to designing appropriate studies to isolate driving forces.

Most of conservation biology is concerned with changes on the population level. Designing studies to isolate and understand factors that underlie population change is a central focus of The Center. Over the years, we have invested a great deal in quantifying vital rates for many species. Understanding the range of births and deaths allows us to better design field projects on factors that influence these rates and to more effectively interpret the population consequences of results.

(Top) Banding a nestling red-cockaded woodpecker within the Piney Grove Preserve in Virginia. The Center has given all individuals within the population a unique combination of color bands so that we can follow them throughout their life. This effort allows us to estimate mortality rate and longevity, one of the key parameters that drive population dynamics. *Photo by Bobby Clontz.*

(Bottom) A young ruffed grouse just after hatching. Productivity is one of the key population parameters that informs research design and also allows us to evaluate results of studies in a population context. *Photo by Bryan Watts.*

(Opposite page) A brood of black-crowned night herons. Reproductive rate is one of the key demographic parameters that we monitor to assess population health and to understand the natural history of a species. *Photo by Bryan Watts.*

STATISTICAL DESIGN

Science moves forward along a very slow, methodical and deliberate path. In order for us to be confident in where we are as the journey pushes forward, each step must be built on a strong foundation. Statistics is a technology that describes and compares patterns from samples. It is a process of inferring an unknown quantity from a target population using sample data. Most importantly for our confidence, statistics let us quantify the uncertainty of the measurements or patterns and makes it possible for us to estimate the departure of our understanding from the truth.

When all of the elements come together a great field design combines statistical theory, constraints imposed by natural history, logistical limitations and practical matters related to available resources. When it works, a field design is a seamless thing of beauty that has its own resonance – it is a piece of art. The Center has developed hundreds of field designs involving many species and landscapes to address a wide range of questions. Some of these have been simple treatments while others have been very complex in both logistic and statistical considerations. Although many have been challenging, they have also been rewarding.

(Top) A female peregrine on her favorite perch on a bridge. Within urban settings, bridges have become important nesting sites for peregrines mimicking high natural cliffs. However, many bridges do not attract peregrines. In order to determine if the structures on movable bridges were more likely to attract peregrines we selected several replicate movable and unmovable bridges, developed a survey approach and systematically surveyed the two bridge types. Movable bridges were more likely to attract nesting peregrines. *Photo by Bryan Watts.*

(Bottom) Sarah Rosche counts wax myrtle berries as part of a fruit preference study focused on fall migrants. In order to evaluate preference, we used mesh bags to exclude migrants and compared fruit loss on exclusion limbs to control limbs. Several replicate limbs were used for each category and fruit species. Differences in consumption rates between fruit species was used to make recommendations about forest management for migrants. *Photo by Bart Paxton.*

A seaside sparrow gathers food for nestlings in a coastal salt marsh. We investigated patch size requirements for seaside and several other marsh birds by screening marsh patches by size, establishing target size categories and randomly selecting several replicate patches for each category. Four rounds of surveys were conducted for each patch within a seasonal window known to be the peak breeding period. Birds were surveyed during the early morning when the species are most detectable. All of the natural history, logistics and statistical requirements are considered in the overall design. *Photo by Bryan Watts.*

CONTROLLED EXPERIMENTS

The gold standard for linking cause and effect is the randomized controlled experiment. This approach allows us to isolate the response of a statistical population to an introduced "treatment." The design includes a treatment group that is exposed to the treatment and a control group that has no exposure to the treatment. Measuring the treatment response is made possible by contrasting the treatment group with the control group. A critical component of a controlled experiment is the random assignment of statistical units (e.g., individuals, habitat patches) to the groups. Random assignment means that all subjects in the study have an equal likelihood of being assigned to both groups. Randomization is intended to minimize bias by forming comparable populations within the two groups prior to treatment exposure.

Although increasingly common within ecological and conservation research, controlled experiments are still relatively rare within the world of field-based studies. In most natural systems, controlled experiments are rare because exposure cannot be practically or ethically assigned to research units. Because The Center works with species of high conservation concern, very few of our studies utilize controlled experiments.

(Top) The white-throated sparrow is a species of woody edges and forests. Their body design allows for good maneuverability and rapid acceleration. They depend on woody vegetation for protection against predators. Experimental manipulation of woody cover has a significant influence on distribution. The Center has done several controlled experiments using this species.

(Bottom) The savannah sparrow is a species of open grasslands. Their body design allows for high-end speeds and they use grass as cover from predators. They depend on grass seeds during the winter. Manipulation of grass cover and food has a direct influence on distribution. *Photos by Bryan Watts.*

A patch of grassland in late fall. Many grassland patches are ideal for controlled experiments because they are a continuous canvas of cover and food that may be manipulated by removing cover in the winter or by stopping seed production with mowing in summer. The Center has used this blank canvas to create controlled experiments with winter sparrows to better understand factors controlling space use and species interactions. *Photo by Bryan Watts.*

NATURAL EXPERIMENTS

A natural experiment is a study in which an event or situation (e.g., disease outbreak, snow storm, forest fire) that allows for the seemingly random assignment of subjects to different groups is exploited to answer a particular question. Because these events are outside the control of the researcher and the assignment of subjects to groups is not technically random, they are often considered to be quasi experiments. Since traditional manipulation is not possible or ethical in many field settings, natural experiments often offer the best alternative. However, most of these events are episodic and researchers must act quickly to capture the opportunity. They should not be relied upon to drive a research program.

Natural experiments of various types happen around us on a continuing basis. In order to capitalize on these events researchers need to be aware and nimble. The Center has exploited several natural events to better understand how populations respond. In addition to hurricanes and tornadoes, we have also studied responses to man-made events such as clear-cuts, controlled burns or herbicide treatments.

A low-intensity controlled burn runs along the ground and disturbs the ground vegetation. Fires are a natural part of many ecosystems and serve to set the successional stage back. Burns can be considered natural experiments and may be exploited to understand where species fit within the successional trajectory. *Photo by Bryan Watts.*

Dune vegetation buried in sand by high winds during a winter storm. Ipswich sparrows depend on seed crops that are vulnerable to being buried. During some years, winter storms may force them to redistribute during the winter. These storms are classic natural experiments. *Photo by Bryan Watts.*

(Opposite page) Migrant black-bellied plover in the hand. Black-bellies migrate from arctic breeding grounds to winter grounds in South America and use staging areas along the way. During high-tide periods, black-bellies and some other species will forage in uplands particularly during wet years. Plowing makes insects more available on the surface and is a human-driven treatment that can be exploited to better understand plover behavior. *Photo by Bryan Watts.*

OBSERVATIONAL STUDIES

Observational studies include the investigation of responses of subjects to changes in conditions (e.g., climate change, pollution, succession) over time or a comparison of subjects that occupy different settings (e.g., habitat types, salinity, predation pressure). Taking advantage of natural variation across the landscape in order to answer questions about how species respond to factors of interest requires an understanding of both the focal species and how the factors vary.

Because The Center works with species of high conservation concern and works in complex field settings, it is not ethical or practical to employ controlled experiments to answer most questions. More than 90% of the work conducted by The Center is based on observational study designs. These designs are challenging and require both an intimate understanding of focal species and innovation. We have effectively used these studies to move conservation forward.

(Top) Laughing gull on a post. Laughing gulls that nest in tidal salt marshes are exposed to ongoing sea-level rise. By monitoring colony locations relative to elevation over time we are able to evaluate how sea-level may be influencing nesting success and distribution. *Photo by Bryan Watts.*

(Bottom) Northern saw-whet owl during migration along the Delmarva Peninsula. This species is a small rodent specialist that breeds throughout the boreal zone. It is an irruptive migrant with high year to year variation in migration strength. This variation allows us to evaluate potential explanations for their migration system. High movement years are dominated by hatch-year birds. Irruption events appear to be driven by high productivity followed by failure of the prey base. *Photo by John DiGiorgio.*

(Opposite page) An incubating osprey is under surveillance by a nest camera. Nests make ideal statistical units. When some factor such as salinity, prey species or nest substrate varies across the landscape we are able to classify nests according to their exposure to the factor and draw a random sample of nests within different settings to reveal how a target ecological metric responds to the factor of interest. *Photo by Bryan Watts.*

REPETITION *or* REPLICATION

We are often told about an animal exhibiting an unusual behavior or the way that an animal responded to an event and are asked for an interpretation. Although the behavior may be interesting or notable, we have no way from a sample of one to interpret the implications on a population level. This is because individuals vary in a population and the observation may be the result of the “luck of the draw” landing on an oddball. Our interpretation may be different if one hundred individuals responded in the same way to an event. Sample statistics measure many individuals in order to characterize a population. In a study design, replication is the assignment of many individuals or statistical units to a group. The goal of replication is to reduce the role of chance variation on the results of our experiment. Increasing the number of individuals in our samples typically increases statistical power and reduces uncertainty when we make comparisons between groups.

There is a direct tradeoff between the number of replicates that a project can manage and the available resources. Reducing resources drives down replication which increases uncertainty. Researchers must be aware that below a threshold number of replicates uncertainty may be so high that the study is not worth conducting. Because replication is so tightly tied to producing clear results, The Center always attempts to include as many replications as possible. We push to improve design efficiency in order to include more replication.

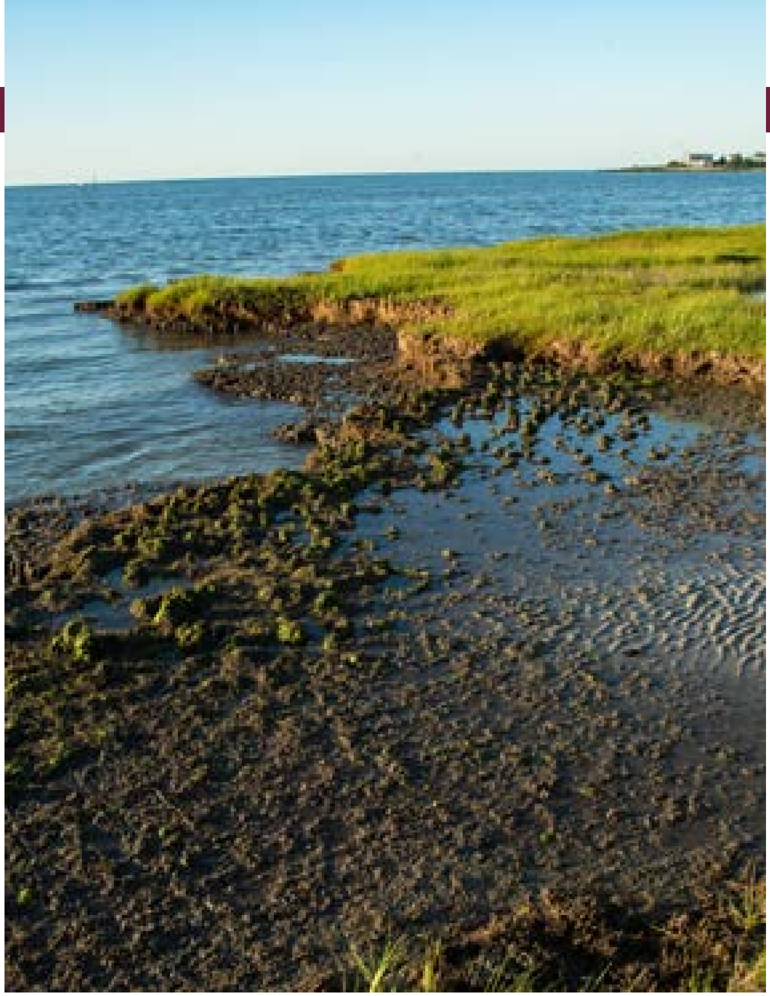
(Top) A patch of tidal marsh on the Mattaponi River. Isolated marsh patches represent great statistical units for studying bird communities. Marsh patches may be categorized according to factors such as size or salinity in order to reveal factors that influence distribution. *Photo by Bryan Watts.*

(Bottom) A "ghost hummock" along the York River that has lost most of its trees to sea-level rise. Because these patches are discrete and common they represent good replicates for understanding relationships between elevation and inundation that may influence bird communities. *Photo by Bryan Watts.*

Mixed cattle and great egret colony. Waterbird colonies are discrete units that support several to many nesting pairs. These colonies represent ideal replicates for study designs to examine dependent variables such as productivity, chick growth or brood provisioning. Because colonies are often widespread, they may be grouped according to exposure to independent factors of interest. ***Photo by Bryan Watts.***

DESIGN PROCESS

In many ways designing a research project is like planning a long journey. Although the journey begins with our current location, the planning actually begins with our stated destination. We work back from the destination to determine our route and mode of travel. Backward design is also the process we use to develop research designs because the design itself must be built to serve the question we need to answer. Whether building a chair or an iPhone, good design attempts to solve a problem. A clear and concise statement of the purpose or problem is a critical part of the design process. After we have stated the question, we outline the evidence that is sufficient to answer the question with an acceptably high degree of certainty. The question and associated evidence establish the objectives for the design. The design itself must juggle a long list of competing demands (statistical needs, logistics, available resources). Being able to consistently thread the needle and consider all of these demands requires a deep understanding of the species, a familiarity with the setting and an experienced hand.



(Top) Tidal salt marsh in the Chesapeake Bay with an erosion scar. Salt marshes are changing. They are moving upslope due to sea-level rise and they are eroding along the outer edges. All marshes are not showing the same patterns. We were interested in how exposure to winds may influence erosion rates. We examined the relationship between erosion rate and the length of fetch or open water using a range of marsh patches that varied according to exposure. The project identified a problem and an acceptable metric and then collected data to evaluate the question. *Photo by Bryan Watts.*

(Bottom) A view from a bald eagle nest in Maryland. The costs and logistical difficulty of collection varies between data sets. When considering the overall design we need to consider the full range of alternative pathways to address the questions posed. All elements should be practical and achievable. *Photo by Bryan Watts.*

When osprey within the lower Chesapeake Bay experienced low productivity, one of the initial questions was why. We investigated the possible role of prey availability by establishing a control and treatment group where the nests in the treatment group were provided with menhaden. Considering logistics, resources and statistical requirements, we successfully executed a study that demonstrated prey was playing a role in low productivity. We utilized backward design in order to move from a stated problem to identify acceptable evidence and then to the design. ***Photo by Bryan Watts.***

THE PROBLEM

As in rock climbing, science moves forward through a series of pitches punctuated by questions or problems. The answer to one question often leads to additional questions that could not be anticipated in the beginning. Although the sequence of answers may map a circuitous route, they push science forward. The clarity of the question itself is important in determining how definitively the question may be answered. A muddled question often leads to a muddled answer and a higher chance of a fall. Research design begins with a clear purpose or question. The question or problem statement should identify the context of the information gap, state the specific question that needs to be answered and lead to distinct hypotheses to be tested. This statement launches consideration of designs and methodologies.

Given unlimited time and resources there is an endless list of questions that could be asked and addressed through research. However, all questions are not equal in terms of their potential to move science forward. The Center has invested a great deal of effort to identify questions that can be answered and that when answered will make a difference.

(Top) Sanderling on a winter beach. Several shorebird species depend on beaches for foraging and roosting. Human disturbance denies some shorebird species access to beach habitat. A central question is how much human disturbance will different shorebirds tolerate. We evaluated this question by selecting a number of public and isolated beaches and repeatedly surveying both human and shorebird density. *Photo by Bill Portlock.*

(Bottom) Bald eagle nestling waiting to be weighed. Growth rate in the bald eagle population throughout the Chesapeake Bay has varied with salinity. One possible explanation for the difference is systematic variation in prey availability. We asked the question how does salinity influence brood provisioning rate and the related question how does salinity influence chick growth rate. *Photo by Catherine Markham.*

(Opposite page) Alex Wilke holds a whimbrel after transmitter attachment. Following work establishing that whimbrels using the Atlantic Flyway were declining, the question of why focused on where whimbrels were spending their time throughout the year. Whimbrels were tracked with satellite transmitters to answer this question. The result has led to follow-up investigations in critical locations throughout the flyway. *Photo by Bryan Watts.*

ACCEPTABLE EVIDENCE

For most projects within our daily lives the finish line is clearly defined. The concert is over when we sing the last song or a fence is completed when we set the last post. Although these thresholds may be set intuitively, they were established before the activity began. It is critical in research to determine what evidence and criteria we will accept in order to declare that a question has been answered. These criteria are one of the primary considerations in the research design. Research is blind to the outcome of a study. The specific answer to the question is not important, but rather that there be a definitive answer with a high degree of confidence. The criteria are set so that we have a high likelihood of differentiating between possible outcomes. Meeting the data needs of the criteria is a central objective of the design.

Setting appropriate criteria for many critical questions for species of high conservation concern is often difficult because frequently there is not enough information to insure that the study design will deliver the evidence needed. Pilot projects may be needed to remedy this problem. The Center will often over design projects in order to overcome the uncertainty. Another signature of projects conducted by The Center is to operate parallel investigations such that a constellation of related questions are evaluated simultaneously. This approach allows us to evaluate supporting evidence from several perspectives rather than relying on an isolated project.

(Top) Mason Neck National Wildlife Refuge. Bald eagles are vulnerable to human disturbance. We identified differences in reproductive rates in bald eagles between residential areas and wildlife refuges as one of several parameters that may provide insight into the influence of development on the eagle population. We identified several areas that have been developed over the past decade and several wildlife refuges that remain intact and used aerial surveys to monitor breeding performance to evaluate potential impacts. *Photo by Bryan Watts.*

(Bottom) Osprey productivity varies throughout the Chesapeake Bay according to salinity and associated prey communities. We want to investigate the role of realized fish availability on brood provisioning rates. Acceptable evidence that fish availability varies in high and low salinity areas is the amount of effort required for males to capture a fish. Developing catch-per-unit effort foraging models using tracking data will help to clarify foraging profitability and inform fisheries management. *Photo by Bryan Watts.*

Adult bald eagle caught in a rocket net on Aberdeen Proving Ground in Maryland. The installation had chronic eagle mortality caused by collisions with overhead lines. To investigate the underlying causes of variation in strike frequency along the electrical system, we used transmitters to track eagles and evaluated the correspondence between mortality rate and the line crossing rate. Our stated criterion for a positive relationship was a significant correspondence between mortality rate and crossing rate. A highly significant relationship allowed us to use movement patterns to identify additional problem lines for removal. *Photo by Bart Roberts.*

THE DESIGN

Many conservation problems and questions are very complex. The purpose and evaluation criteria establish the objectives of the design but they do not provide the road-map to its completion and often there is more than one way to get there. An integrated field design must consider how to achieve the objectives while considering constraints of logistics and resources as well as the features of the target species and study area. Developing a field design is more of an art than a science, and in the end a design is finished when all of the considerations are in balance. Designers should be open to all options including new technologies and techniques. Important characteristics of a good designer are maintaining a “beginner’s mind,” having a willingness to explore new options and being undeterred by failure.

The Center has been fearless in its field designs. We have developed new technologies and methodologies just to make designs more effective and we have always been willing to “borrow” any ideas or new discoveries from other disciplines. We believe that innovation is a key component to field projects and may ponder design solutions for months before going into the field to collect data.

(Top) Bald eagle transmitter harnesses that were designed and built by The Center. We are constantly adopting new technologies or adjusting old technologies to improve data collection and efficiency. Innovation is always an important component of designing fieldwork. *Photo by Bryan Watts.*

(Bottom) Maxi Galmes (left) and Manu Grande (right) conduct a prey transect count in Argentina as part of a comprehensive study of Chaco eagle ecology. When a large project is balanced and comes together there is a solid feeling of resonance. This outcome is the essence of good design. *Photo by Bryan Watts.*

(Opposite page) Traveling in a jon boat through a southern swamp to reach a field site. For many species of conservation concern, habitats are widespread and often difficult to access. Logistics may be the most important consideration in the design after purpose. In the end, the design has to work from a practical standpoint and all considerations should be balanced. *Photo by Bryan Watts.*

INSTITUTIONAL PARTNERS 2023

Acadia University

Advanced Conservation Strategies

Aluminum Company of America

American Bird Conservancy

American Eagle Foundation

American Wind Wildlife Institute

Arborscapes, LLC

Arizona Bird Conservation Initiative

Atlantic Coast Joint Venture

Audubon North Carolina

Audubon South Carolina

Audubon Louisiana

Avian Research and Conservation Institute

Bird Studies Canada

BirdsCaribbean

Boreal Songbird Initiative

Brooks Bird Club

Buck Island Ranch

Canadian Wildlife Service

Carmeuse Lime & Stone, Inc.

Center for Coastal Resources Management

Chesapeake Bay Bridge Tunnel Authority

Chesapeake Bay Foundation

Chesapeake Conservancy

Coastal Conservation Alliance

Coastal Virginia Wildlife Observatory

Colorado State University

Conserve Wildlife New Jersey

Cornell Laboratory of Ornithology

Cube Hydro Carolinas

Dalhousie University

Delaware Division of Fish and Wildlife

Delaware Natural History Museum

Discover the James

Dominion Energy

EA Engineering

EDM International

Environment Canada

Exelon Corporation

Florida Audubon

Florida Fish and Wildlife Conservation Commission

Friends of Dragon Run

Friends of Rappahannock River

George Mason University

Georgia Dept of Natural Resources

Georgia Ornithological Society

Georgian Bay Osprey Society

Gomez and Sullivan Engineers

Good Shepherd Fund

Gulf Coast Bird Observatory

Hampton Roads Bird Club

Hanover Aviation

Idaho Bird Observatory

Illinois Natural History Survey

Institute for Integrative Bird Behavior Studies

International Osprey Foundation

James River Association

Kentucky Dept of Fish and Wildlife Resources

Kissimmee Prairie Preserve

Kleinschmidt Associates

Laramie Audubon

Louisiana Fish and Wildlife

Low Country Institute

Luck Stone Corporation

Maine Dept of Inland Fisheries and Wildlife

Maine Natural History Observatory

Manomet, Inc

Martha's Vineyard Raptor Research

Maryland Dept of Natural Resources

Maryland Ornithological Society

MathScience Innovation Center

Michigan Audubon

Michigan Dept of Natural Resources

Michigan Natural Features Inventory

Microwave Telemetry, Inc

Midstream Technology, LLC

Midwest Coordinated Bird Monitoring Partnership

Mississippi Museum of Natural Science

Mississippi State University

Mount Allison University

Movebank

National Aeronautics and Space Administration

National Audubon Society

National Fish and Wildlife Foundation

National Park Service

New Hampshire Audubon

New Jersey Audubon

New Jersey Conservation Foundation

New Jersey Division of Fish and Wildlife

Norfolk Southern Corporation

North Carolina Wildlife Resources Commission

Northern Neck Audubon Society

Northern Virginia Conservation Trust

Ohio Dept of Natural Resources

Oklahoma State University

Osprey Watch Alliance

Panama Audubon

Parks Canada
Partners in Flight
Pennsylvania Game and Fish Commission
Progress Energy
Richmond Audubon
Richter Museum of Natural History
Rockbridge Bird Club
Rockingham Bird Club
Santa Rosa Ranch
Smithsonian Institution
Smithsonian Tropical Research Institute
Solertium Corporation
South Carolina Dept of Natural Resources
Southern Company
Southern Illinois University
State University of New York
Tennessee Ornithological Society
Tetra Tech, Inc
Texas Parks and Wildlife
The Carolina Bird Club
The Nature Conservancy
The Peregrine Fund
The Wildlife Center of Virginia
Theodore Roosevelt Conservation partnership
Toronto Ornithological Club
Three Lakes WMA
United States Army Corps of Engineers
United States Coast Guard
United States Dept of Agriculture
United States Dept of Defense
United States Fish and Wildlife Service
United States Forest Service
United States Geological Survey
Universidad de La Pampa, Argentina
University of Connecticut
University of Delaware
University of Georgia
University of Maine
University of Maryland
University of Moncton
University of Queensland
University of Rhode Island
University of Virginia
Virginia Academy of Science
Virginia Aquarium
Virginia Coastal Zone Management Program
Virginia Dept of Conservation and Recreation
Virginia Dept of Environmental Quality
Virginia Dept of Mines, Minerals, and Energy
Virginia Dept of Transportation
Virginia Dept of Wildlife Resources
Virginia Institute of Marine Science
Virginia Marine Resources Commission
Virginia Master Naturalists
Virginia National Estuarine Research Reserve
Virginia Outdoors Foundation
Virginia Saltwater sportfish Association
Virginia Society of Ornithology
Vulcan Materials Company
West Virginia Dept of Natural Resources
West Virginia University
Whitaker Center
William & Mary
Williamsburg Bird Club
Williamson Ranch
Wisconsin Bird Conservation Initiative
Woods Hole Group, Inc
XL Ranch
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(Back cover) Tide receding at dawn to expose mudflat just before the shorebirds arrive from their night roosts to forage. Foraging in tidal species is constrained and time must be considered in field designs. *Photo by Bryan Watts.*

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