NEW CONSERVATION PRIORITIES IN A CHANGING ARCTIC ALASKA

WORKSHOP SUMMARY

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* All photography in the document courtesy WCS—Steve Zack, Joe Liebezeit, & Kevin Titrzak.

ABSTRACT

Climate change is transforming Arctic Alaska and is impacting spectacular wildlife populations there. This region is renowned for its polar bear[1], muskox, vast herds of barren ground caribou, and the millions of migratory birds that come from around the globe to breed on the Arctic coastal plain. Projections for the near future indicate that the Arctic is changing dramatically, not incrementally, due to the cascading effects from steadily increasing temperatures. What such profound changes mean for wildlife conservation is not clear.

The Wildlife Conservation Society convened a workshop of expert stakeholders, scientists and managers, concerned with wildlife and landscapes of Arctic Alaska. This White Paper presents an overview of stakeholder discussion and tentative consensus for a diversity of topics that reflect emerging wildlife conservation priorities of a changing Arctic Alaska, a region greatly affected by climate change. The subsequent conclusions and recommendations included here will help shape wildlife conservation, research direction, and management planning in this region of international importance to wildlife.

[1] Latin names for species mentioned within text can be found in Table 1.

BACKGROUND

In the Arctic, climate change is occurring at twice the global average over the past 100 years (IPCC 2007). Changes to Arctic land and seascapes are occurring at an alarming pace, and climate models project a very different and transformed Arctic in the near future (ACIA 2004, Anisimov et al., 2007; Lenton et al., 2008). Transformative processes underway now include recession of Arctic sea ice and increasing dominance of open water, melting of permafrost triggering numerous changes including widespread thermokarst (erosion effects), shoreline erosion, and encroachment of woody vegetation into sedge tundra dominated systems (Tape et al. 2006, Sturm et al. 2005, Smith et al. 2005, Smol et al. 2005). Although there are some signals that wildlife is affected by such changes (Pamperin et al. 2006, Tulp and Schekkerman 2008), there is a seeming lag in widespread effects on wildlife in the Arctic relative to the climate-driven changes observed so far. Although it seems inevitable that there will be dramatic changes for wildlife in the changing Arctic, there is little consensus on what those changes might be and thus no clear management or conservation planning for wildlife.

Our collaborators from federal and state agencies, academia, the North Slope Borough, and NGOs have deep histories in Alaska's Arctic and collectively have a wealth of information and insight into Arctic wildlife conservation and management concerns. With support from the McCaw Foundation and with the help of an ad-hoc steering committee, we reached out to our collaborators and other stakeholders experienced and concerned with the effects of climate change on Arctic wildlife and convened a workshop entitled, "New Conservation Priorities in a Changing Arctic Alaska, A collaborative workshop sponsored by the Wildlife Conservation Society". The workshop was held at the Hawthorn Suites in Anchorage on April 20-21 2009.

OBJECTIVES AND GOALS

The workshop occurred at a time that Alaska's federal and state agencies were just getting underway with new processes of evaluating how the changing climate affects their abilities to manage wildlife and landscapes. And there are, of course, numerous research efforts underway and completed that are investigating the manifold effects of climate change and wildlife responses. Our intent and effort with this workshop was to bring together key scientific and management stakeholders and press to identify, under specified scenarios of change, new priorities of wildlife conservation with the changing climate. Our geographic scope included terrestrial Arctic Alaska, north of the Brooks Range. Our wildlife focus was that of the birds and mammals in the terrestrial Arctic of Alaska. In doing so, our objectives were to:

1. Gain a common understanding of how the key organizations/agencies with a mission to steward Arctic wildlife and geographies are integrating climate change into their management/conservation plans and initiatives;
2. Develop strategies how we can work collectively to better address conservation, management, and research specific to climate change (layered with current and pending energy development) by:
   a) Identifying the pressing knowledge gaps for Arctic wildlife and landscapes associated with a changing climate;
   b) Determine which wildlife species appear most vulnerable in a changing Arctic
   c) Identify which geographies appear to be most affected by a changing climate;
   d) Identify synergies between our groups, and how we can work together to implement effective understanding, conservation, and management.
3. Using potential climate change scenarios develop strategies that maximize wildlife conservation given the hypothetical conditions. Key questions to consider:
   a) What wildlife species/groups will be most affected?
   b) What geographies will be most affected and which ones will remain as potential refugia?
   c) What are the core uncertainties?

With this framework, we convened 24 experts across different stakeholder groups and collectively attempted to frame the near-future priorities, challenges and opportunities for wildlife conservation in Arctic Alaska.

SESSION I: THE STATE OF ARCTIC CLIMATE SCIENCE AND WILDLIFE

Both governmental agencies and NGO groups are just getting underway with formal processes of evaluating how the changing climate affects their abilities to manage wildlife and landscapes in Arctic Alaska. For the U.S. Fish and Wildlife Service (USFWS), their WildREACH effort (which includes WCS as a formal collaborator) has brought together ecosystem scientists with understanding in climate modeling, hydrology, and geology to inform wildlife biologists on the Arctic's changing processes. The U.S. Geological Survey (USGS) scientists are modeling populations of polar bears, of walrus, and the shifting populations of molting geese to understand how projected changes are reshaping key wildlife populations. The Bureau of Land Management (BLM) is trying to fit in climate change analysis within the framework of on-going studies and management interests in western Arctic Alaska, in the National Petroleum Reserve (NPR-A). The State of Alaska (Alaska Department of Fish and Game; ADF&G) has a new effort underway to evaluate how climate change is reshaping its institutional interests across the State, including wildlife concerns. On the NGO side, climate modeling efforts have begun to examine key issues related to climate change. For example, The Wilderness Society is developing region-specific models in the Arctic derived from Global Circulation Models to understand how temperature and precipitation interactions are affecting water balance in Arctic Alaska. The Nature Conservancy is developing biome shift models, while WCS has developed sea ice models to predict refugia for polar bears as well as conducting long-term monitoring research on nesting birds.

However, despite these nascent efforts, it is obvious that the challenges ahead due to climate changes are daunting. The reasons for this are 1) As stated earlier, climate change initiatives (and subsequent funding) specific to wildlife management in Alaska are just getting underway; 2) There are huge information gaps on how climate change, via disparate ecological processes, impacts Arctic wildlife and; 3) There currently exists no overall collaborative strategy (between all stakeholders) on how research efforts, subsequent management actions, and conservation efforts should be coordinated and carried out. Such activities need to be discussed and planned with the ultimate goal of providing effective management and conservation.

SESSION II: IDENTIFYING KEY GAPS AND IMPORTANT SYNERGISMS

Stakeholder Activities in Arctic Alaska: Key Gaps and Important Synergisms.

Following presentations by representative experts from the diverse stakeholder groups highlighting their recent and ongoing climate change-related activities in Arctic Alaska, we collectively identified important "gaps" in geography and of species in our collective efforts. We then identified where the most important overlaps in effort were and brought forth the key synergisms of research that can leverage important conservation activity with the changing climate. The resulting highlights are outlined below:

A. Geography Gaps

The group concurred that one of the best ways to better understand how climate change is affecting Arctic Alaskan wildlife would be to develop a network of monitoring sites (ideally in a systematic grid) established across the entire North Slope that represent:

1. The full range of climatic variation (e.g. temperature - coldest to warmest places on the slope);
2. All ecoregions (Brooks Range, foothills, coastal plain);
3. The full hydrological gradient.

The WildREACH workshop held earlier by USFWS similarly recommended the establishment of at least three long-term observatories on the North Slope where interdisciplinary monitoring efforts be conducted to better understand climate change impacts.

At the same time, in addition to region-wide monitoring, focused research on particular species in specific places was recognized as important in providing essential information in helping better understanding impacts to sensitive species in key places.

The costs and coordination involved in a North Slope-wide monitoring network would be a challenge to maintain. So, prior to identifying geography gaps it is important to first identify currently existing sites where we have the most knowledge and that already have (or have had) some form of monitoring and thus would not be as burdened as with the costs of establishing a new site. The sites where long-term wildlife research efforts have been established include: Barrow (multiple ongoing studies of wildlife and climate; some studies date to the 1950s), oil fields (Prudhoe, Kuparuk, etc. – diverse studies since the 1970s), Toolik Lake (University of Alaska's Long Term Ecological Research Station – includes most intense hydrological study – Kuparuk River), and 1002 area of the Arctic National Wildlife Refuge (USFWS base-line studies of the 1980s, diverse studies more recently). Long-term aerial survey studies for both mammal and bird species also have taken place across large parts of the coastal plain and foothills regions, in some cases for longer than 30 years.

Of all the ecoregions, most current information exists for the Arctic coastal plain, the region of the highest diversity and abundance of wildlife during the productive summer months. Less is known about the foothills and still less about the Brook's Range. Sites identified as the most important in terms of information gaps included Kasegaluk lagoon, Utukok foothills, foothills east of Toolik, and the Teshekpuk-Dease Inlet-Meade River area (Figure 1). These are areas of recognized wildlife importance but that we know little about the wildlife and the ecological processes. When selecting sites, it is important to consider a combination of land uses in including

both research and conservation implications. A site that would satisfy both of these needs (as well as other needs) would be ideal. At each established site, other key information could be collected to provide insight into key ecological processes and conservation-related issues. For this latter point, research that can assist in the identification of important wildlife corridors (e.g. Utukok to Kasegaluk lagoon for western arctic caribou herd) and refugia for particular species would be vital.

Important variables to measure at a network of monitoring sites (other than the direct measures of wildlife) include climate data (via weather stations), on-the-ground vegetation data, and remotely sensed primary productivity and climate data (satellite measurements like NDVI, etc.). It is important to note that aquatic fresh-water invertebrates are poorly known but probably drive higher trophic levels thus there is a need for quantifying this group at a network of sites. In general, key variables to measure would be ones that, from a climatic perspective, could lead to tipping points in climate while key biotic measures include the relevant species and ecological processes that tie the system together.

B. Species Gaps

The intent was to 1) identify mammal and bird species (or populations) where information is lacking (particularly with respect to climate change impacts) and 2) Identify species that could be monitored for climate change impacts at a network of North Slope sites (as was proposed previously).

In Arctic Alaska, most species (or species group) have been well-studied in at least one site for at least one aspect of their life history, typically during the summer season. However, few studies have examined any species across a large range and few if any studies have examined how climate change may impact particular species either at a local level or across a wide region.

The mammal that has the strongest support for monitoring at a network of sites are the two lemming species (brown and collared) since 1) they would likely be present at most of the sites; 2) they are relatively sedentary (not migratory) so would be more susceptible to Arctic-related climate change impacts; and 3) they are a key vertebrate species in the food web and are important in predator-prey dynamics (e.g. foxes, Pomarine Jaegers).

Mammals of importance for more intensive studies include the Alaska marmot which may be particularly sensitive to climate change since it is attitudinally dependent in its Brooks Range habitat. This species has a restricted range and a small population so it would not be a good candidate for monitoring at a network of sites. Wolverines have high densities in the Utukok Uplands and are relatively poorly known. More work with this species may be justified although no clear connection to a climate change has been identified. Wolverine populations are skewed to the foothills and Brook's Range so they would not be a good candidate to monitor at a network of sites. Some evidence suggests arctic fox are being replaced by red fox (e.g., Pamperin et al. 2006). More research on range changes in these species with regard to a changing climate is appropriate. The western and Teshekpuk caribou herd calving grounds in the Utukok region and near Teshekpuk Lake are poorly studied and would need more work to tie into what has been done for the more eastern herds (Central Arctic and Porcupine herds), including examining potential climate change effects. Polar bears are becoming more terrestrial so continued monitoring of this trend is important. Muskox response to climate change should be investigated in focused studies.

The birds that have the strongest support for monitoring at a network of sites include both ptarmigan species (Rock and Willow) and the American Golden Plover. These species occur broadly across the North Slope and so would be amenable to monitoring at most sites in a network. Ptarmigans are year-round residents, so are likely to be more influenced by a changing Arctic than migratory species. They are also less studied than most of the migratory bird species. American Golden Plovers are a species of concern with evidence of a declining population but with poor understanding as to the mechanism for this decline. Semipalmated Sandpipers were identified as an important species to monitor at a network of sites, however they are largely relegated to the coastal plain so would only provide information for that ecoregion. Some shorebirds of the Brook's Range foothills are species of concern or have low population numbers (Upland Sandpiper, Red Knot, Whimbrel, etc.) but because their densities are extremely low and their range is restricted to upland areas they would not be good candidates for a monitoring network or for more focused studies. The Yellow-billed Loon, a candidate species for listing, is also a species to consider for climate change impacts, especially as they rely on fish-producing lakes on the coastal plain, particularly in the west. Again, this species range and density would not allow it to be monitored at a range-wide network of sites. However, focused studies would be appropriate with efforts already underway by USGS researchers.

The overall consensus is that for individual species concerns, species in specific geographies represent the most important gaps (e.g., polar bears becoming more terrestrial; caribou at Utukok and near Teshekpuk; Smith's longspur in the foothills, etc.). These issues can be resolved by focused research. On the other hand, monitoring key species that occur over a broad range at a systematic grid of sites with a common protocol, collecting key biotic and abiotic data would offer the best insight into climate change impacts at a region-wide level.

C. Building Upon Information, Creating New Synergies

The most logical way to build on information is to continue long-term efforts while adding new sites, being sure to include components in the research design that address potential climate change effects. Current areas (or projects) that could be part of a more synergistic effort

SESSION II: IDENTIFYING KEY GAPS AND IMPORTANT SYNERGISMS (CONT.)

(involving diverse collaborators) that address key climate change issues include:

1. Government agency aerial surveys have monitored large nesting bird (waterfowl, loon, etc.) populations (e.g. Larned et al. 2005). Much data has already been collected as part of these efforts for more than 20 years with some information already accessible to examine potential climate change impacts. These efforts should include focused climate change related measures in future data collection. Specifically, it would be important to link a comparable remote sensing data set with these efforts;
2. Potential opportunities for long-term tundra-nesting bird monitoring (esp. shorebirds) for longitudinal studies (Barrow, Prudhoe Bay, Canning River) on the Arctic Coastal Plain. There have been sites set up across large parts of the Arctic Coastal Plain for other studies in recent years (e.g. Liebezeit et al. 2009). Two sites are still operational (USFWS at Barrow, WCS at Prudhoe Bay) and so the current monitoring could continue with a renewed focus on climate change impacts. Both of these sites also have had previous similar bird studies with data sets collected as far back as the 1950s for Barrow and the 1970s for Prudhoe Bay. It would be ideal to include these other data sets (if possible) in climate change assessments for birds in this region;
3. Examining all four caribou herds across the slope under a common protocol and including a component of climate change assessment. Current studies are intensive for the eastern herds.
4. Increasing ability to follow polar bear trends as more animals are collared as part of current USGS and USFWS studies.

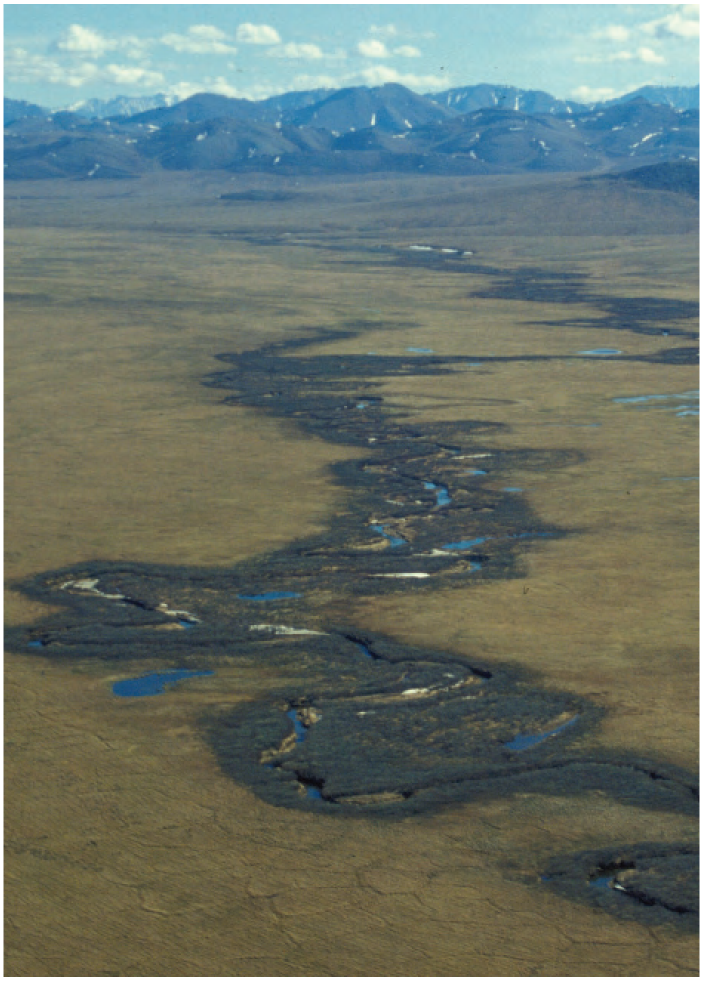
In addition, resources that are already available could be used to assist in collaborative efforts to investigate climate change and wildlife. Two examples include:

5. Synthetic organizing maps go back to the 1940s with caribou data and pressure records (e.g. outflow of the McKenzie River, Canada). Such information is vital for understanding historical trends in climate and wildlife and can be shared by groups on collaborative projects. It is important to note that extreme events drive a lot of what is happening so being able to ascribe cause is difficult;
6. There is the opportunity for a taxa-wide assessment of range shifts on the North Slope (e.g. Parmesan & Yohe 2003). Pieces from various existing data sets may be able to help

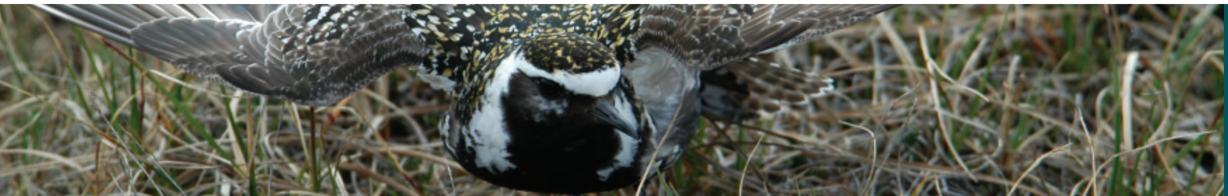
with such an endeavor.

D. Collaborative Funding Opportunities (to apply above)

In recent years, as evidence for climate change impacts have grown, there has been a shift in interest to funding climate change related projects. The Alaska Department of Fish and Game, State Wildlife Action plans (and Congressional support to fund these) includes climate change as a focus in their Comprehensive Wildlife Conservation Strategy (CWCS), however it should allocate specific funds for such efforts for both game and non-game species. ADFG does emphasize that they would like to support collaborative efforts. Current funds available are likely inadequate in providing comprehensive support for some of the suggested efforts, however, these funds can certainly help. Many foundations have also shifted interest to climate change and, as we emerge from the recent economic downturn there will be more funds available from these groups. There is specific interest in "adaptation" for some foundations. As a case in point, the Kresge Foundation has a climate change emphasis and collaboration is important. The National Fish and Wildlife Foundation currently has money available (largely through industry – Shell, ConocoPhillips) for research although it is not clearly specified for climate change work. The National Science Foundation has a new Arctic-centric grants program. Some of these NSF grants fund research; others fund coordination of research at multiple sites so both of these opportunities could help in collaborative climate change projects. The Bureau of Land Management and the U.S. Fish and Wildlife also have challenge cost-share grants (1:1 non-federal match) that could be used to help fund collaborative projects



such as those described above. The USFWS cost-share is not as comprehensive as that of the BLM since it tends to be for smaller amounts and for a one-year funding cycle. The Landscape Conservation Cooperative (a USFWS climate change strategy currently under internal review) may eventual offer competitive grants for climate change / wildlife research. One focus may be to create partnerships looking at climate change at a landscape level. As of yet, the North Slope Science Initiative (NSSI), a consortium of different agencies and groups, has not come through with funds to support any climate change related work.



SESSION III: CLIMATE CHANGE MODELING IN THE ARCTIC - CORE UNCERTAINTIES AND NEEDS

Following a series of presentations on changing climate modeling, with applications from global circulation models (GCMs), we evaluated the shortcomings and needs of such modeling to help our interest in identifying the most important issues of wildlife conservation in a changing Arctic. From the presentations at the workshop, it is clear that climate change is affecting Alaska in multifarious ways including: glacier and sea ice recession, coastal erosion, melting permafrost, shrinking wetlands, and an increase in tundra and forest fire frequency. In the Arctic, temperature increases, reduced snow cover, and an interesting interaction between both increased precipitation and increased evapo-transpiration are characterizing landscapes although coastal cloud cover may ameliorate some of the evaporation increases. Further, the complex interactions between permafrost water (a huge reservoir) amid evaporation led to uncertainty whether overall drying will characterize the coastal plain as seems fairly certain in parts of the Canadian high Arctic (Smith et al. 2005).

A. Core Uncertainties: The Interface of Climate Modeling and Wildlife

Some of the key gaps in our understanding of climate model include:

1) Habitat selection for individual wildlife species needs to be fully integrated into climate models to understand more of what is expected to change;
2) Interaction of behavioral and physiological plasticity of different wildlife species needs to be better understood with respect to a changing climate;
3) More weather stations in the Arctic are needed for better predictions. Currently, weather stations are coastally biased; more are needed in the foothills and Brook's Range (i.e. along topological and latitudinal gradients). At minimum, linkages between existing weather stations can be improved by collecting biotic data within the vicinity of each one (as in a North Slope-wide monitoring network described earlier). Greater coverage of weather stations will further improve the next round of GCMs which are expected to be better at local scales. A regional-scale model tuned to local area (local GCM) might be most appropriate;
4) Incorporation of a good regional vegetation model with a permafrost model is needed. (There are researchers currently working on this, E. Witten, P. comm.);
5) Better regional hydrology models are clearly needed, including more river gauges;
6) Need to incorporate severe weather events (and other extreme events) into models;

7) The prospect of plant succession (e.g. sphagnum moss succession to wet tundra) is alarming and need to be considered in models.

B. On the Potential for Arctic-Like Climate "Refugia": Criteria and Direction

As the Arctic climate changes dramatically and quickly, one hope for wildlife conservation is that some regions remain more "Arctic-like" amid climate changes. The group discussed what criteria and processes would characterize such "climate refugia":

Potential for Arctic-Like Climate "Refugia"and Important Clarifications

The definition of Arctic refugia is challenged by a number of different factors. Arctic refugia must first be held to certain criteria:

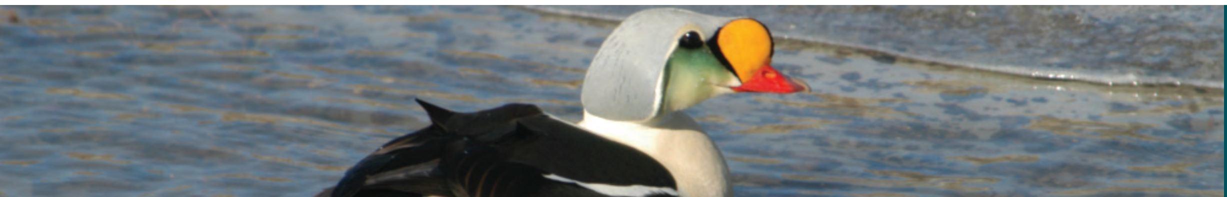
1. The scale of refugia (size and shape) likely will change depending on a species life history requirements. It is necessary to define the scale that allows a particular species persistence. The refugia must be large enough to encompass critical habitats (and in some cases multiple ecoregions for a target species);
2. The area may not have fixed boundaries and may be more important in terms of connectivity since many species require movement between various habitats;
3. It must be an area that will help or assist species (or populations) adapt to a situation or provide the room to adapt to climate change. The range of adaptation for particular species must be determined;
4. The climatic conditions must be buffered (i.e. remain somewhat constant compared to adjacent areas). Areas that experience the least amount of a temperature, precipitation, and biome shift would be the best sites to consider;
5. It is important to include current and proposed human disturbance (e.g. energy development) in helping to identify potential refugia.

Identifying the best refugia sites in Arctic Alaska is complicated by a number of factors including: 1) Predictions of local and regional level climate change are still not very accurate so an area that may look good as a refugium initially may not be an ideal site in the future; 2) Seasonal differences in climate change may make a site a refugium candidate in one season but not another (e.g. Barrow is predicted to warm more during the summer than it will during the winter compared to recent times).

In the near future, our best strategy may be to define relatively large areas as refugia that encompass multiple species and as we get more empirical information (e.g. at regional level) we can hone down key refugia into smaller areas and perhaps identify species-specific refugia. It is clear that linkages (corridors) between refugia will also be important to define.

C. Identifying Potential "Tipping Points" / Thresholds

Although scientific literature reviews talk about a transforming Arctic, it remains unclear how such transformations may be manifest on Arctic landscapes. The group sought to identify metrics of Arctic "tipping points" (Lenton et al. 2008) in the near future. The first obvious tipping point would be the 0°C freezing threshold. If this barrier is exceeded the Arctic hydrology will by dramatically affected via high levels of melting permafrost and could have subsequent dramatic



effects on wildlife. Related to this, loss of multi-year ice (both terrestrial in glaciers and sea ice) is a threshold we have already hit. Loss of sea ice, in particular, may be particularly important in driving regional climate patterns in the arctic. Another temperature threshold is 12°C – the tree line threshold. This is of less immediate concern in the Arctic, but again could result in biome shift of taiga into tundra and impact wildlife in both positive and negative ways. Such a threshold may also reduce soil moisture and increase fire hazard.

As the water balance (P-PET) in the arctic shifts to a negative trend (evapotranspiration exceeding precipitation) as is suspected by current GCM models (O'Brien), a tipping point may be reached in that there will be a point where mid-summer drying levels may reach a level where there is a fundamental change in habitat. In this case, a tipping point may be signaled by habitat change with respect to negative P-PET (e.g. the disappearance of wetlands).

An important biotic tipping point may be the loss or dramatic alteration of keystone species populations. Although loss of large megafauna like polar bear would certainly have repercussions on other wildlife (i.e., seal populations) arctic systems are driven from the bottom up. For example, changes in lemming populations may have dramatic impacts (both positive and negative) on predator populations. Of equal or greater importance, a drying of tundra may result in loss of freshwater invertebrate species which form the food basis for many species. Such a change may have dramatic effects on higher trophic levels. In particular, many bird species that breed in the arctic would be directly affected as most depend almost entirely on such invertebrates as a food source. In terms of functionality, the biotic processes in the Arctic are often related to bursts of productivity (e.g. insect emergence) that draw species or that effect timing of species life cycles. If the Arctic becomes more temperate-like (drawn out productivity), that portends a "tipping point" because of a disruption or decoupling of species life cycles (Tulp and Schekkerman 2008). Finally, the invasion of temperate zone diseases into the Arctic could represent another tipping point.

As mentioned previously we have already past the tipping point for retention of multi-year ice in some areas. In addition, we are past the tipping point of carbon sequestration, it is now in release after millennia trapped in permafrost.

SESSION IV: CLIMATE CHANGE SCENARIOS AND WILDLIFE CONSERVATION PRIORITIES

In order to jump-start discussion on how to deal with future climate change impacts on wildlife we framed possible scenarios of climate change for the group to address. It is clear that we currently do not have sufficient empirical data to make the best decisions in managing wildlife with respect to such climate change scenarios. However, the point of this exercise was to start a discussion on how we would deal with these hypothetical (yet plausible) situations given our current state of knowledge.

We picked three scenarios (drier arctic and increasing shrubs, changing phenology, boreal animal invasion) among a larger subset (Table 2) and developed a common set of questions for each scenario. The questions included:

1. What wildlife species / groups will be most affected?
2. What geographies will be most affected and which ones will remain as potential refugia?
3. What are the core uncertainties?

A. Scenario #1: Drier Arctic tundra & increasing shrubs.

1. What wildlife species / groups will be most affected?

Species impacts from a drying Arctic would be complicated with some clear "winner" and some "loser" species, while for others it would be hard to quantify an effect. In coastal areas, reconfiguration of barrier islands could allow fox access and thus increase predation on common eider nests. Seasonal wetlands are likely to dry prior to larger, deeper lakes. Because of this, eiders, dabbling and diving ducks, and loons would probably not be significantly impacted in terms of foraging habitat loss. However, piscivorous birds (e.g. loons, arctic terns) may have reduced foraging from drying because of reduced connectivity between lakes impeding fish dispersion. Shorebirds that typically nest in wet tundra habitats (e.g. phalarope species, long-billed dowitcher) may be impacted most in terms of loss of nesting habitat. On the other hand, species that typically nest in drier habitats (e.g. plovers, whimbrel) may actually benefit from drying tundra in terms of increasing nesting habitat. For both shorebirds species, a drying tundra will likely negatively impact foraging since invertebrate prey abundance will be reduced (or emergence times will go from a burst to more gradual emergence) and also less foraging habitat may be available since drying will reduce wetlands and pond edges. Protection from mammalian predators (i.e. foxes) via the "moat effect" for breeding birds that nest on small islands (e.g. gulls, eiders, long-tailed ducks, arctic terns) may be reduced since small islands may connect with the mainland as a consequence of drying. Increased shrubs may provide more nesting habitat for predatory birds.

For mammals, a significant increase in shrubs my benefit some small mammals, like arctic hare (and subsequently lynx encroaching from the boreal forests), and ground squirrels since it would potentially provide more forage and increase cover. However other small mammals may be negatively impacted. For example, brown lemmings might lose habitat since they are tied to wetter areas. Brown lemming populations are cyclical and tied to obligate predators (i.e. Pomarine Jaegers) and thus it may additionally strain these predator populations. Collared lemmings might do better since they are better adapted to drier habitats and may actually increase and replace brown lemmings as habitats dry.

If drying were to occur widely, it is likely that shrub cover would expand northward and potentially outward from riparian areas. Some level of shrubs would provide cover for some species. For example, eiders may benefit from some shrub cover (but not too much). On the other hand, most shorebirds prefer little shrub cover so they can see and escape from predators easily. Some passerine species would benefit since many (e.g. redpolls, wagtails, bluethroat) nest in shrubby habitat. For mammals, browsers like moose and porcupine would benefit. Caribou forage may be impacted since more forage may be available but will likely be of lower quality. Caribou movements are not likely to be impacted.

2. What geographies will be most affected and which ones will remain as potential refugia?

In coastal areas, sedimentation rates could affect barrier islands (either via erosion or accretion). On the coastal plain, wetlands that are precipitation-driven are most likely to be affected so shallow ponds and wetlands will be most threatened. Larger water bodies will be less affected, but nonetheless will see changes in ecology that affect wildlife. In riverine systems, less water in braided channels could have significant wildlife consequences. At the same time, ice wedge tapping and new drainage passages are expected to emerge. In the foothills, upland meadows may disappear. Tundra fires are expected to increase in intensity and frequency. This is significant since it takes a long time for tundra to come back after fire, and such fires may indeed jump-start succession to more shrubby habitats.

Identification of refugia is difficult. However, two potential areas include: 1) New lakes may form in the ice-rich lower foothills region thus providing new habitat (refugia) for species tied to the thaw lakes; and 2) The coastal fringe could be a refugia because the high levels of summer fog and cooler climatic conditions could potentially buffer this region from warmer temperatures associated with climate change, however, this may be tempered by the coastal erosion that will eat away habitat in some places (e.g. north of Teshekpuk Lake). Deeper lakes that persist through drying throughout the Arctic Coastal Plain may also act as refugia.

3. Core uncertainties of ecological interaction

The first steps in helping to increase our ability to identify refugia would be to 1) Better understanding the hydrology, permafrost, lake tapping through ice wedge degradation via modeling (e.g. lakes with different origins may respond differently to drying); 2) Study if and how fire is increasing in the Arctic north; 3) Better understand how aquatic and semi-aquatic invertebrates can handle the prolonged drying.

B. Scenario #2: Changing Phenology

1. What wildlife species / groups will be most affected?

For bird species, “capital breeders” – those bird species that gain nutrients for reproduction away from breeding grounds in wintering and stopover sites (e.g., some geese and possibly tundra swan) would appear less susceptible to changing phenological conditions as compared to “income breeders” that gain nutrients for reproduction on the breeding grounds (e.g., King Eider, shorebirds). However, range shifts could still affect capitol breeders. For example, larger trumpeter swans are moving northward and could replace tundra swans. A key issue for geese would be the relationship between spring arrival and green plant emergence. A warming climate may allow production of more forage although quality may be compromised. For shorebirds, it is possible that those that arrive to Arctic after long flights with few stops (e.g., red knot, bar-tailed godwit) may be more at risk than those species that have many stopovers along the way (e.g., Stilt Sandpiper). The primary risk for shorebirds is the potential for decreased food availability for chicks with changing phenology although bird species with replacement clutches may benefit from a more sustained insect emergence.

For mammals, an earlier green up means earlier senescence in the fall which could result in lower survivorship. For the Teshekpuk Lake Caribou Herd, calving timing depends greatly on snow melt thus changes in timing of snow melt could create problems. Increased precipitation and lingering snow packs in the spring have caused a shift in the location of the calving grounds as seen in Porcupine Caribou Herd. For muskoxen there is some evidence of calves being born earlier in spring.

Some suggest that the 7-year population cycle in many invertebrates has been reduced to 4-5 years (from studies by Matt Butler for his PhD in Barrow in early 1980s). Such a change would likely have an effect on the food chain, although there is not enough information to postulate the degree and type of impact it will have.

2. Core uncertainties of ecological interaction

We need to better understand extreme weather events (e.g. are they increasing) and what role do they have, if any, in affecting a changing phenology. Also, how would seasonal transitions such as snowmelt and breakup affect phenology of wildlife, in particular keystone species like lemmings and voles. How would a possible “broadened” versus peaked emergence in insects and vegetation affect bird hatchlings? What would be the implications of a longer growing season on vegetation and insects?

C. Scenario #3: Boreal Animal Invasion

Current evidence of range expansion for boreal species includes a suite of bird species. For example, Tree swallows have now been reported breeding in Barrow and Umiat (significant northward extension to range of this very southerly species). American robins have been observed on the north side of the Brooks Range and into the foothills near the coastal plain of the Arctic. Dabbling” ducks (many in the genus Anas)

seem to be moving into Arctic from typical range in boreal forests although no evidence from aerial surveys supports this (B. Larned, pers. Obs.). For shorebirds, there appears to be a shift in long-billed dowitcher range.

For mammals, red fox invasion is well documented in Scandinavia (Selås and Vik 2007) and Canada (Hersteinsson and Macdonald 1992) but not yet well documented in Arctic Alaska, however anecdotal evidence is raising concern over the possibility of it replacing Arctic fox (Pamperin et al. 2006). Reports of interbreeding between grizzly bears and polar bears have led some to speculate that this could be a growing trend. It is important to point out that polar bears are historically resilient to climate changes and have made it through bottlenecks (glacial and interglacial periods) of the Pleistocene, but the scientific jury is out for whether they can weather this next warming trend. Grizzly bears could potentially increase on the North Slope if anadromous fish (especially salmon) shift their range to coastal plain rivers. More moose are seen on the North Slope, but there is no indication that they are staying year-round. If they are able to gain a foothold on the coastal plain this would expand the prey base for predators and could lead to more numerous wolves in this ecoregion. This could also benefit other ungulates via reduced predation pressure. Porcupines appear to be moving north along with their forage (shrub / tree bark).

In summary, ranges of some species appear to be shifting northward although much of the current information is based on anecdotal information and it is not entirely clear if these range shifts are related to climate change. A network of wildlife monitoring sites across the slope could slowly piece together the exact nature of these shifts and why they are occurring. A few overarching questions to keep in mind would be 1) What would be the consequence of more species in the Arctic? For example, is there a limit to nesting densities of birds?; 2) Would the old ecological truism of generalists outcompeting specialists in changing conditions apply to the Alaskan Arctic?; 3) What would be the ecological repercussions and how would the food web be altered as boreal species invade and establish themselves? For example, how would invading common loons interact with arctic loons? Would new parasites and disease vectors be introduced into the Arctic (e.g. spruce budworm in southern Alaska) and how would this alter the ecosystem?

SESSION V: CONCLUSIONS AND RECOMMENDATIONS

This workshop follows up a larger interdisciplinary effort by the U.S. Fish and Wildlife Service called WildREACH of which the Wildlife Conservation Society was a supporter and participant. Both of these workshops aimed to begin the process of developing a strategy to manage Arctic Alaskan wildlife with respect to a changing climate. Although there was inevitably overlap between these two workshops the aim of this second effort was to compliment and build upon some specific topics, and to focus more on hypothetical scenarios of wildlife response to a changing arctic and the resulting conservation implications (including how human development may play a part in these decisions). In addition, in this workshop we set out to identify how government agencies and NGOs can work together more effectively to better understand climate change impacts to wildlife in Arctic Alaska. This second workshop complemented WildREACH by allowing smaller more intimate discussions with a narrower focus (in terms of abiotic ecological processes). These two workshops take the first steps in tackling this important and daunting issue. There is still much more to be done.

Below is a bulleted list of the main findings under each of the workshop goals:

OBJECTIVE #1: *Gain a common understanding of how the key organizations/agencies with a mission to steward Arctic wildlife and geographies are integrating climate change and pending energy development patterns into their management / conservation plans and initiatives.*

- Efforts by agencies and organizations to develop strategies are in their infancy and as of yet there is little synergy between groups to develop a universal strategy to manage wildlife with respect to climate change in Arctic Alaska.

OBJECTIVE #2: *Develop strategies how we can work collectively to better address likely conservation, management, and research specific to Climate Change.*

- Two main research strategies were defined:

1. Focused wildlife studies on particular climate change impacts to key species;
2. The development of an arctic-wide monitoring network where biotic, climate, and hydrologic data are monitored over the long term.

- Within the "focused studies" approach key species to investigate include those that are recognized as being vulnerable to climate change impacts (e.g. Alaska Marmot, Yellow-billed Loon).

- For the arctic-wide monitoring network, sites should be picked based on the following criteria:

1. Choose areas that already have (or have had) wildlife monitoring preferably with long-term data set (>5 years) and that have a component of or access to climate data from the same region.
   - » Candidate sites include Barrow, Toolik, Prudhoe Bay (and surrounding oilfields), and sites in the 1002 area of the Arctic National Wildlife Refuge.
2. Choose areas of known or suspected conservation importance particularly where little information on wildlife currently exists.
   - » Candidate sites include Kasegaluk

Lagoon, Utukok Uplands, Meade River area, Teshekpuk Lake region, Dease Inlet, foothills east of Toolik, and the 1002 area of the Arctic National Wildlife Refuge.

- Within an arctic-wide monitoring network the approach would be to select a few species that are common across most of the North Slope (e.g. lemmings, American golden-plover, Semipalmated Sandpiper) and that ideally are important drivers in the food web (e.g. lemmings).
- It was identified that the best way to work synergistically is to build upon the information we already have and apply it to solving climate change problems. Four long-term efforts, one map data set, and one literature review idea were identified that could help in this regard.
- Although there is a growing trend in funding climate change related projects, funds currently available from many contributors would not be adequate for answering big questions or supporting on-going region-wide monitoring. However, we identified seven funding opportunities that support climate change including collaborative projects.
- The group identified seven key ways that climate modeling efforts should be improved including:

1. Incorporation of habitat selection information;
2. Include interaction of behavioral and physiological plasticity;
3. More weather stations needed;
4. Incorporation of a good regional vegetation model with a permafrost model
5. Better regional hydrology data
6. Incorporate severe weather events;
7. Plant succession scenarios.

- We identified several criteria that should help define and determine placement of arctic refugia including:

1. The scale (size and shape);
2. Boundaries may be changeable and connectivity needs to be considered;
3. Allow species (or populations) to adapt to climate change;
4. Climatic conditions must be more "buffered" compared to adjacent areas;
5. Important to consider current and proposed human development.

- Six potential tipping points in climate change were identified that could dramatically accelerate climate change. These include:

1. 0°C freezing threshold;
2. 12°C – the tree line threshold;
3. Habitat change with respect to a negative P-PET;
4. Loss or dramatic alteration of keystone species populations;
5. Decoupling of species life cycles;
6. Invasion of temperate zone diseases.

Objective #3: Using potential climate change scenarios develop strategies that maximize wildlife conservation given the hypothetical conditions.

1. Drying arctic scenario:
   - Impacts to wildlife will likely be complicated with some "winner" and "loser" species.
   - Two potential refugia include:
     » New lakes that could form in the ice-rich foothills ecoregion could provide habitat

lost in other regions;
  - » The coastal fringe could act as a refugia because fog and cooler climatic conditions in the summer may buffer climate change.

2. Changing phenology scenario:
   - Capitol breeders will be less subject to phenological change than income breeders.
3. Boreal animal invasion scenario:
   - The ranges of some species are shifting northward;
   - A network of wildlife monitoring sites across the slope could slowly piece together these shifts and why they are occurring.

Future Directions: The Wildlife Conservation Society will build upon this White Paper to help craft a manuscript, written collectively by the attendees, of the main points, uncertainties, and directions arising from this workshop. The eventual publication of such a peer-reviewed paper would go a long way in helping to shape conservation priorities of wildlife in a changing Arctic.

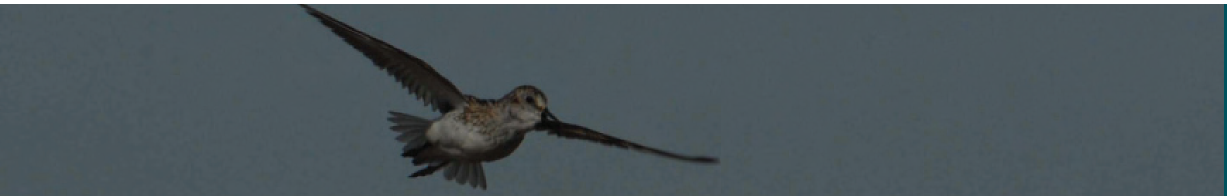


Table 1. Arctic Terrestrial Birds and Mammals Species Lists Used During the Workshop Discussions.

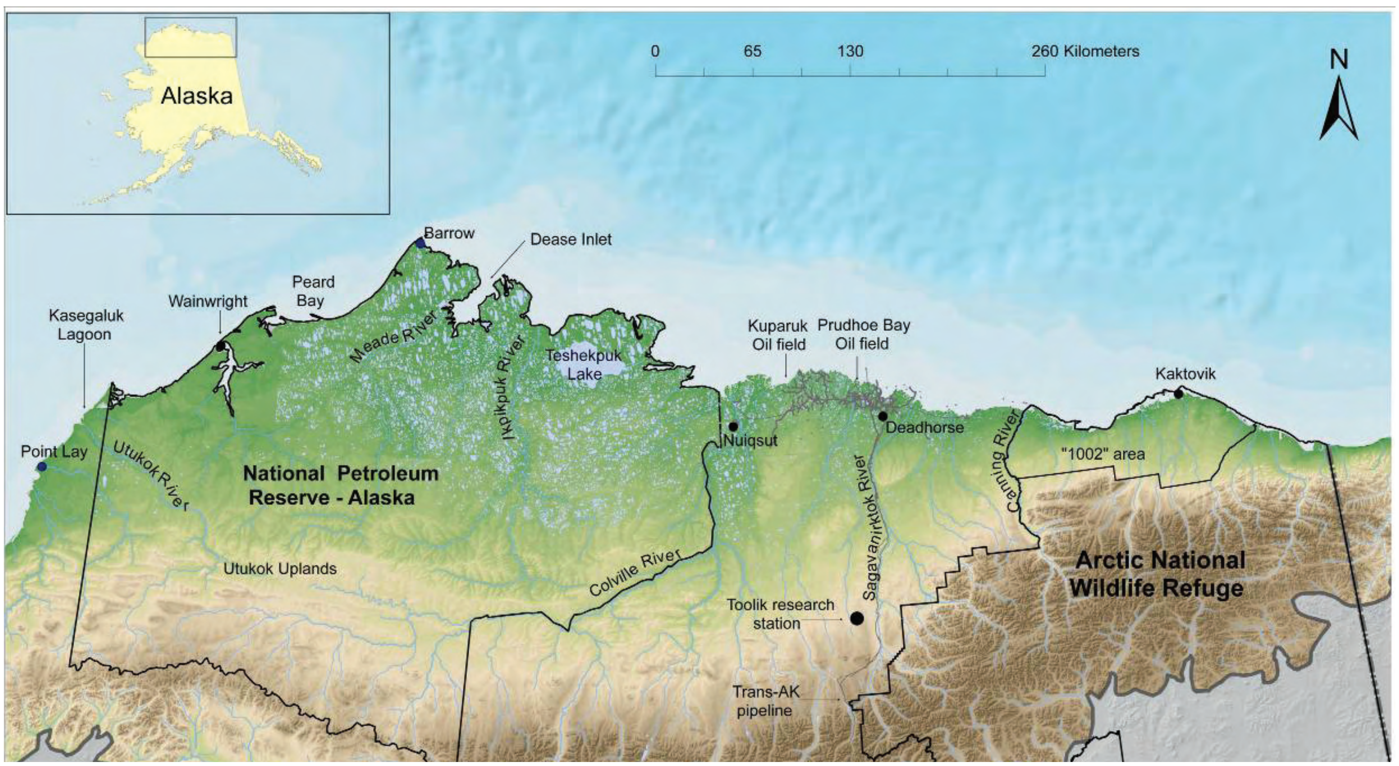
COMMON NAME	LATIN NAME
BIRDS	
SHOREBIRDS	
Black-bellied Plover	*Pluvialis squatarola*
American Golden-Plover	*Pluvialis dominica*
Pacific Golden-Plover	*Pluvialis fulva*
Semipalmated Plover	*Charadrius semipalmatus*
Upland Sandpiper	*Bartramia longicauda*
Whimbrel	*Numenius phaeopus*
Bar-tailed Godwit	*Limosa lapponica*
Ruddy Turnstone	*Arenaria interpres*
Red Knot	*Calidris canutus*
Sanderling	*Calidris alba*
Semipalmated Sandpiper	*Calidris pusilla*
Western Sandpiper	*Calidris mauri*
White-rumped Sandpiper	*Calidris fuscicollis*
Baird's Sandpiper	*Calidris bairdii*
Pectoral Sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpina*
Stilt Sandpiper	*Calidris himantopus*
Buff-breasted Sandpiper	*Tryngites subruficollis*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Wilson's Snipe	*Phalaropus tricolor*
Red-necked Phalarope	*Phalaropus lobatus*
Red Phalarope	*Phalaropus fulicaria*
JAEGERS, GULLS, TERNS	
Pomarine Jaeger	*Stercorarius pomarinus*
Parasitic Jaeger	*Stercorarius parasiticus*
Long-tailed Jaeger	*Stercorarius longicaudus*
Glaucous Gull	*Larus hyperboreus*
Sabine's Gull	*Xema sabini*
Ross' Gull	*Rhodostethia rosea*
Ivory Gull	*Pagophila eburnea*
Arctic Tern	*Sterna paradisaea*
LOONS	
Red-throated Loon	*Gavia stellata*
Arctic / Pacific Loon	*Gavia arctica / pacifica*
Yellow-billed Loon	*Gavia adamsii*
RAPTORS	
Bald Eagle	*Haliaeetus leucocephalus*
Northern Harrier	*Circus cyaneus*
Sharp-shinned Hawk	*Accipiter striatus*
Rough-legged Hawk	*Buteo lagopus*
Golden Eagle	*Aquila chrysaetos*
Merlin	*Falco columbarius*
Gyrfalcon	*Falco rusticolus*
Peregrine Falcon	*Falco peregrinus*
CRANES	
Sandhill Crane	*Grus canadensis*
PASSERINES	
Arctic Warbler	*Phylloscopus borealis*
Common Raven	*Corvus corax*
Yellow Wagtail	*Motacilla flava*
White Wagtail	*Motacilla alba*
American Tree Sparrow	*Spizella arborea*
American Pipit	*Anthus rubescens*
Lapland Longspur	*Calcarius lapponicus*
Smith's Longspur	*Calcarius pictus*
Snow Bunting	*Plectrophenax nivalis*
McKay's Bunting	*Plectrophenax hyperboreus*
Common Redpoll	*Carduelis flammea*
Hoary Redpoll	*Carduelis hornemanni*
Blue throat	*Luscinia svecica*

COMMON NAME	LATIN NAME
BIRDS (CONT.)	
GEESE, SWANS, DUCKS	
Tundra Swan	*Cygnus columbianus*
Greater White-fronted Goose	*Anser albifrons*
Snow Goose	*Chen caerulescens*
Brant	*Branta bernicla*
Cackling Goose	*Branta hutchinsii*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Gadwall	*Anas strepera*
American Wigeon	*Anas americana*
Northern Shoveler	*Anas clypeata*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Greater Scaup	*Aythya marila*
Steller's Eider	*Polysticta stelleri*
Spectacled Eider	*Somateria fischeri*
King Eider	*Somateria spectabilis*
Common Eider	*Somateria mollissima*
Surf Scoter	*Melanitta perspicillata*
Long-tailed Duck	*Clangula hyemalis*
Red-breasted Merganser	*Mergus serrator*
GROUSE, PTARMIGAN	
Willow Ptarmigan	*Lagopus lagopus*
Rock Ptarmigan	*Lagopus mutus*
OWLS	
Snowy Owl	*Nyctea scandiaca*
Short-eared Owl	*Asio flammeus*
MAMMALS	
INSECTIVORES	
Tundra Shrew	*Sorex tundrensis*
Barren Ground Shrew	*Sorex ugyunak*
LAGOMORPHS	
Alaskan (Tundra) Hare	*Lepus othus*
RODENTS	
Arctic Ground Squirrel	*Spermophilus parryii*
Tundra Vole	*Microtus oeconomus*
Singing Vole	*Microtus miurus*
N. Red-backed Vole	*Myodes rutilus*
Brown Lemming	*Lemmus sibiricus*
Collared Lemming	*Dicrostonyx groenlandicus*
Porcupine	*Erethizon dorsatum*
CANIDS	
Gray Wolf	*Canis lupus*
Arctic Fox	*Vulpes lagopus*
Red Fox	*Vulpes vulpes*
URSIDS	
Brown Bear	*Ursus arctos*
Polar Bear	*Ursus maritimus*
MUSTELIDS	
Ermine	*Mustela erminea*
Least Weasel	*Mustela nivalis*
Wolverine	*Gulo Gulo*
CERVIDS	
Moose	*Alces Alces*
Caribou	*Rangifer tarandus*
BOVIDS	
Muskox	*Ovibos moschatus*
Dall Sheep	*Ovis dalli*

Table 2. Potential scenarios of Climate Change Impact in the Alaskan Arctic.

Scenario	Description	Literature Support
Drier arctic tundra	Evaporation exceeds precipitation; wet tundra tends towards dry, shrinking of thaw lakes.	Prowse et al (2006), Smith et al. (2005); Smol et al. (2005), Smol & Douglas (2007)
Tundra becomes shrubbier with fire, succession	Increasing tundra fires jump-start succession from tundra- to shrub-dominated landscape.	Sturm et al (2005), Tape et al. (2006), Chapin et al. (2008)
Tundra becomes shrubbier with fire, succession	Coastal shorelines continue dramatic erosion with ongoing salt water intrusion inland.	Flint et al. (2007), Mars & Houseknecht (2007)
Changing phenology	Springs arrive earlier and earlier with ongoing changes in plant and insect phenology decoupling with wildlife migrations.	Coppack & Both (2002), Both and Visser (2001), Tulp & Schekkerman (2008)
Other Scenarios		
More frequent "rain on snow" events	Such events create hard icy surfaces during early spring.	Grenfell and Putkonen (2008)
Boreal animal invasion	Increasing numbers of red fox, brown bear, moose, and pond ducks with potential for trophic and food web changes.	Parmesan (2006)

Figure 1. Map of Arctic Alaska with Relevant Place Names and Locations.



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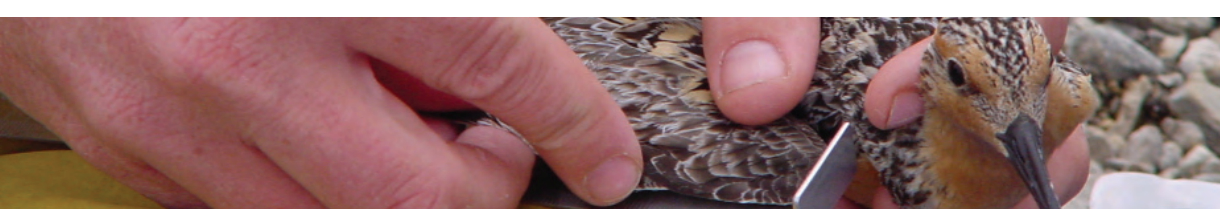

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