



Air Quality Related Values (AQRVs) for Southwest Alaska Network (SWAN) Parks

Effects from Ozone; Visibility Reducing Particles; and Atmospheric Deposition of Acids, Nutrients and Toxics

Natural Resource Report NPS/SWAN/NRR—2016/1204



ON THE COVER

Photograph of air quality related values within various National Park units. Wildflowers, clear views, aquatic species, and lichens may all be threatened by air pollution.

Photographs courtesy of the National Park Service

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Summary

This report describes the Air Quality Related Values (AQRVs) of the Southwest Alaska Network (SWAN). AQRVs are those resources sensitive to air quality and include streams, lakes, soils, vegetation, fish and wildlife, and visibility. The SWAN parks that are included in the NPS Inventory and Monitoring (I&M) Program, and discussed in this report, are Alagnak Wild River (ALAG), Aniakchak National Monument and Preserve (ANIA), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), and Lake Clark National Park and Preserve (LACL).

Sullivan et al. (2011a, 2011b) and Kohut (2007) conducted risk assessments for acidification, eutrophication, and ozone (O_3) for the SWAN parks; their results are described in this report. This report also describes air pollutant emissions and air quality, and their effects on AQRVs. The primary pollutants likely to affect AQRVs include nitrogen (N) and sulfur (S) compounds (nitrate [NO_3^-], ammonium [NH_4^+], and sulfate [SO_4^{2-}]); ground-level O_3 ; haze-causing particles; and airborne toxics. Background for this section can be found in “Air Quality Related Values (AQRVs) in National Parks: Effects from Ozone; Visibility Reducing Particles; and Atmospheric Deposition of Acids, Nutrients and Toxics” (Sullivan 2016).

There are no large human population centers within the SWAN and only one (Anchorage) in close proximity to the network. Although emissions from marine transportation and fossil fuel production have the potential to impact SWAN parks, emissions of both S and N are generally low throughout the network. Atmospheric deposition is presumed to be low, but is only recently monitored in the SWAN. The available atmospheric deposition data for Alaska are consistent with the general understanding that atmospheric deposition of both N and S tend to be very low at national park lands within Alaska. It can be assumed that both N and S deposition in the SWAN would be lower than about 1 kg/ha/yr, on average.

Even low levels of N deposition can cause undesirable enrichment of natural ecosystems, leading to changes in plant species diversity and soil nutrient cycling. Effects of atmospheric N deposition may be particularly evident in northern regions where vegetation is sparse, growing seasons short, and temperatures low; as a result, ecosystem capacity to assimilate added N is typically low. It is in these areas that climate change is most evident. Increased availability of N may exacerbate or otherwise alter effects associated with climate change.

Sulfur and N pollutants can cause acidification of streams, lakes, and soils. Although aquatic and/or terrestrial resources in the SWAN may indeed be sensitive to acidification, this is not an important concern at this time in view of the very low levels of S and N emissions and deposition near this network.

Ozone pollution can harm human health, reduce plant growth, and cause visible injury to foliage. However, levels of O_3 are very low and there are no data suggesting any effects of O_3 on vegetation in SWAN parks.

Particulate pollution can cause haze, reducing visibility. The contribution of human-caused air pollutants to haze in these parks is expected to be minimal. However, under a warming climate, effects of wildfire on visibility might be expected to increase.

Airborne toxics, including mercury (Hg) and other heavy metals, can be deposited from the atmosphere and accumulate in food webs, potentially reaching toxic levels in top predators. Airborne toxics can originate from local sources (e.g., power plants, mines) and also from distant sources, including international sources. The observation, initially mainly in the Western Airborne Contaminants Assessment Project (WACAP) study, that pesticides and heavy metal contaminants reached levels of concern in some remote Arctic ecosystems lacking local and watershed sources confirmed that long-range atmospheric transport of contaminants is a risk to remote Arctic parks (Flanagan 2009, Landers et al. 2008). Research is ongoing within two parks in SWAN to assess the dynamics and effects of Hg, other heavy metals, and persistent organic pollutants (POPs) in aquatic ecosystems in these parks.

Background

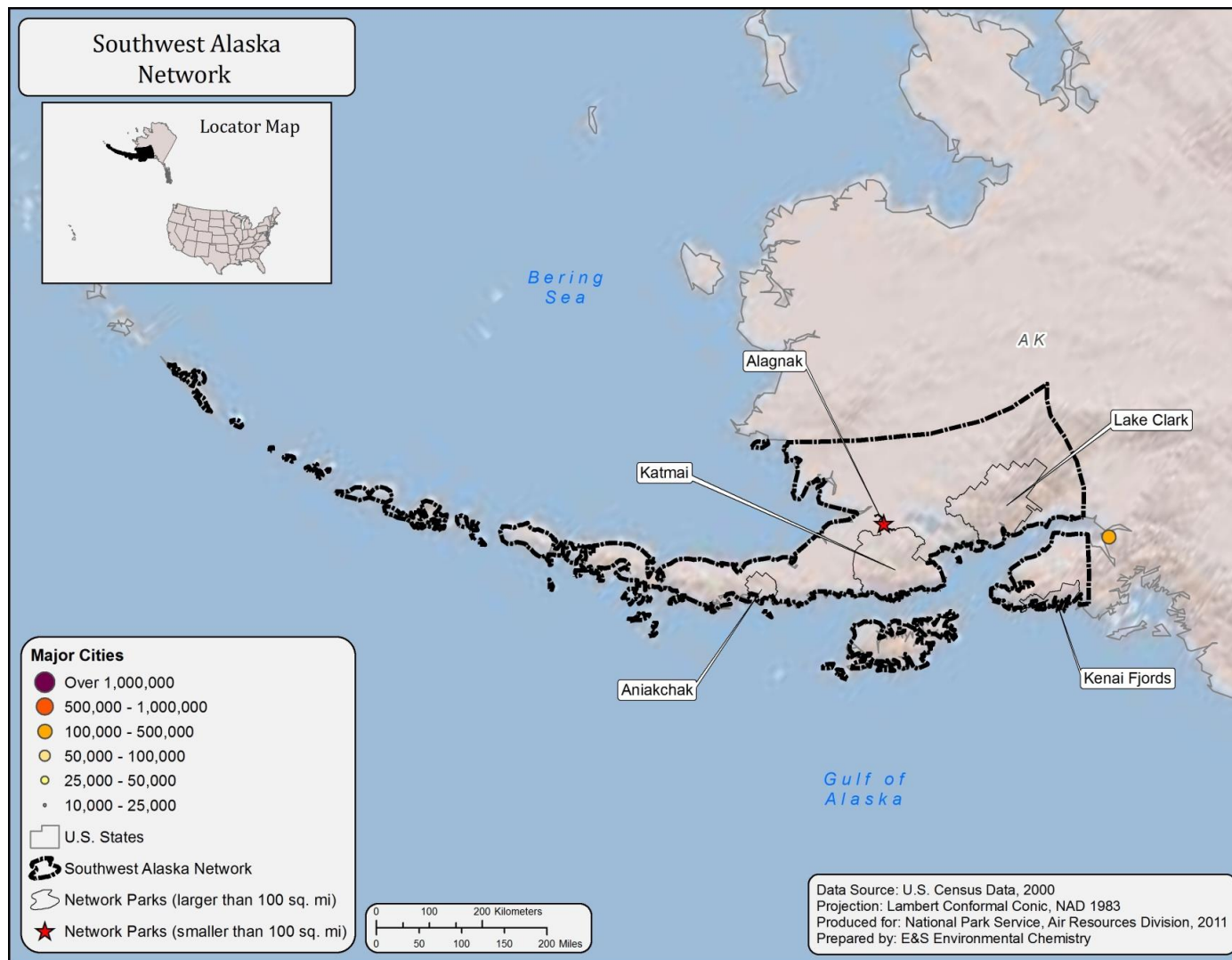
There are five parks in the Southwest Alaska Network (SWAN). Four of them are larger than 100 square miles: Aniakchak National Monument and Preserve (ANIA), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), and Lake Clark National Park and Preserve (LACL). The other, smaller, park is Alagnak Wild River (ALAG). Larger parks generally have more available data with which to evaluate air pollution sensitivities and effects. In addition, the larger parks generally contain more extensive resources in need of protection against the adverse impacts of air pollution.

There are no large population centers within the network area and only one in close proximity to the network. Map 1 shows the network boundary along with locations of each park and population centers having more than 10,000 people. The SWAN encompasses portions of the Tundra, Taiga, and Northwestern Forested Mountains ecoregions. The predominant cover types within this network are generally shrubland and perennial ice and snow. Forest cover is also extensive at some locations.

Atmospheric Emissions and Deposition

Annual emissions in 2002 of both sulfur (S) and nitrogen (N) within the network were uniformly less than 1 ton of sulfur dioxide (SO₂) and total N per square mile per year (ton/mi²/yr; Sullivan et al. 2011b). There were few point sources of S or N emissions in this network, and those that did occur tended to be small.

There are only five active National Atmospheric Deposition Program/National Trends Network (NADP/NTN) wet deposition monitoring sites in Alaska: Poker Creek, Juneau, Denali National Park (DENA), Gates of the Arctic National Park (GAAR), and KATM, with data collected since 1980 at Denali and since 1993 at Poker Creek. The other three monitoring sites have been added within the last decade. There are also Clean Air Status and Trends Network (CASTNET) dry deposition measurements at Denali and, through 2004, at Poker Flat. At all monitored sites in Alaska, wet N deposition has consistently been less than 1 kg N/ha/yr, and it has been less than 0.5 kg N/ha/yr at all monitored sites except Juneau. Wet S deposition has been slightly higher than 1 kg S/ha/yr at Juneau, but less than that at the other monitoring sites. The dry deposition measurements by CASTNET have also been low. Thus, the sparse available atmospheric deposition data for Alaska are consistent with the general understanding that atmospheric deposition of both N and S tends to be very low at national park lands within Alaska. Available data suggest that both N and S deposition throughout the SWAN are lower than about 1 kg/ha/yr, on average, at most locations.



Map 1. Network boundary and locations of national parks and human population centers around the SWAN.

Primary pollutants are emitted along sealanes by tankers, cargo ships, ferries, fishing boats, and cruise ships in the Gulf of Alaska. These pollutants and their by-products threaten visibility and the aesthetic attraction of popular tourist destinations, including national parks. Trans-Pacific transport of N from southeast Asia is also a source of air pollutants to parks in the SWAN, but the amounts are uncertain (Fenn et al. 2003). Emissions of N and S in Asia are higher than in North America (Fenn et al. 2003) and have increased dramatically in recent decades (Akimoto and Narita 1994). Emissions of N can be transported across the Pacific Ocean from Asia as peroxyacetyl nitrate (PAN), which has a lifetime in the atmosphere of days to weeks. Because of the comparatively short lifetime of oxidized nitrogen (NO_x) in the atmosphere (generally less than 24 hr), conversion of NO_x to a longer-lived form (such as PAN) is necessary for long-range transport of N. Once in the troposphere, PAN can be transported long distances over a period of many days and then moved back into the boundary layer, where it regenerates NO_x and HNO_3 (Kotchenruther et al. 2001). Long-range transport of PAN from Asia to North America is well documented (Jaffe et al. 1999). Thus, it is likely that NO_x emissions in Asia contribute some, albeit an unknown amount of, N deposition to the SWAN. If Asian NO_x emissions continue to increase as predicted (cf., Klimont et al. 2001, Streets and Waldhoff 2000), trans-Pacific sources of N may become more important to west coast locations of the United States, including those in the SWAN, in the future.

Trans-Pacific long-range atmospheric transport of mercury (Hg) and pesticides has also been documented. The Western Airborne Contaminants Assessment Project (WACAP) study (Landers et al. 2008) provided an initial indication of the scale and distribution of contaminants across portions of the western United States, including Alaska (Flanagan 2009). Designed as a screening study, WACAP provided a general indication of contaminants of concern in KATM and several other parks in the Arctic region.

Mölders et al. (2010) investigated the effects of ship emissions on air quality in and around the SWAN using the Weather Research and Forecasting model coupled with a chemistry module (WRD/Chem; Grell et al. 2005, Peckham et al. 2009). The model was run with and without inclusion of ship emissions for the duration of the 2006 tourist season. Tankers, cargo ships, and during the tourist season also cruise ships, were identified as the largest contributors to human-caused air pollutant emissions near the SWAN.

Air quality in and around the SWAN generally follows patterns governed by local meteorological conditions and the locations of ship emissions. For example, the channeling of east winds between the Kenai Peninsula and Kodiak Island enhances inland transport of pollutants from ship traffic toward LACL and KATM (Mölders et al. 2010). Cool summer temperatures contribute to formation of PAN, which enhances long range transport of NO_x .

Emissions near the SWAN, based on data from the EPA's National Emissions Inventory (NEI) during a recent time period (2011), are depicted in Maps 2 through 4 for SO_2 , oxidized N (NO_x), and reduced N (NH_3), respectively. Emissions were low (generally $< 1 \text{ ton/mi}^2/\text{yr}$ throughout most of the network region).

Acidification

The network rankings developed by Sullivan et al. (2011b) in a coarse screening assessment of acid Pollutant Exposure, Ecosystem Sensitivity to acidification, and Park Protection yielded an overall network acidification Summary Risk ranking for the SWAN that was in the middle of the distribution among networks. The overall level of concern for acidification effects on I&M parks within this network, based on this coarse-level screening, was judged by Sullivan et al. (2011b) to be Moderate.

All of the parks in the SWAN were ranked by Sullivan et al. (2011b) for acid Pollutant Exposure in the lowest quintile among parks (Table 1). Ecosystem Sensitivity to acidification rankings varied: one park (ALAG) was ranked Low, two parks were ranked High (ANAI and KEFJ), and two parks were ranked Very High (KATM and LACL; Table 1). Ecosystem sensitivity to acidification rankings take into account elevation and land slope, which often influence the degree of acid neutralization provided by soils and bedrock within the watershed. Most of the land slope within the parks in this network is less than 20°. There is some steeper land (between 20° and 30°) in LACL, suggesting increased potential for acid sensitivity of aquatic ecosystems.

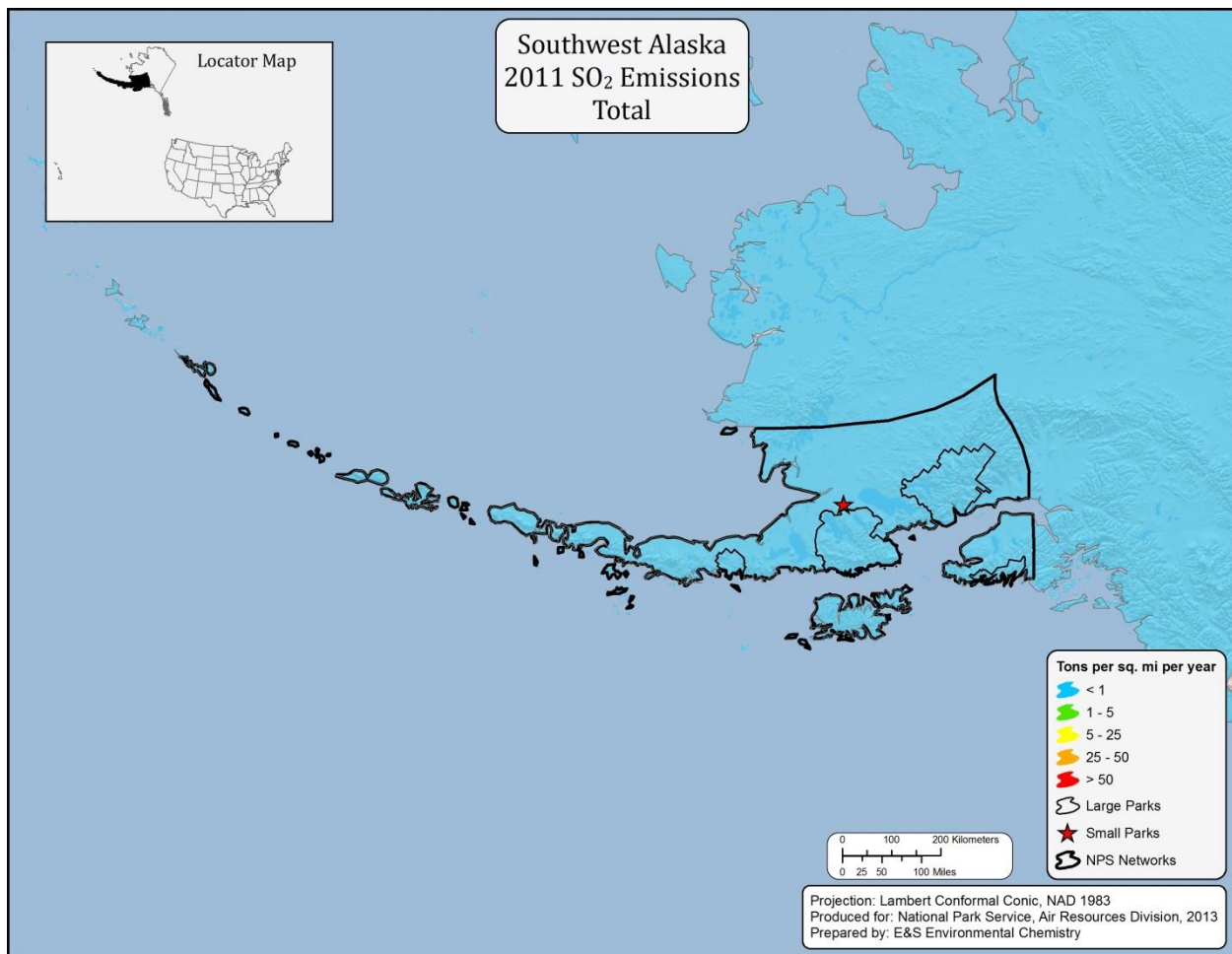
Although aquatic and/or terrestrial resources in some SWAN parks may indeed be sensitive to acidification, this is not an important concern at this time in view of the very low levels of S and N emissions and deposition within and near this network.

Table 1. Estimated I&M park rankings¹ according to risk of acidification impacts on sensitive receptors (Source: Sullivan et al. 2011b)

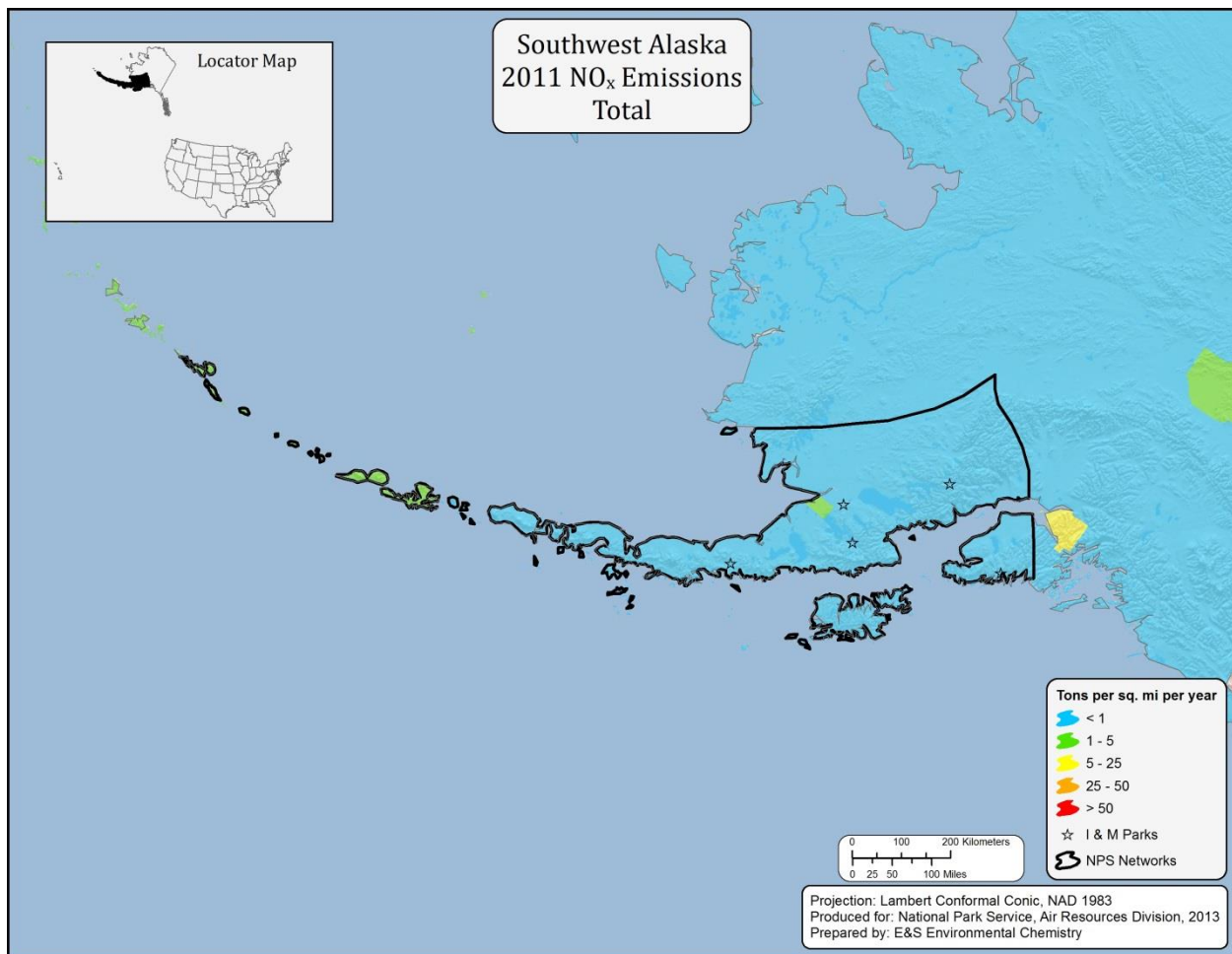
Park Name ²	Park Code	Estimated Acid Pollutant Exposure	Estimated Ecosystem Sensitivity to Acidification
Alagnak	ALAG	Very Low	Low
Aniakchak	ANIA	Very Low	High
Katmai	KATM	Very Low	Very High
Kenai Fjords	KEFJ	Very Low	High
Lake Clark	LACL	Very Low	Very High

¹ Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (Very Low risk) to the highest quintile (Very High risk).

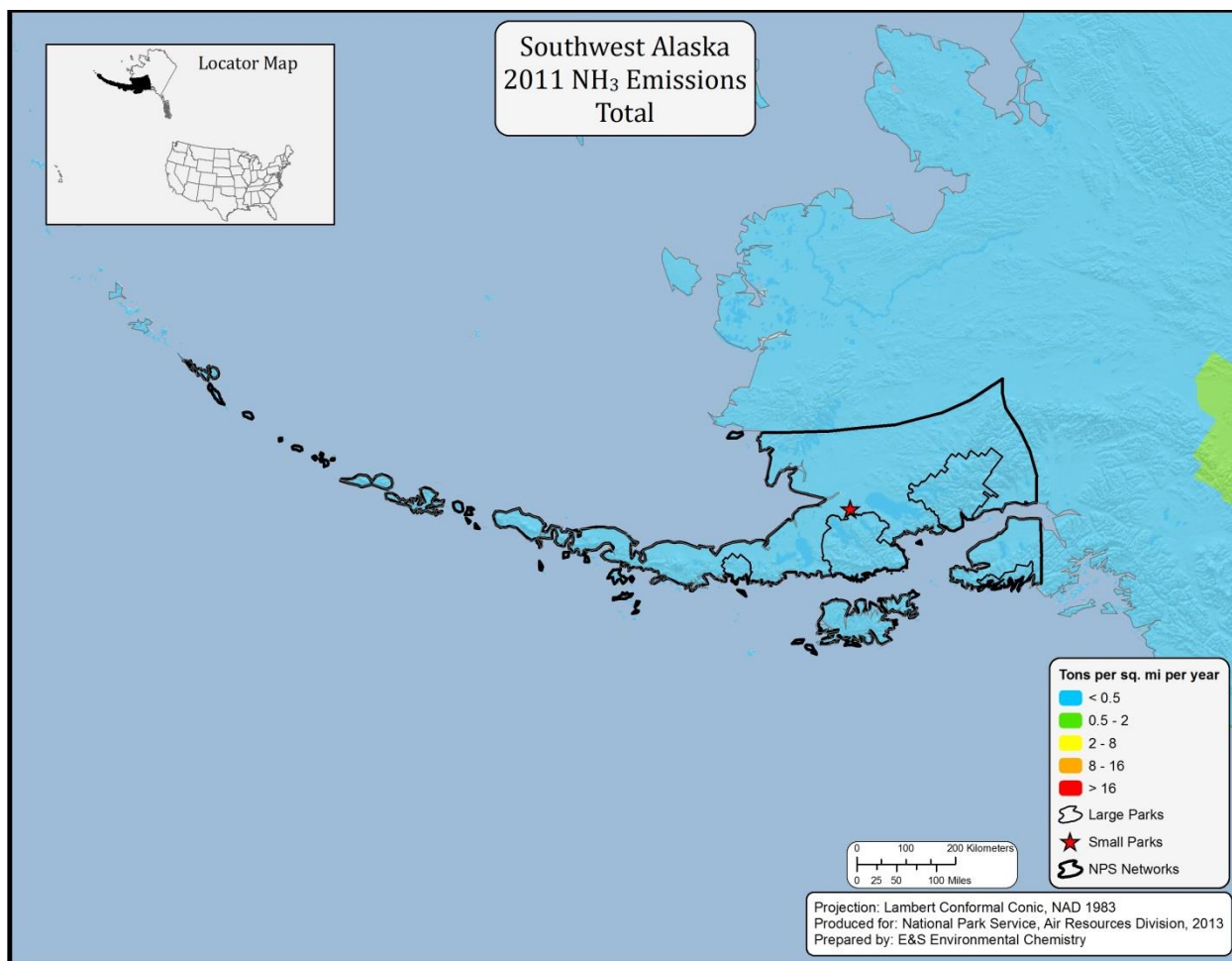
² Park names are printed in bold italic for parks larger than 100 mi².



Map 2. Total SO₂ emissions near the SWAN for the year 2011. Data from EPA's National Emissions Inventory.



Map 3. Total NO_x emissions near the SWAN for the year 2011. Data from EPA's National Emissions Inventory.



Map 4. Total NH₃ emissions near the SWAN for the year 2011. Data from EPA's National Emissions Inventory.

Nutrient Nitrogen Enrichment

The network rankings developed by Sullivan et al. (2011a) in a coarse national assessment for nutrient N Pollutant Exposure, Ecosystem Sensitivity to nutrient N enrichment, and Park Protection yielded an overall network nutrient N Summary Risk ranking for the SWAN that was Low among all networks. All of the parks in the SWAN showed nutrient N Pollutant Exposure rankings in the lowest quintile among parks (Table 2). All of the parks had Ecosystem Sensitivity to nutrient N enrichment rankings in the middle (Moderate; ALAG, ANIA, and KATM) or second lowest (Low; KEFJ and LACL) quintile (Table 2). In the absence of field data, it is not possible to determine if the rankings of Sullivan et al. (2011a) are reflective of true sensitivity of SWAN resources to nutrient enrichment.

In general, the predominant vegetation types within these parks that are presumed to be especially sensitive to nutrient N enrichment are arctic herbaceous, alpine, and wetland. Lichen communities would also be expected to be relatively sensitive. The sensitivities to nutrient N enrichment of shrublands, which are common within the SWAN, are generally not known. Some work has been done on the response of prostrate dwarf-shrub herb tundra in Greenland to experimental N and P addition (Arens et al. 2008). They documented substantial changes in ecosystem Ca exchange and vegetative cover and composition in response to addition of 5 and 10 kg N/ha/yr over a two-year period. The largest responses of the dominant vascular plants (*Salix arctica*, *Carex rupestris*, and *Dryas integrifolia*) were observed at the 10 kg N/ha/yr treatment level. However, this likely represents at least a fivefold increase above ambient N deposition levels at SWAN parks. Possible effects of nutrient enrichment on vegetation in these parks in response to more modest increases in N deposition are not known.

Table 2. Estimated park rankings¹ according to risk of nutrient enrichment impacts on sensitive receptors (Sullivan et al. 2011a).

Park Name ²	Park Code	Estimated Nutrient N Pollutant Exposure	Estimated Ecosystem Sensitivity to Nutrient N Enrichment
Alagnak	ALAG	Very Low	Moderate
<i>Aniakchak</i>	ANIA	Very Low	Moderate
<i>Katmai</i>	KATM	Very Low	Moderate
<i>Kenai Fjords</i>	KEFJ	Very Low	Low
<i>Lake Clark</i>	LACL	Very Low	Low

¹ Relative park rankings are designated according to quintile ranking, among all I&M Parks, from the lowest quintile (Very Low risk) to the highest quintile (Very High risk).

² Park names are printed in bold italic for parks larger than 100 mi².

Plant species distributions in arctic tundra are often N-limited (Shaver and Chapin 1980). Soluble N in tundra soil solution is dominated by organic N, including free amino acids, rather than NH₄⁺ or NO₃⁻ (Kielland 1995). Tundra plants appear to exhibit a range of interspecific differences that allow coexistence under conditions that reflect a single limiting element. Species differ in rooting depth, phenology, and uptake preferences for organic and inorganic forms of N (Chapin et al. 1993,

Kielland 1994, McKane et al. 2002, Shaver and Billings 1975). McKane et al. (2002) demonstrated, based on ^{15}N field experiments, that arctic tundra plant species were differentiated in timing, depth, and chemical form of N utilization. Furthermore, the species that exhibited greatest productivity were those that efficiently used the most abundant N forms.

Effects of atmospheric deposition, especially of N, may be particularly evident in northern regions, and these are the areas where climate change is most evident. For example, the distribution and abundance of trees at DENA is strongly influenced by the occurrence of permafrost. Expected future thawing of permafrost may dramatically transform vegetation patterns in the park as individual tree species respond to changes in soil condition (Roland 2011). Thus, increased availability of N through atmospheric deposition may exacerbate effects associated with ongoing climate change. Such interactions may occur at parklands within the SWAN.

Ectomycorrhizal fungal (EMF) communities are important in tree nutrition, and EMF trees tend to be dominant in N-limited forest ecosystems. Progressive decline in EMF species richness in Alaskan coniferous forest (white spruce [*Picea glauca*] dominant) occurred along a local N deposition gradient, from 1 to 20 kg N/ha/yr, downwind from a fertilizer facility, now shut down, on the Kenai Peninsula west of KEFJ (Lilleskov et al. 2001, Lilleskov et al. 2002).

Future climate warming could have important effects on N cycling in arctic tundra ecosystems. In the past, organic materials accumulated in tundra soils, largely because decomposition has been slower than plant growth in this harsh environment. Climate warming may increase the decomposition of soil organic matter, thereby increasing the availability of stored N (Weintraub and Schimel 2005). The distributions of woody plant species are also increasing in response to warming, with likely feedbacks on C and N cycling. For example, the dominant shrub species in the arctic tundra in Alaska is *Betula nana*; it is expanding its distribution in tussock vegetation communities (Weintraub and Schimel 2005).

Pardo et al. (2011) compiled data on empirical critical loads (CL) for protecting sensitive resources in Level I ecoregions across the United States against nutrient enrichment effects caused by atmospheric N deposition. Available data on empirical CL of nutrient-N potentially applicable to the SWAN suggested that the lower end of the estimated range of the empirical CL for resource protection was generally about 1 kg N/ha/yr (Table 3). Estimated ambient N deposition in the SWAN is less than about 1 kg N/ha/yr. This is slightly lower than these lower estimates of empirical CL. It does not appear that there are CL exceedances in the SWAN at this time, based on these empirical CL estimates and limited data on N deposition.

Table 3. Empirical critical loads for nitrogen in the SWAN, by ecoregion and receptor from Pardo et al. (2011). Ambient N deposition reported by Pardo et al. (2011) is compared to the lowest critical load for a receptor to identify potential exceedance. Atmospheric N deposition at each of the parks in the SWAN was below the identified critical loads, suggesting that the receptors are not at increased risk for harmful effects.

NPS Unit	Ecoregion	N Deposition (kg N/ha/yr)	Critical Load (kg N/ha/yr)				
			Mycorrhizal Fungi	Lichen	Herbaceous Plant	Forest	Nitrate Leaching
Alagnak Wild River	Tundra	<1	NA	1	1	NA	NA
Aniakchak Preserve NM & NPRES	Marine West Coast Forests	<1	5	2.7	NA	5	NA
Aniakchak Preserve NM & NPRES	Tundra	<1	NA	1	1	NA	NA
Katmai NP & Pres	Marine West Coast Forests	<1	5	2.7	NA	5	NA
Katmai NP & Pres	Tundra	<1	NA	1	1	NA	NA
Kenai Fjords NP	Marine West Coast Forests	<1	5	2.7	NA	5	NA
Lake Clark NP & Pres	Marine West Coast Forests	<1	5	2.7	NA	5	NA
Lake Clark NP & Pres	Northwestern Forested Mountains	<1	5	1.2	4	4	4
Lake Clark NP & Pres	Taiga	<1	5	1	6	NA	NA

Relatively little information is available regarding the effects of atmospheric N inputs on fresh waters in arctic settings. However, Levine and Whalen (2001) reported results of nutrient enrichment bioassays in 39 lakes and ponds in the Arctic Foothills region of Alaska. Significant ^{14}C uptake responses were observed subsequent to experimental addition of N + phosphorus (P), N alone, and P alone in 83, 35, and 22% of the bioassays, respectively. Overall, the data suggested that N was somewhat more important than P in regulating phytoplankton production in lakes and ponds in this arctic region. As the summer progressed, the strength of the response to nutrient addition decreased, but this decrease was not related to irradiance or water temperature. This suggests secondary limitation by a micronutrient such as iron during the latter parts of the growing season.

Hobbs et al. (2010) synthesized diatom records from lakes in western North America and west Greenland, finding that both temperature and N deposition drove species composition changes in diatoms, with temperature driving changes in the Arctic and N deposition driving changes in mid-latitude alpine lakes. The researchers concluded that remote lakes will likely continue to experience diatom species shifts, particularly in regions where increasing temperatures intersect with increasing N deposition.

Anadromous salmonid fish constitute an important source of N to nutrient-poor streams and lakes in major parts of Alaska. These fish accumulate nutrients, including N, during adult life in the ocean, and then return to spawn and die in fresh waters that can be considerable distances inland. Anadromous salmonids transport to inland fresh waters the N and other nutrients that they accumulated while in the ocean. Thus, fisheries management can have important feedbacks on N cycling in Alaskan aquatic ecosystems.

Ozone Injury to Vegetation

The ozone (O₃)-sensitive plant species that are known or thought to occur within the I&M parks in the SWAN are listed in Table 4. Those considered to be bioindicators, because they exhibit distinctive symptoms when injured by O₃ (e.g., dark stipple), are designated by an asterisk. Each of the parks in this network contained at least one (red elderberry [*Sambucus racemosa*]) O₃-sensitive and/or bioindicator species. Two of the parks (ALAG and KEFJ) contained quaking aspen (*Populus tremuloides*), thought to be among the most sensitive hardwood tree species to O₃ damage.

The W126 (a measure of cumulative O₃ exposure that preferentially weights higher concentrations) and SUM06 (a measure of cumulative exposure that includes only hourly concentrations over 60 ppb O₃) exposure indices and Kohut's (2007) O₃ risk rankings were not available for any of the I&M parks found in the SWAN at the time of preparing this assessment. Given the low N emissions within the network, O₃ formation and exposure are expected to be low, and corresponding risk to plants is also low. Mölders et al. (2010) concluded that O₃ formation caused by ship emissions in and near the SWAN is relatively minor despite long daylight hours during summer.

Table 4. Ozone-sensitive and bioindicator plant species known or thought to occur in the I&M parks of the SWAN. (Data Source: E. Porter, National Park Service, pers. comm., August 30, 2012); lists are periodically updated at <https://irma.nps.gov/NPSpecies/Report>).

Species	Common Name	Park ¹				
		ALAG	<i>ANIA</i>	<i>KATM</i>	<i>KEFJ</i>	<i>LACL</i>
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	x			x	x
<i>Populus tremuloides</i> *	Quaking aspen	x			x	
<i>Salix scouleriana</i> *	Scouler's willow			x	x	x
<i>Sambucus racemosa</i> *	Red elderberry	x	x	x	x	x

¹ Park acronyms are printed in bold italic for parks larger than 100 mi².

* Bioindicator species

Visibility Degradation

Natural Background and Ambient Visibility Conditions

The Clean Air Act set a specific goal for visibility protection in Class I areas: “the prevention of any future, and the remedying of any existing, impairment of visibility¹ in mandatory Class I federal areas which impairment results from manmade air pollution” (42 U.S.C. 7491). In 1999, EPA passed the Regional Haze Rule (RHR), which requires each state to develop a plan to improve visibility in Class I areas, with the goal of returning visibility to natural conditions in 2064. Natural background visibility assumes no human-caused pollution, but varies with natural processes such as windblown dust, fire, volcanic activity and biogenic emissions. Visibility is monitored by the Interagency Monitoring of Protected Visual Environments Network (IMPROVE) and typically reported using the haze index deciview² (dv). All Class I air quality areas have an on-site or representative monitor. A monitoring site is considered by IMPROVE to be representative of an area if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area.

Although there are no NPS Class I areas in the SWAN, there is an IMPROVE sampler located adjacent to LACL (TUXE1). This sampler was established to characterize visibility at Tuxedni Wilderness, a Class I U.S. Fish and Wildlife Service area located about 30 miles (50 km) northeast from the sampler. Data from the sampler can also be used to characterize visibility in the portions of LACL that occur within 60 miles (100 km) and 425 ft (130 m) elevation. Natural background and ambient visibility conditions have been estimated by IMPROVE for LACL for the 20% clearest visibility days, the 20% haziest visibility days, and average days (Table 5).

Current visibility estimates reflect current pollution levels and were used to rank conditions at parks in order to provide park managers with information on spatial differences in visibility and air pollution. Rankings range from very low haze (very good visibility) to very high haze (very poor visibility). Only parks with on-site or representative IMPROVE monitors (i.e., LACL) were used in generating the baseline visibility ranking. Table 5 gives the relative park haze rankings on the 20% clearest, 20% haziest, and average days. Natural haze levels were high in LACL relative to other monitored I&M parks. However, ambient haze levels were not much higher than natural haze and were relatively low compared with monitored parks in other networks for the 20% clearest, 20% haziest, and average days. Human-caused haze is not considered to be of great concern in this park.

¹ Visibility impairment means any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions.

² The *deciview* visibility metric expresses uniform changes in haziness in terms of common increments across the entire range of visibility conditions, from pristine to extremely hazy conditions. Because each unit change in deciview represents a common change in perception, the deciview scale is like the decibel scale for sound. A one deciview change in haziness is a small but noticeable change in haziness under most circumstances when viewing scenes in Class I areas.

Table 5. Estimated natural haze and measured ambient haze in I&M parks averaged over the period 2004 through 2008¹.

Park Name ²	Park Code	Site ID	Estimated Natural Haze (dv)					
			20% Clearest Days		20% Haziest Days		Average Days	
Alagnak	ALAG	No Site						
Aniakchak	ANIA	No Site						
Katmai	KATM	No Site						
Kenai Fjords	KEFJ	No Site						
Lake Clark ³	LACL	TUXE1	3.15		11.31		6.31	
Park Name	Park Code	Site ID	Measured Ambient Haze (For Years 2004 through 2008)					
			20% Clearest Days		20% Haziest Days		Average Days	
			dv	Ranking	dv	Ranking	dv	Ranking
Alagnak	ALAG	No Site						
Aniakchak	ANIA	No Site						
Katmai	KATM	No Site						
Kenai Fjords	KEFJ	No Site						
Lake Clark ³	LACL	TUXE1	4.00	Low	13.57	Low	8.10	Low

¹ Parks are classified into one of five ranks (Very Low, Low, Moderate, High, Very High).

² Park names are printed in bold italic for parks larger than 100 mi².

³ Data are borrowed from a nearby site. A monitoring site is considered by IMPROVE to be representative of an area if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area.

Composition of Haze

Various pollutants make up the haze that causes visibility degradation. IMPROVE measures these pollutants and reports them as ammonium sulfate, ammonium nitrate, elemental carbon, coarse mass, organic mass, sea salt, and soil. Sulfates form in the atmosphere from sulfur dioxide (SO₂) emissions from coal-burning power plants, smelters, and other industrial facilities. Nitrates form in the atmosphere from NO_x emissions from combustion sources including vehicles, power plants, industry, and fires. Organic compounds are emitted from a variety of both natural (biogenic) and anthropogenic sources, including agriculture, industry, and fire. Atmospheric sea salt concentrations are higher in coastal areas. Soil can enter the atmosphere through both natural processes and human disturbance.

Figure 1 shows estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze and its composition for LACL. Seasalt is estimated to be a major contributor to natural background haze at this park, especially on the 20% haziest days. Sulfates are responsible for almost half of the current levels of haze in LACL on the 20% clearest, 20% haziest, and average days.

Trends in Visibility

Available haze monitoring data are shown in Figure 2 for the period of record at LACL. There is no indication of a trend in ambient haze at this park on the 20% clearest or average days over the period of available monitoring data, since 2002. An analysis of data from 2000-2009 found no significant trend in visibility on either the haziest or the clearest days (NPS 2013).

Development of State Implementation Plans

Progress to date in meeting the national visibility goal is illustrated in Figure 3 using a uniform rate of progress glideslope. A decrease in haze in 2010 on the haziest days suggests that progress is being made, even though no trend was detected in the 2000-2009 data. It is unclear, however, based on the available data, to what extent visibility on the 20% haziest days at LACL is decreasing sufficiently to comply with the long-term glideslope required by the RHR to improve visibility at Tuxedni Wilderness. Additional data are needed.

Toxic Airborne Contaminants

Munk et al. (2010) reported results of a study of trace element concentrations and accumulation rates in sediment cores collected from five lakes in the SWAN region. Lakes containing anadromous salmonid fish had higher (up to 250 parts per billion [ppb]) Hg concentrations than did lakes lacking anadromous fish (average ~ 25 ppb). Trends in trace element accumulation rates suggested that landscape processes, especially associated with volcanic and glacial activity, were largely responsible for trace element contributions to the study lakes (Munk et al. 2010).

Although none of the parks in the SWAN were included in the group of core parks in the WACAP study of airborne contaminants, extensive data from DENA in the Central Alaska Network suggested that long-range transport of toxic compounds to parks in Alaska is occurring. Fish in both WACAP study lakes in DENA had dieldrin concentrations that exceeded health thresholds for mammals (otter and mink), and both lakes exceeded Hg thresholds for piscivorous birds. In Wonder Lake, concentrations of Hg and lead in sediments showed increasing trends since the 1920s, likely a result of changes in global emissions (Landers et al. 2008).

Although most of the contaminants that were investigated during WACAP were shown to be below levels of concern in national parks in Alaska, others appeared to be accumulating in fish and wildlife. Mercury concentrations in some fish exceeded wildlife consumption thresholds at some lakes in some parks. Concentrations of historic use pesticides, dieldrin, and dichlorodiphenyldichloroethylene

LACL

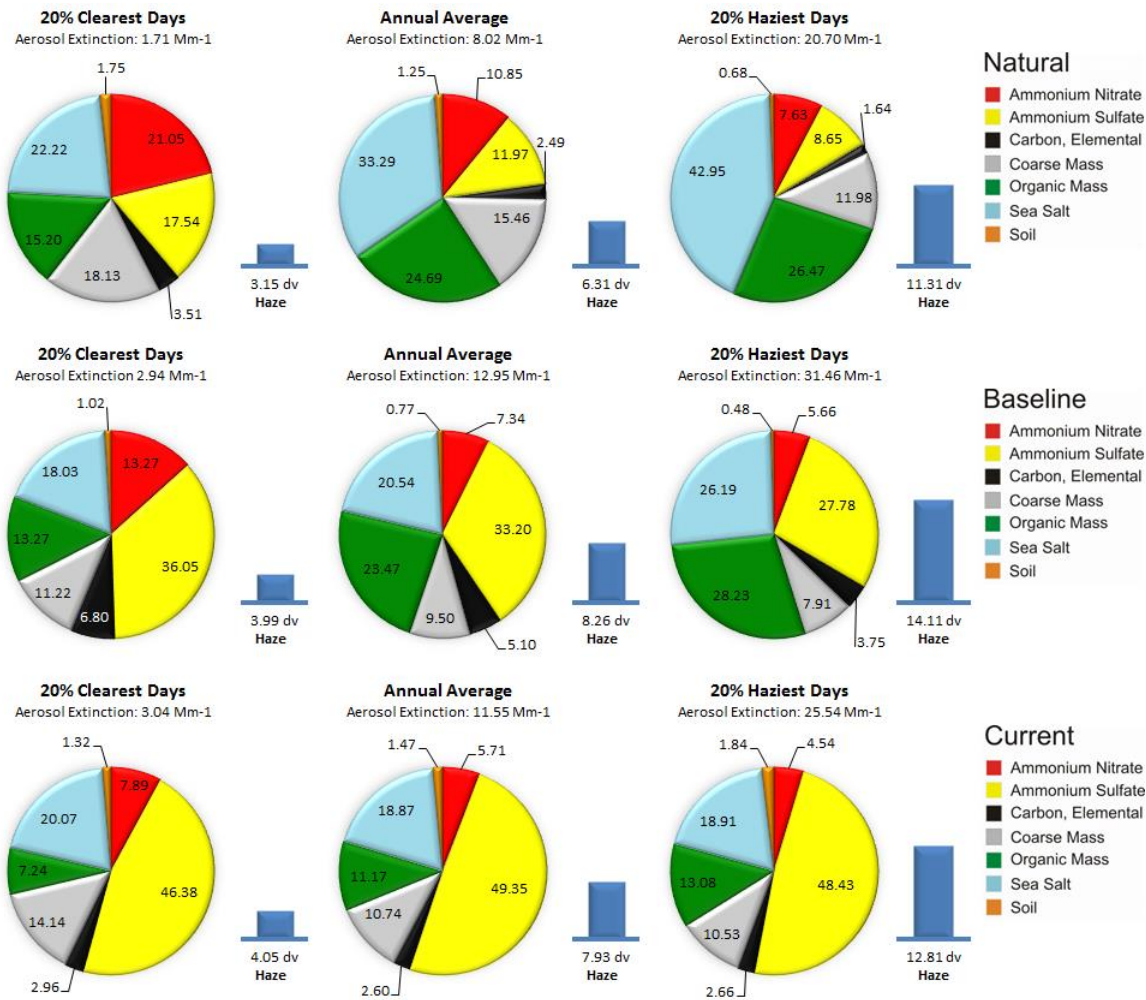


Figure 1. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for LACL. The site monitor is TUXE1. LACL has no data for the years 2000 and 2001. Data Source: NPS-ARD

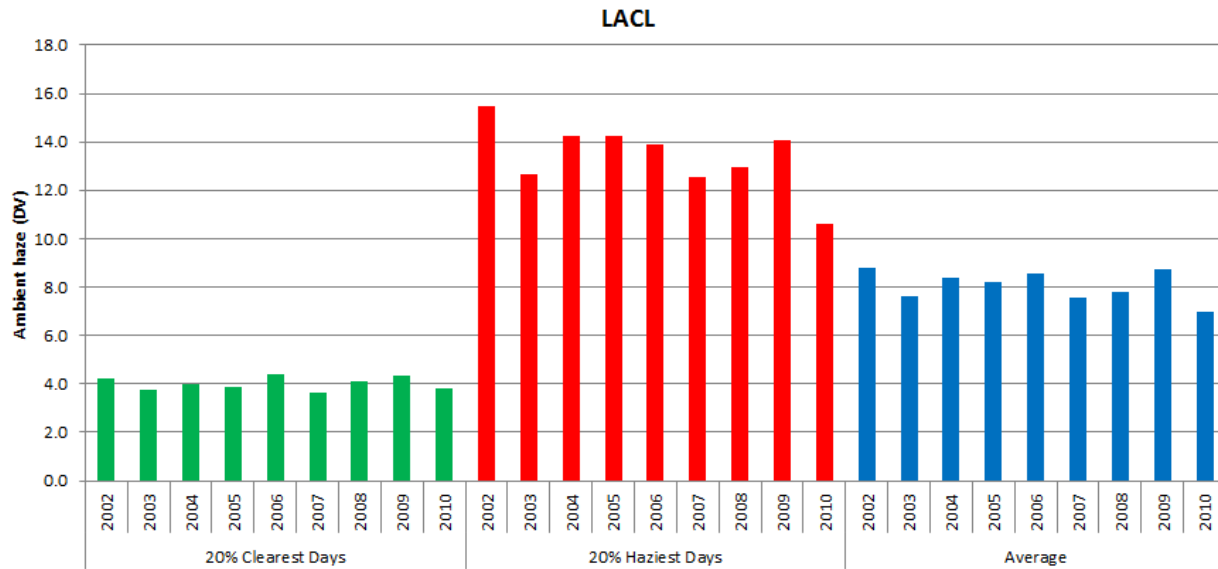


Figure 2. Trends in ambient haze levels at LACL, based on IMPROVE measurements on the 20% clearest, 20% hazeiest, and annual average visibility days over the monitoring period of record. Data were taken from a nearby site. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

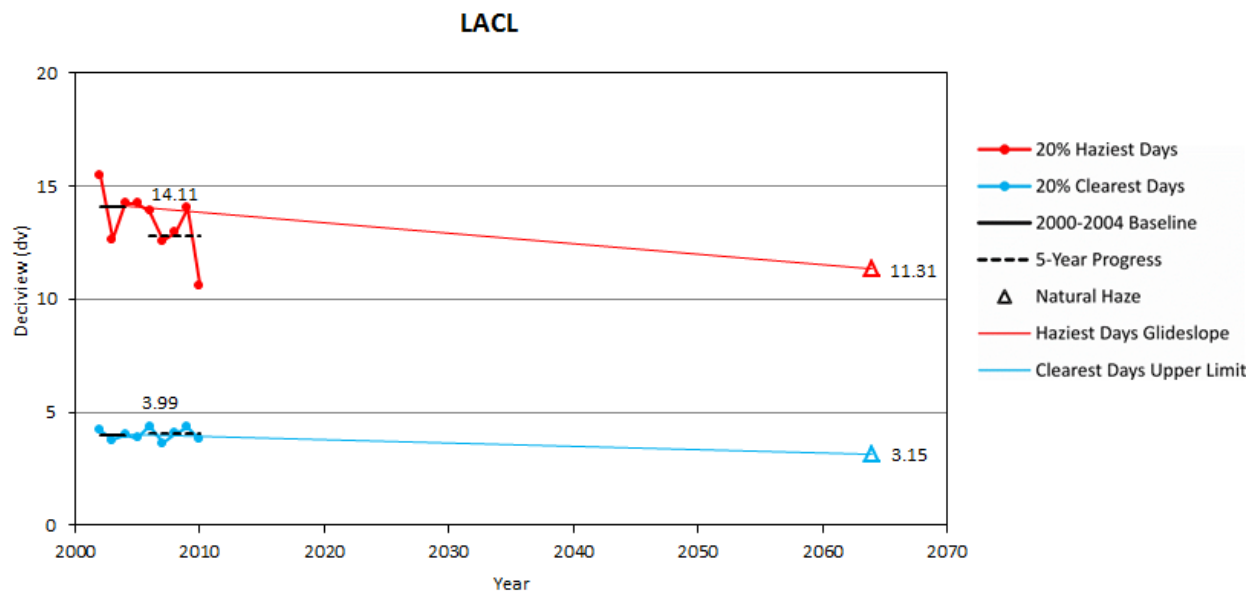


Figure 3. Glideslopes to achieving natural visibility conditions in Tuxedni Wilderness near LACL in 2064 for the 20% hazeiest (red line) and the 20% clearest (blue line) days in LACL (TUXE1). In the regional haze rule, the clearest days do not have a uniform rate of progress glideslope; the rule only requires that the clearest days do not get any worse than the baseline period. Also shown are measured values during the period 2000 to 2010. LACL has no data for the years 2000 and 2001. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

(DDE) were relatively high in some fish collected from Noatak National Preserve (NOAT), DENA, and GAAR. Based on WACAP results in other networks of Alaskan Parks, there is growing concern that some fish in lakes within parks in the SWAN may exhibit elevated levels of Hg and some pesticides. Resident lake fish are important food sources for subsistence users in this network.

Simonich et al. (2013) measured airborne SOC contaminant concentrations in 40 fish collected from lakes in LACL and KATM in 2011. Study lakes were selected to be remote and distant from development areas to isolate contaminant loading by atmospheric deposition. Lake trout (*Salvelinus namaycush*) and arctic char (*S. alpinus*) were sampled, as they represented top fish predators. Results were compared with wildlife health thresholds (Ackerman et al. 2008). None of the fish exceeded any of the mink or river otter thresholds. However, thresholds to protect kingfisher were exceeded in some fish from some lakes for chlordane and P,P'-DDE. This result contrasts with those from the WACAP study, in which kingfisher thresholds were not exceeded at any Alaska study lakes.

Fisheries biologists have been collecting and analyzing fish tissue samples from selected lakes in LACL and KATM. Analyses include Hg, arsenic, copper, selenium, lead, and zinc every 5 years and for certain POPs every 10-15 years. Baseline sampling was conducted in 2011 for lake trout, northern pike (*Esox lucius*), and slimy sculpin (*Cottus cognatus*; http://science.nature.nps.gov/im/units/swan/assets/docs/resourcebriefs/RB_AQ_fish_contam_revision_LR_20120109.pdf). Data collected on future sampling occasions will shed light on potential trends in bioaccumulation of toxics in aquatic receptors.

Eagles-Smith et al. (2014) sampled fish in 21 national parks and analyzed them for Hg concentrations in tissue. Results varied substantially by park and by water body. Lake trout sampled from three lakes in LACL contained varying levels of Hg. At the lower end, Hg levels appeared to pose limited risk to wildlife. However, concentrations were substantially higher in fish from Lake Kontrashibuna and Lake Clark, exceeding the benchmark for reproductive impairment in piscivorous birds in Lake Kontrashibuna.

Flanagan Pritz et al. (2014) analyzed SOC data for fish collected from 14 national parks in Alaska and the western United States. The study included data for fish sampled in KATM and LACL in the SWAN. Contaminant loading was highest in fish from Alaskan and Sierra Nevada parks. Historic use compounds were highest in Alaskan parks, whereas current-use pesticides were higher in Rocky Mountain and Sierra Nevada parks. Concentrations of the HUPs dieldrin, p,p'-DDE, and/or chlordanes in fish exceeded U.S. EPA guidelines for wildlife (kingfisher) health thresholds at 13 of 14 parks. Additional research is needed to determine how best to manage the risk of toxic substances in these parks and to judge the role played by anadromous fish in defining that risk (Flanagan Pritz et al. 2014).

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