



Air Quality Related Values (AQRVs) for Pacific Islands Network (PACN) Parks

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

Natural Resource Report NPS/PACN/NRR—2016/1181



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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Contents

	Page
Figures.....	iv
Tables.....	iv
Maps.....	v
Summary	vi
Background.....	1
Atmospheric Emissions and Deposition	1
Acidification	5
Nutrient Nitrogen Enrichment	9
Ozone Injury to Vegetation.....	9
Sulfur Dioxide Injury to Vegetation	11
Visibility Degradation.....	11
Natural Background Visibility and Monitored Visibility Conditions	11
Composition of Haze	14
Trends in Visibility.....	14
Development of State Implementation Plans	19
Toxic Airborne Contaminants.....	20
References Cited	22

Figures

	Page
Figure 1. Three representative photos of the same view in HAVO illustrating the 20% clearest visibility, the 20% haziest visibility, and the annual average visibility.	15
Figure 2a. 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 HALE and KALA.....	16
Figure 2b. 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 HAVO.....	17
Figure 3a. Trends in monitored visibility for HALE and KALA, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record	18
Figure 3b. Trends in monitored visibility for HAVO, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record.....	18
Figure 4a. Glideslopes to achieving natural visibility conditions by 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days for HALE and KALA.....	20
Figure 4b. Glideslopes to achieving natural visibility conditions by 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days for HAVO.....	21

Tables

	Page
Table 1. Estimated I&M park rankings ¹ according to risk of acidification impacts on sensitive receptors.....	8
Table 2. Ozone-sensitive and bioindicator plant species known or thought to occur in PACN parks	10
Table 3. Estimated natural background visibility and monitored visibility in PACN parks averaged over the period 2004 through 2008.....	13

Maps

	Page
Map 1. Network boundary and locations of parks and population centers with more than 10,000 people within the American Affiliated Islands in the PACN region.	2
Map 2. Map showing network boundary and locations of parks and population centers with more than 10,000 people within the Hawaiian Islands in the PACN region.	3
Map 3. Total SO ₂ emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.	5
Map 4. Total NO _x emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.	6
Map 4. Total NH ₃ emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.	7

Summary

This report describes the Air Quality Related Values (AQRVs) of the Pacific Island Network (PACN). The PACN parks that are included in the NPS Inventory and Monitoring (I&M) Program, and discussed in this report, are American Memorial Park (AMME), Hawaii Volcanoes National Park (HAVO), Haleakala National Park (HALE), Kalaupapa National Historical Park (KALA), Kaloko-Honokohau National Historical Park (KAHO), National Park of American Samoa (NPSA), Pu'uuhonua o Honaunau National Historical Park (PUHO), Puukohola Heiau National Historic Site (PUHE), and War in the Pacific National Historical Park (WAPA). HALE and HAVO are designated as Class I, giving them a heightened level of protection against harm caused by poor air quality under the Clean Air Act.

AQRVs are those resources sensitive to air quality and include streams, lakes, soils, vegetation, fish and wildlife, and visibility. This report also describes air pollutant emissions and air quality in the PACN, 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 ozone (O_3), haze-causing particles, and airborne toxics. Background for this section can be found in “Air Quality Related Values (AQRVs) in the Inventory and Monitoring (I&M) National Parks: Status of Visibility Degradation, Ozone Effects on Vegetation, and the Effects on Natural Resources of Atmospheric Acid, Nutrient, and Toxics Deposition” (Sullivan 2016).

Air pollution levels are relatively low in most of the PACN parks. The exception is HAVO, where sulfur dioxide (SO_2) emissions from volcanic activity frequently contribute to high levels of air pollution. The PACN parks are spread across a large portion of the Pacific Ocean. The only human population center in the PACN region of any magnitude (more than 100,000 people) is Honolulu on the island of Oahu.

Air pollutant emissions information from the National Emissions Inventory is available for the Hawaiian Islands, but not the other PACN areas. Based on a screening assessment by Sullivan et al. (2011), county-level annual human-caused N and S emissions in Hawaii both ranged from less than 1 ton per square mile per year ($\text{ton}/\text{mi}^2/\text{yr}$) on the big island of Hawaii to between 20 and 50 $\text{tons}/\text{mi}^2/\text{yr}$ on Oahu. Annual emissions of N and S from the other Hawaiian Islands were intermediate, between 1 and 5 $\text{tons}/\text{mi}^2/\text{yr}$. Emissions sources include vehicles, power plants, and industry. These human-caused emissions have local island effects, but are now set against the background of large SO_2 emissions from the Kilauea Volcano, which generally range from 1,600 to 4,000 tons per day since the most recent eruption in 2008 (Elias and Sutton 2012). Volcanic emissions affect primarily the Big Island, Hawaii, but are occasionally transported to the other islands, particularly Maui, Molokai, and Oahu.

Current atmospheric N and S deposition data are not available for PACN parks, but it is expected that deposition is relatively high at some locations, especially on Oahu, because of nitrogen oxides (NO_x) emissions from vehicles, and fuel combustion for power production, and on Hawaii, because of SO_2 emissions from the volcano. Deposition measurements from 2000 to 2005 confirmed that S deposition resulting from SO_2 emissions was high at HAVO, not surprisingly. Deposition is likely

much higher now downwind of the volcano, as emissions have increased significantly since the 2008 opening of a new vent in the volcano.

Sulfur and N pollutants can cause acidification of streams, lakes, and soils. Nitrogen pollutants can also cause undesirable nutrient enrichment of natural ecosystems, leading to changes in plant species diversity and soil nutrient cycling. The extent of such changes in PACN to date is not known.

Particulate pollution can cause haze, reducing visibility. Monitoring has found high levels of haze at times in HAVO and HALE. Sulfate from volcanic emissions causes the majority of haze at both HAVO and HALE, but SO_4^{2-} from fuel oil combustion (associated with power production) also contributes to haze.

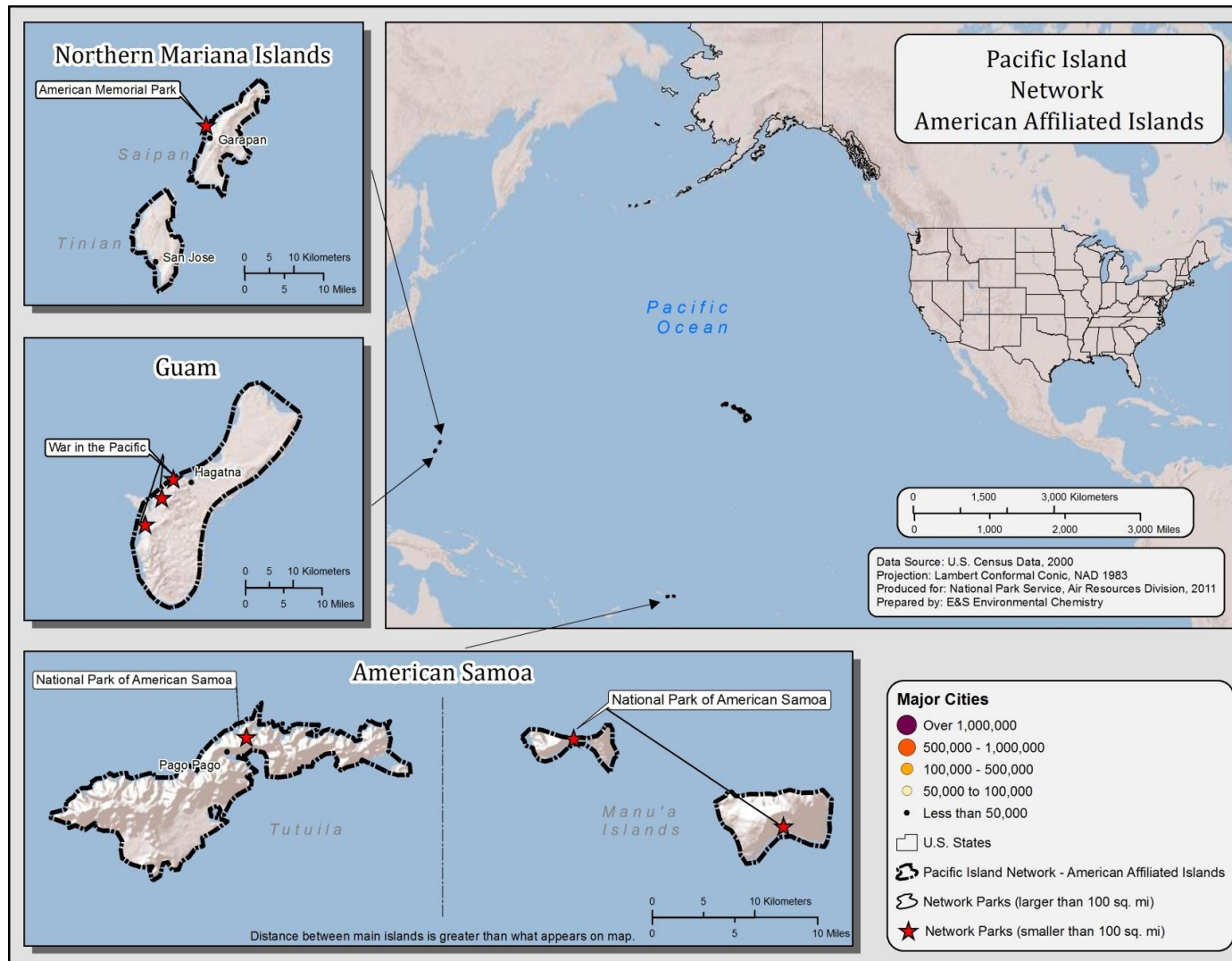
Background

The Pacific Island Network (PACN) includes islands at diverse locations in the Pacific Ocean. It includes the Hawaiian Islands, Northern Mariana Islands, Guam, and American Samoa. Maps 1 and 2 show the PACN boundaries along with locations of each park and population centers with more than 10,000 people around the network. There are nine parks in the PACN that are included in this assessment: American Memorial Park (AMME), Hawaii Volcanoes National Park (HAVO), Haleakala National Park (HALE), Kalaupapa National Historical Park (KALA), Kaloko-Honokohau National Historical Park (KAHO), National Park of American Samoa (NPSA), Pu'uhonua o Honaunau National Historical Park (PUHO), Puukohola Heiau National Historic Site (PUHE), and War in the Pacific National Historical Park (WAPA). It is located on the island of Hawaii. HALE and HAVO are Class I air quality areas, which receive the highest level of protection under the Clean Air Act (CAA) from effects attributable to poor air quality; the rest of the PACN parks are Class II areas. The NPS air quality efforts focus largely on the Class I areas. The only population center in the PACN region of any magnitude (more than 100,000 people) is Honolulu on Oahu. There are no large population centers on any of the U.S. Affiliated Islands. Data reflecting sensitivity to, and effects from, air pollutants are particularly sparse for the U.S. Affiliated Islands.

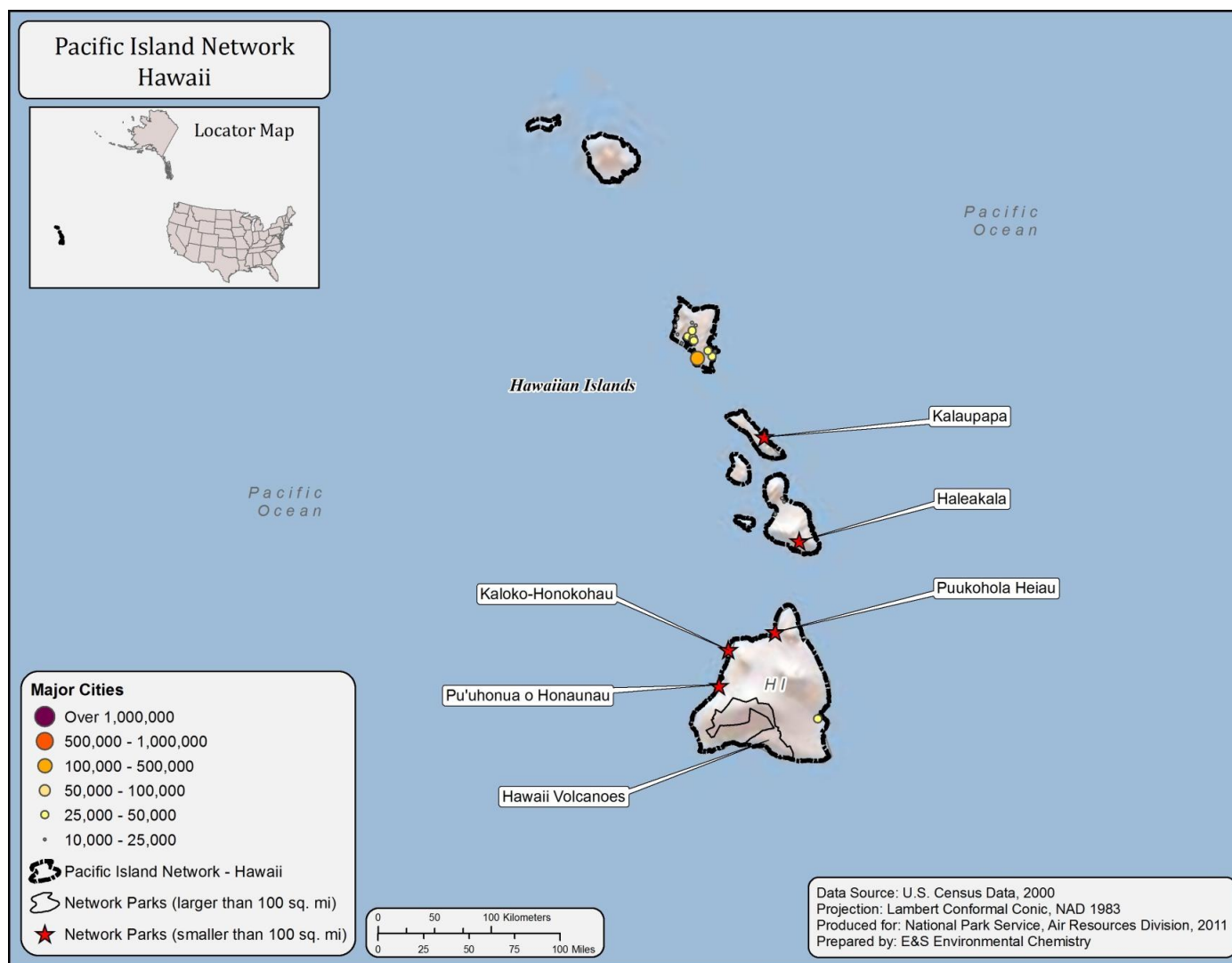
Some of the largest areas of protected humid tropical forest and humid subtropical forest in the United States are located within HAVO and HALE. NPSA contains the only paleotropical rainforest in the NPS system. These forests contain a large number of endemic species. In the United States, the tropical and subtropical humid forest ecoregion occurs only in southern Florida, Puerto Rico, and Hawaii. Biodiversity is very high in this ecoregion, and includes many species of epiphytes, which have been found to be highly sensitive to nitrogen (N) inputs in other biomes.

Atmospheric Emissions and Deposition

In a screening analysis by Sullivan et al. (2011), human-caused county-level sulfur (S) emissions within the Hawaii portion of the PACN ranged from less than 1 ton per square mile per year ($\text{ton}/\text{mi}^2/\text{yr}$) of sulfur dioxide (SO_2) on the big island of Hawaii and Kauai to the range of 5 to 20 $\text{tons}/\text{mi}^2/\text{yr}$ on Oahu. Other islands in the Hawaiian archipelago generally had human-caused SO_2 emissions in the range of 1 to 5 tons per square mile per year. Emissions data were not available for the American Affiliated Islands. There were very few human-caused point sources of SO_2 on any of the Hawaiian Islands and none of any magnitude. All emitted less than 5,000 tons of SO_2 per year. Natural S emissions sources include the Kilauea Volcano, whose emissions ranged from about 600,000 to 1.4 million tons per year of SO_2 from 2008 to 2010 (Elias and Sutton 2012). High levels of atmospheric SO_2 concentrations, caused by the Kilauea volcano, have led to closures of parts of HAVO because of human health concerns. The HAVO alert site provides real time air quality data for SO_2 along with wind direction and speed (<http://www.hawaiiiso2network.com/>).



Map 1. Network boundary and locations of parks and population centers with more than 10,000 people within the American Affiliated Islands in the PACN region.



Map 2. Map showing network boundary and locations of parks and population centers with more than 10,000 people within the Hawaiian Islands in the PACN region.

Human-caused county-level N emissions within the PACN region ranged from less than 1ton/mi²/yr on the big island of Hawaii to between 20 and 50 tons/mi²/yr on Oahu. Important sources of N emissions include motor vehicles, agriculture, and industry. Annual emissions of N from the other Hawaiian Islands were intermediate, between 1 and 5 ton/mi²/yr. There are relatively few N point sources in Hawaii. Most are located on Oahu.

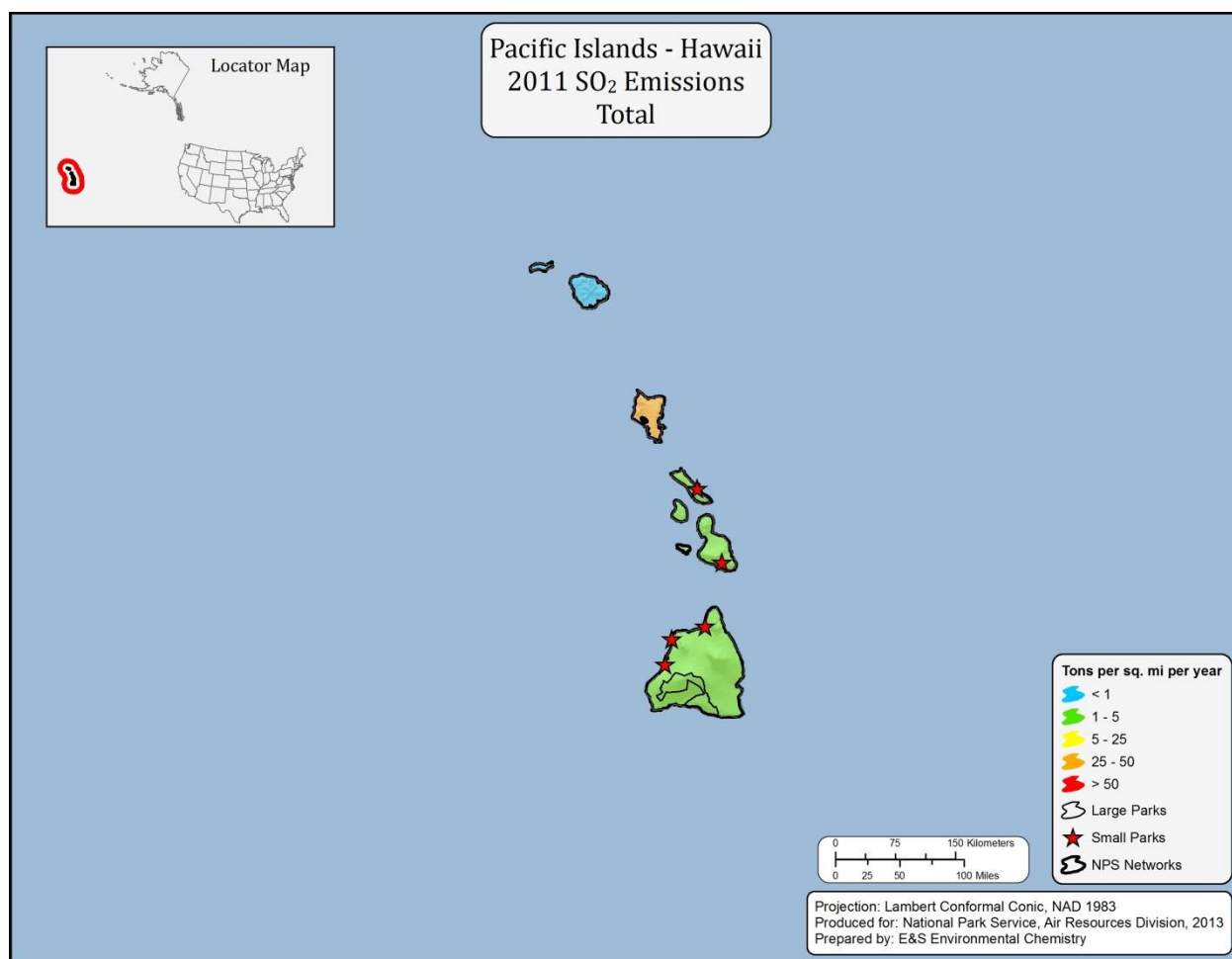
County-level emissions near PACN, based on data from the EPA's National Emissions Inventory (NEI) during a recent time period (2011), are depicted in Maps 3 through 5 for SO₂, oxidized N (NO_x), and reduced N (NH₃), respectively. They are available for the Hawaiian Islands, but not for the American Affiliated Islands. Counties in the vicinity of Hawaiian parks had relatively low SO₂ emissions (1 to 5 tons/mi²/yr; Map 2). Emissions of NO_x were lowest on the island of Hawaii (Map 3). Emissions of NH₃ near the Hawaiian parks were below 8 tons/mi²/yr (Map 4).

Atmospheric deposition data are not available for recent years in the PACN region, but deposition of N and S are likely relatively high at some locations on some of the Hawaiian Islands, especially Oahu and Hawaii, and lower elsewhere. There was a National Atmospheric Deposition Program (NADP) wet deposition monitoring station at HAVO that reported deposition data as recently as 2003 and 2004. Wet N deposition was low, less than 1 kg N/ha/yr, during both years. Wet S deposition was considerably higher, about 6 and 11 kg S/ha/yr during those years. There was also a deposition monitoring site in operation at Mauna Loa in HAVO through 1993. Total N and S deposition values at that site were below 1 kg/ha/yr for both N and S during the two most recent years of data collection.

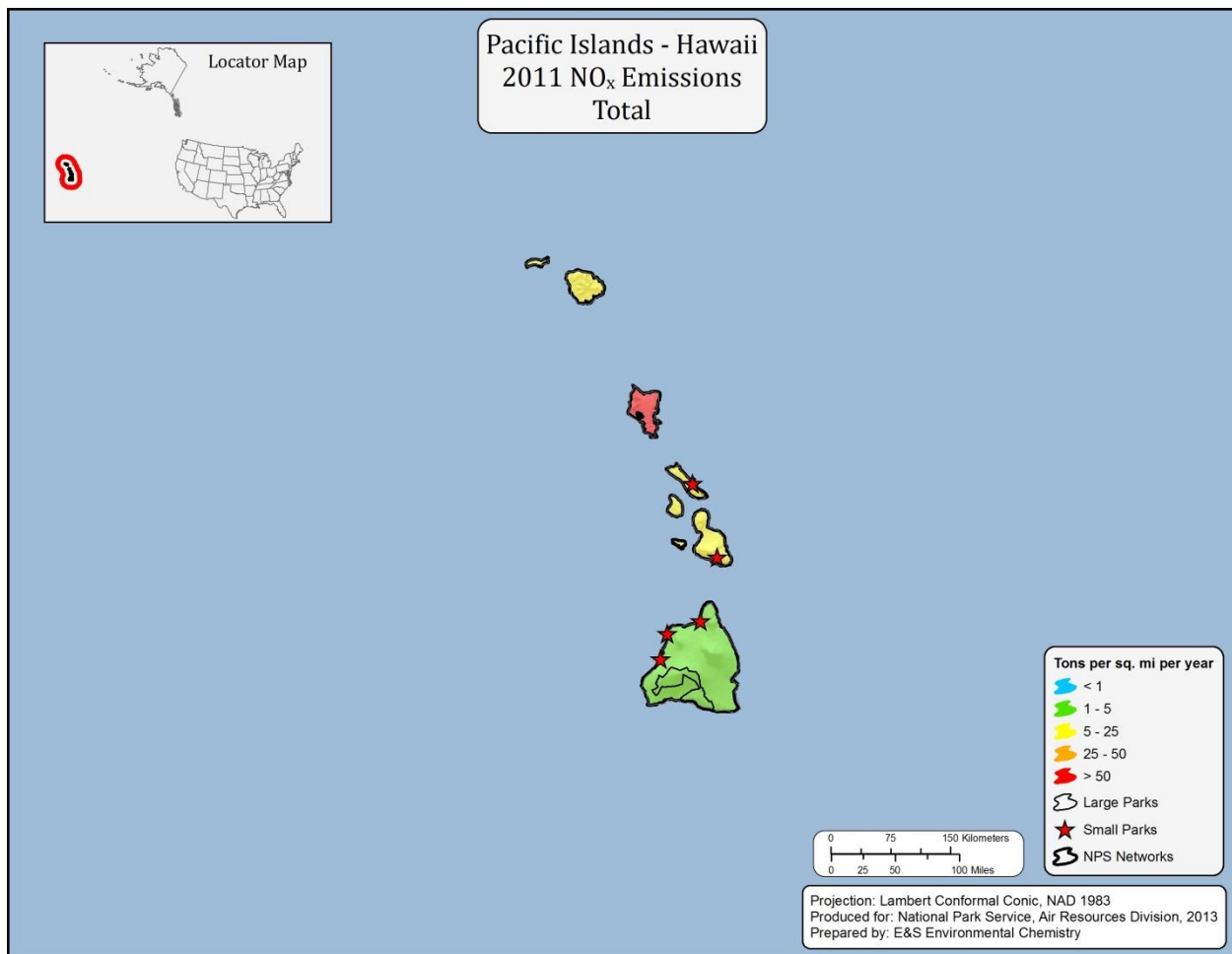
Acidification

Based on a generalized screening analysis, the network risk rankings developed by Sullivan et al. (2011) for acid Pollutant Exposure, Ecosystem Sensitivity to acidification, and Park Protection yielded an overall network acidification Summary Risk ranking for the PACN that was near the middle of the distribution relative to all NPS Inventory and Monitoring (I&M) networks nationwide. The overall level of concern for acidification effects on PACN parks due to human-caused S and N deposition was judged by Sullivan et al. (2011) to be Moderate.

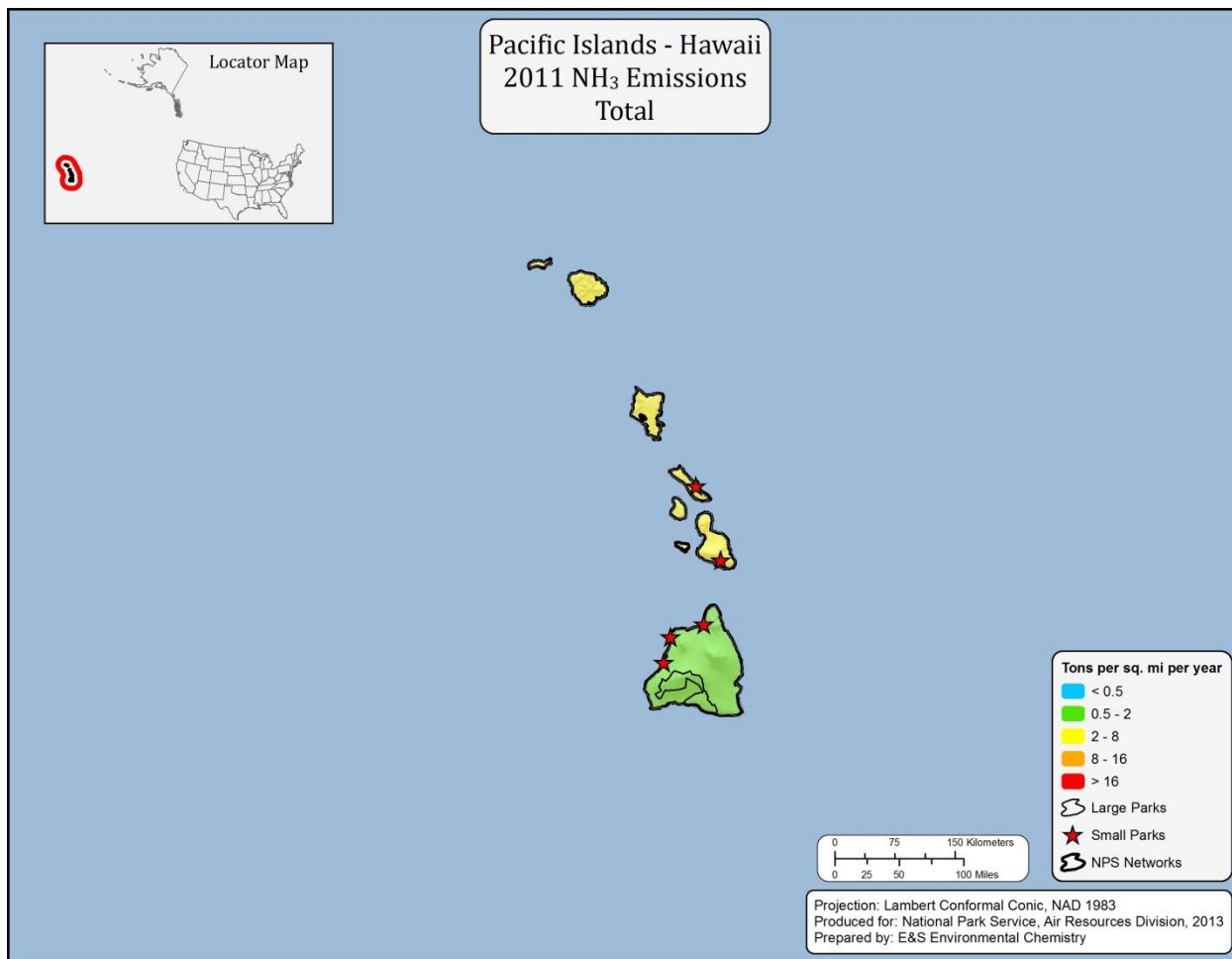
HAVO was in the second highest quintile in Ecosystem Sensitivity to acidification. The smaller parks in the network varied in ranking for Ecosystem Sensitivity. HALE was ranked Very High; three parks were ranked Moderate, two were ranked Low, and one was ranked Very Low for this theme (Table 1). While rankings are an indication of risk, park-specific data, particularly data on ecosystem sensitivity, are needed to fully evaluate risk from acidification.



Map 3. Total SO₂ emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.



Map 4. Total NO_x emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.



Map 4. Total NH₃ emissions, by county, near PACN for the year 2011. Data from EPA's National Emissions Inventory.

Ecosystem sensitivity to acidification rankings take into account land slope and hydrography and the presence of low-order streams, which often influence the degree of acid neutralization provided by soils and bedrock within the watershed. Park slopes on the Hawaiian Islands tend to be low, generally less than 10°. HALE, however, has average slope in the range of 10° to 20°, suggesting increased potential for acid sensitivity of aquatic ecosystems. KALA also has areas of steep terrain.

Many species of moss occur in PACN parks. Moss is known to be especially sensitive to acidic deposition in other biomes. Little is known, however, about the acid sensitivity of moss species in the PACN region. Waite (2007) compiled a list of moss species in HALE, which identified 110 species in and near the park. An estimated 43% of all moss species that occur in the Hawaiian Islands are represented at this park. Thus, potential effects of S and N (and heavy metal) deposition on the rich moss flora of this, and perhaps other, parks in the PACN may be important ecological concerns.

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

Park Name	Park Code	Estimated Ecosystem Sensitivity to Acidification
American Memorial Park	AMME	Moderate
Haleakala	HALE	Very High
Hawaii Volcanoes	HAVO	High
Kalaupapa	KALA	Moderate
Kaloko-Honokohau	KAHO	Very Low
National Park of American Samoa	NPSA	Moderate
Pu'u'honua o Honaunau	PUHO	Low
Puukohola Heiau	PUHE	Low
War in the Pacific	WAPA	Moderate

¹ Relative park rankings, based on a coarse screening analysis (Sullivan et al. 2011), 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).

Information is not available regarding the possible effects of human-caused acidic deposition on aquatic or terrestrial resources in the PACN. However, more data are available regarding effects of natural volcanic emissions of S and other constituents in, and downwind of, HALE (Nelson and Sewake 2008). The Kilauea volcano has been erupting continually since 1983, with increased emissions since late 2007 and 2008. The caldera area and land to the southwest are largely devoid of vegetation, covered mainly by recent lava flows. There are also localized areas affected by high emissions and deposition of S and other volcanic constituents, including heavy metals. Trade winds carry gasses from the volcano in a southwesterly direction. Plant damage has been reported for a variety of crop and other plant species (Nelson and Sewake 2008).

Nutrient Nitrogen Enrichment

Some limited experimental work has been conducted in the PACN region on nutrient N enrichment. Fertilization with NH_4NO_3 in a phosphorus (P)-limited forest on Kaua'i caused increased emissions from soils of N_2O and NO subsequent to addition of 15 kg N/ha/yr, but not subsequent to addition of 5 kg N/ha/yr (Carillo et al. 2002, Hall and Matson 1999). Ambient wet N deposition at this site was < 1 kg N/ha/yr. Experimental addition of a large amount (> 100 kg/ha/yr) of N did not stimulate plant growth or affect species composition in the forest (Harrington et al. 2001, Ostertag and Verville 2002). Similarly, high N addition did not affect epiphytic (above-ground) lichen abundance or diversity in P-limited or N + P-limited lower montane rain forests (Benner et al. 2007, Benner and Vitousek 2007).

On tropical or subtropical sites where N is not limiting, atmospheric N deposition would not be expected to alter productivity or plant species composition. However, loss of N to the atmosphere as gasses produced by denitrification or to drainage water as NO_3^- may be stimulated by increased N deposition (Hall and Matson 1999, Hall 2011, Herbert and Fownes 1995, Lohse and Matson 2005, Templer et al. 2008). On sites where the N supply is limiting, added N would be expected to increase plant growth and perhaps change plant community composition, eventually leading to N-saturation (Erickson et al. 2001, Feller et al. 2007, Hall and Matson 1999).

Tropical and subtropical forests are often relatively rich in N, and other nutrients are more often limiting (Chadwick et al. 1999). Such ecosystems commonly show high rates of N leaching and denitrification, irrespective of atmospheric deposition (Davidson et al. 2007, Hall 2011, Lewis et al. 1999). There are no data suggesting that terrestrial or aquatic resources in the PACN region are affected at this time by nutrient enrichment caused by atmospheric N deposition at current atmospheric loading rates.

Ozone Injury to Vegetation

Ozone (O_3) pollution can reduce plant growth and cause visible injury to foliage. Information regarding O_3 sensitivity of plant species native to PACN parks is limited. The O_3 -sensitive plant species that are known or thought to occur within PACN parks are listed in Table 2.

Those considered to be bioindicators exhibit distinctive symptoms when injured by O_3 (e.g., dark stipple). They are designated in the table by an asterisk. Seven of the parks within the PACN did not contain any known O_3 sensitive and/or bioindicator species. HAVO contained six O_3 sensitive plant species, three of which are recognized as bioindicators. HALE contained three sensitive species, two of which are bioindicators (Table 2). Ozone was monitored for several years at HALE and HAVO (NPS ARD website); levels were quite low, and injury risk to plants is likely to be low.

Table 2. Ozone-sensitive and bioindicator plant species known or thought to occur in PACN parks. (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								
		AMME	HALE	HAVO	KAHO	KALA	NPSA	PUHE	PUHO	WAPA
<i>No Species Present</i>		x			x	x	x	x	x	x
<i>Liquidambar styraciflua</i>	Sweetgum			x						
<i>Pinus jeffreyi</i> *	Jeffrey pine		x							
<i>Pinus ponderosa</i> *	Ponderosa pine		x							
<i>Pinus radiata</i>	Monterey pine		x	x						
<i>Pinus taeda</i>	Loblolly pine			x						
<i>Sambucus mexicana</i> *	Blue elderberry			x						
<i>Vitis vinifera</i> *	European wine grape			x						
<i>Vitis X proliferata</i> *	Northern fox grape			x						

* Bioindicator species

Sulfur Dioxide Injury to Vegetation

Atmospheric concentrations of SO₂ in the range of 0.1 to 1 parts per million can change stomatal conductance for a variety of plant species (Farrar et al. 1977). Winner and Mooney (1980) showed that changes in stomatal conductance in response to SO₂ exposure are associated with foliar injury. Hawaiian plants exposed to volcanic SO₂ showed interspecific differences in leaf injury. Species having leaves that did not close stomata upon exposure developed chlorosis or necrosis; species that did close stomata did not show damage symptoms. Tanner et al. (2007) found decreased stomatal index (number of stomata relative to number of epidermal cells) of swordfern (*Nephrolepis exaltata*) in the plumes of outgassing vents on the Kilauea volcano, where atmospheric concentrations of both SO₂ and carbon dioxide (CO₂) were much higher than background and also at a site where SO₂ (but not CO₂) was elevated.

Visibility Degradation

Natural Background Visibility and Monitored Visibility Conditions

The CAA 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 enacted 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 by 2064. Natural background visibility assumes no human-caused pollution, but varies with natural processes such as windblown dust, wildfire, volcanic activity and biogenic emissions. Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Network and typically reported using the haze index called the deciview (dv)². Lower dv values correspond with better visibility conditions. Visibility is monitored in HALE (HALE1) and HAVO (HAVO1). In 2007, a second IMPROVE monitor was installed in HALE near the crater; the new site is designated HACR1 (Haleakala Crater). The two monitors were run simultaneously for several years for comparison. In 2012 the HALE1 monitor was decommissioned, and the HACR1 monitor now serves to characterize visibility at HALE.

Data from the HALE1 monitor have been used in this analysis to represent visibility conditions for HALE. The HAVO1 monitor data are used to represent conditions at HAVO. Data from HALE are

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.

also considered to be representative of visibility conditions in KALA. A monitoring site is considered by IMPROVE to be representative if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area. Haze from volcanic smog (called vog locally) is caused by gaseous and particulate emissions from the Kilauea volcano (Nelson and Sewake 2008). Such haze can be substantial in western portions of Hawaii Island.

Data from 2004 to 2008 were used to document haze conditions at parks in the PACN in order to provide park managers with information on spatial differences in visibility and air pollution (Table 3). Haze levels ranged from very low haze (very good visibility) to very high haze (very poor visibility). Only parks with on-site or representative IMPROVE monitors were used in generating the table. Haze is reported on the 20% clearest, 20% haziest, and average days for the monitored parks in this network. Since the period 2004-2008 was used for this ranking, it does not reflect changes in haze since the late 2007 enhanced eruption of Kilauea. A more recent analysis showed that haze increased significantly on the haziest days at HAVO and HALE from 2000 to 2009 (NPS 2013).

Table 3. Estimated natural background visibility and monitored visibility in PACN parks averaged over the period 2004 through 2008. Visibility conditions have deteriorated significantly since that time due to increased volcanic activity.

Park Name ¹	Park Code	Site ID	Estimated Natural Background Visibility (dv)		
			20% Clearest Days	20% Haziest Days	Average Days
American Memorial Park	AMME	No Site			
Haleakala	HALE	HALE1	2.66	7.43	4.95
Hawaii Volcanoes	HAVO	HAVO1	2.20	7.17	4.54
Kalaupapa ²	KALA	HALE1	2.66	7.43	4.95
Kaloko-Honokohau	KAHO	No Site			
National Park of American Samoa	NPSA	No Site			
Pu'uuhonua o Honaunau	PUHO	No Site			
Puukohola Heiau	PUHE	No Site			
War in the Pacific	WAPA	No Site			
Park Name	Park Code	Site ID	Monitored Visibility (For Years 2004 through 2008) (dv)		
			20% Clearest Days	20% Haziest Days	Average Days
American Memorial Park	AMME	No Site			
Haleakala	HALE	HALE1	4.39	14.24	8.88
Hawaii Volcanoes	HAVO	HAVO1	3.76	22.59	10.37
Kalaupapa ²	KALA	HALE1	4.39	14.24	8.88
Kaloko-Honokohau	KAHO	No Site			
National Park of American Samoa	NPSA	No Site			
Pu'uuhonua o Honaunau	PUHO	No Site			
Puukohola Heiau	PUHE	No Site			
War in the Pacific	WAPA	No Site			

¹ Data are based on a nearby representative site. A monitoring site is considered by IMPROVE to be representative if it is within 60 mi (100 km) and 425 ft (130 m) in elevation of that area.

Representative photos of a selected vista in HAVO under three different visibility conditions are shown in Figure 1. Photos were selected to correspond with the clearest 20% visibility conditions, haziest 20% visibility conditions, and annual average visibility conditions at that location. The impact of haze on the 20% haziest days is pronounced.

IMPROVE data allow estimation of visual range (VR), which reflect how far a person can see. Data from HALE indicate that haze has reduced average VR from about 150 to 95 miles (242 to 152 km). On the haziest days, VR has been reduced from 110 to 65 miles (177 to 105 km). Severe haze episodes occasionally reduce visibility to 21 miles (34 km) or less. At HAVO, haze has reduced average VR from 150 to 75 miles (242 to 120 km). On the haziest days, VR has been reduced from 120 to 30 miles (193 to 48 km). Severe haze episodes occasionally reduce visibility to 4 miles (6 km) or less.

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 SO_2 emissions. In HAVO, these are primarily volcanic emissions; in other parks, SO_4^{2-} originates primarily from fuel-burning power plants or industrial boilers. 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 human-caused sources, including agriculture, industry, and fires. Atmospheric sea salt concentrations are high in coastal areas and comprise a large proportion of particles in haze in those areas. Soil can enter the atmosphere through both natural processes and human disturbance.

Figure 2 shows estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze and its composition for HALE, HAVO, and KALA (data from HALE are considered representative of KALA). The majority of the haze in both monitored parks for all groups (20% clearest days, annual average, and 20% haziest days) was attributable to sulfate (SO_4^{2-}), sea salt, and coarse mass (Figure 2). By far the largest percentage was attributable to SO_4^{2-} . For the 20% haziest days and annual average, SO_4^{2-} was responsible for more than 50% of the haze in HALE and KALA and more than 85% in HAVO. Results were similar for the HACR1 site in HALE (http://www.wrapair2.org/documents/6.0%20STATE%20AND%20CLASS%20I%20AREA%20SUMMARIES/6.05%20Hawaii/WRAP_RHRPR_Appendix_E_Hawaii.pdf). Sea salt played a larger role on the 20% clearest days, contributing 27.5% in HALE and KALA and 33.3% in HAVO. Nitrates and organics were also responsible for appreciable portions of the haze at these parks.

Trends in Visibility

Visibility monitoring data are shown in Figure 3 for the period of record at HALE and HAVO. Conditions from 2001-2009 degraded significantly on the haziest days at HAVO (NPS 2013). Other trends were more modest.

Hawaii Volcanoes

20% Clearest Days

Taken: 3:00 PM

Haze = 4 dv

VR = 260 km



20% Haziest Days

Taken: 3:00 PM

Haze = 23 dv

VR = 40 km



Average Days

Taken: 3:00 PM

Haze = 9 dv

VR = 160 km



Figure 1. Three representative photos of the same view in HAVO illustrating the 20% clearest visibility, the 20% haziest visibility, and the annual average visibility. Bext is total particulate light extinction; VR is the visual range.

HALE and KALA

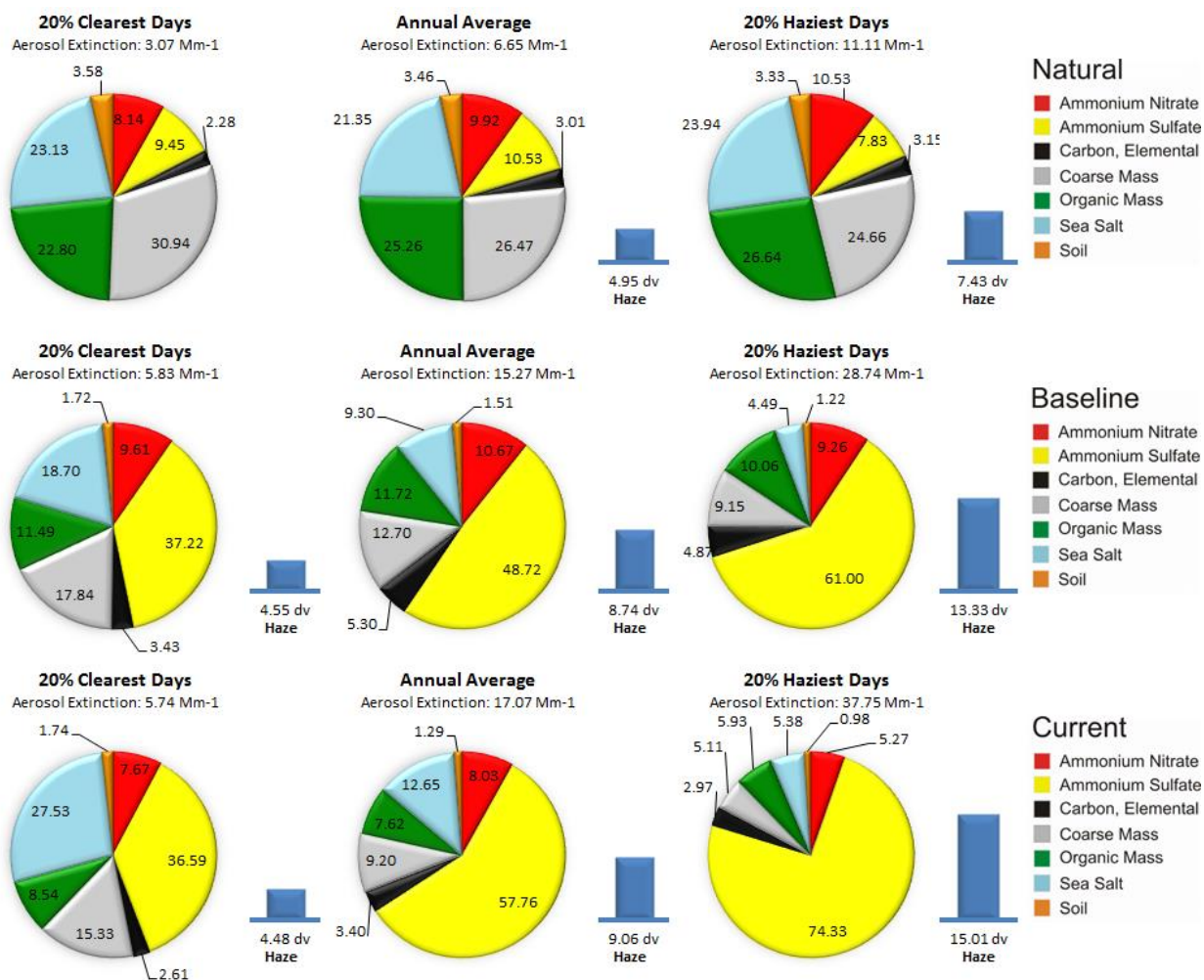


Figure 2a. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% haziest visibility days for HALE and KALA (the sites have no data for the year 2000). Data for KALA are based on the monitor at HALE. Data Source: NPS-ARD

HAVO

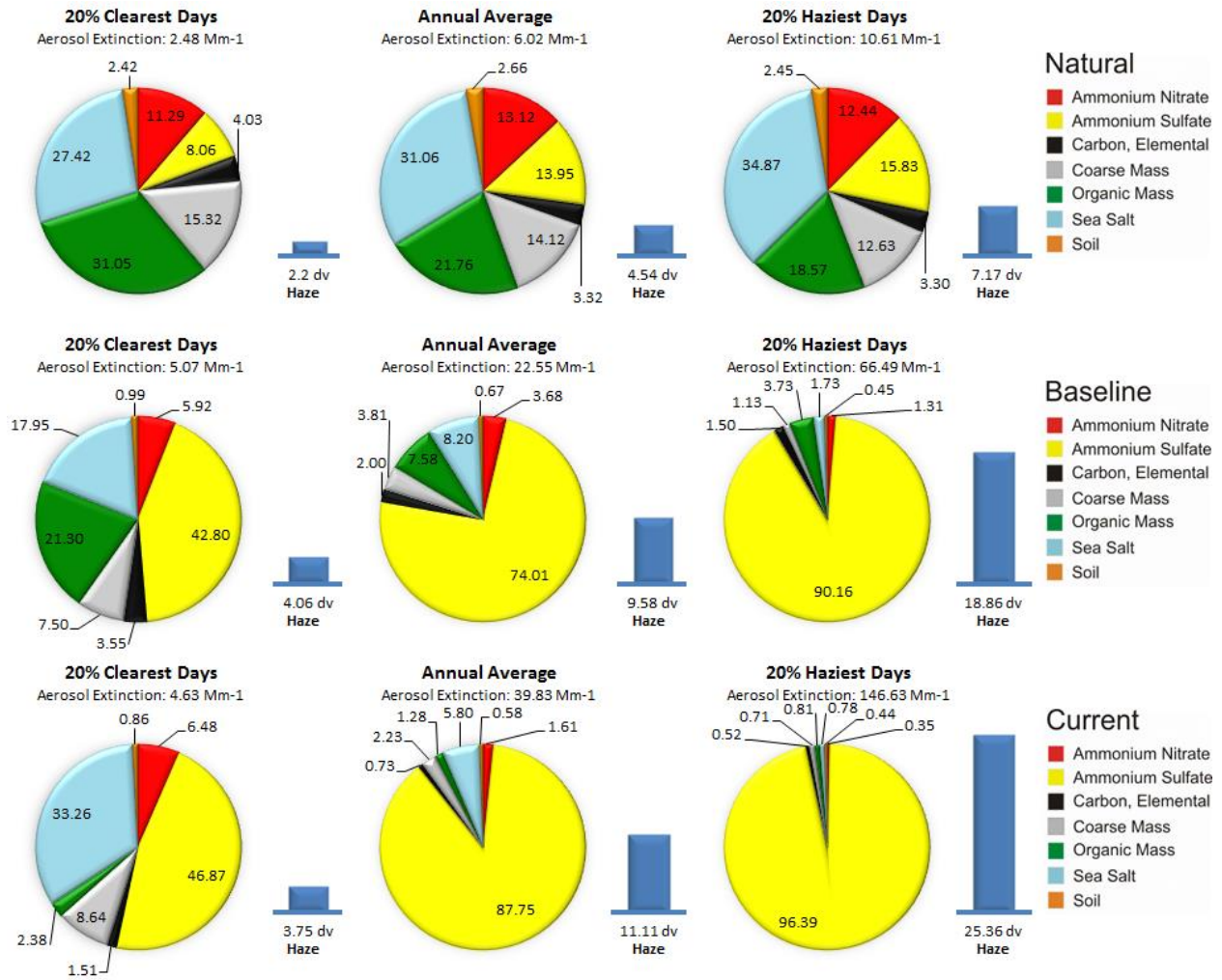


Figure 2b. Estimated natural (pre-industrial), baseline (2000-2004), and current (2006-2010) levels of haze (blue columns) and its composition (pie charts) on the 20% clearest, annual average, and 20% hazeiest visibility days for HAVO (the sites have no data for the year 2000). Data for KALA are based on the monitor at HALE. Data Source: NPS-ARD

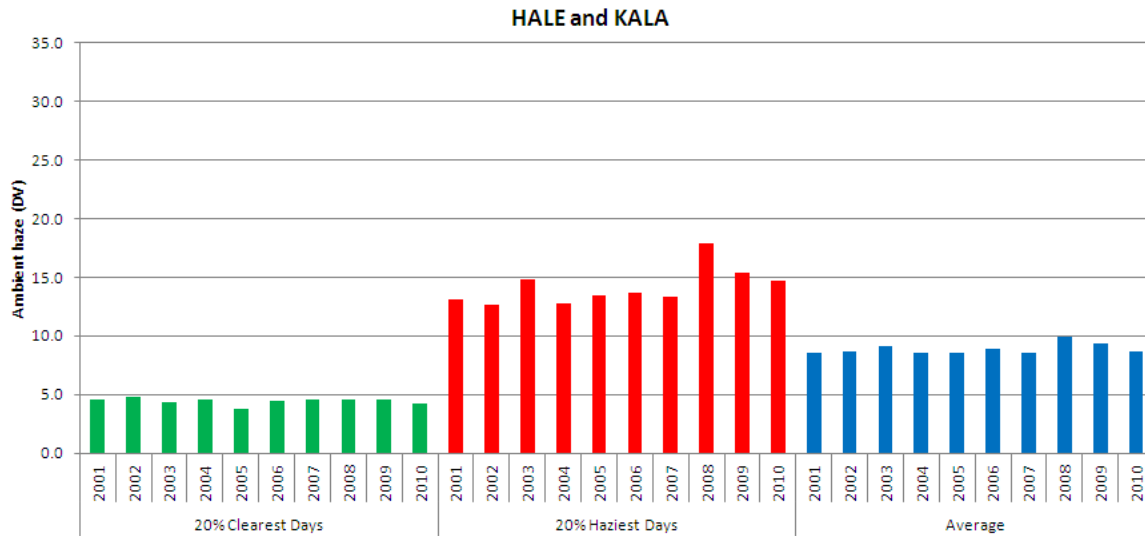


Figure 3a. Trends in monitored visibility for HALE and KALA, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for KALA are from the HALE monitor. Data Source:

http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

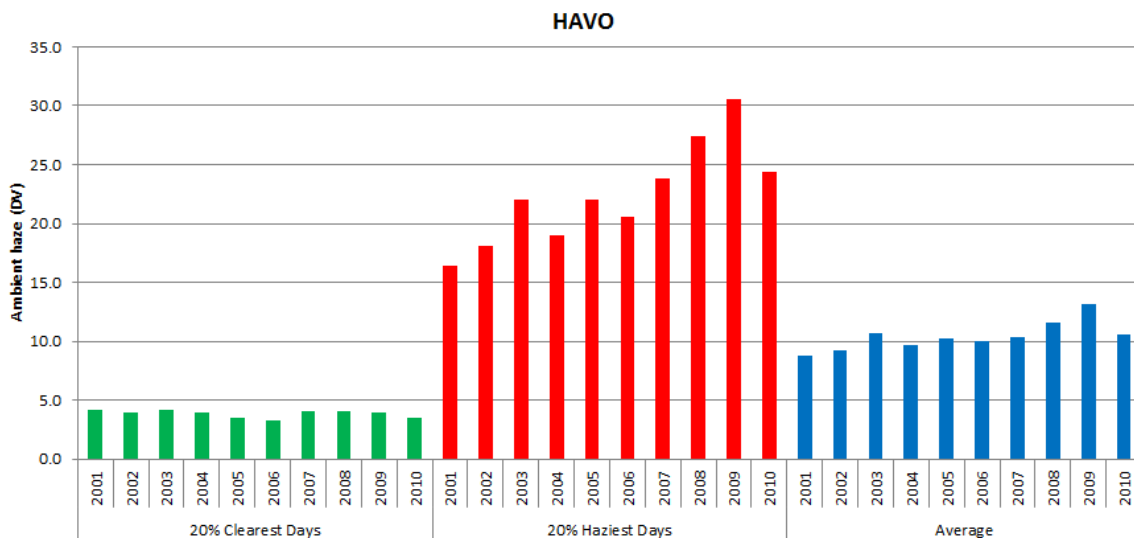


Figure 3b. Trends in monitored visibility for HAVO, based on IMPROVE measurements on the 20% clearest, 20% haziest, and annual average visibility days over the monitoring period of record. Data for KALA are from the HALE monitor. Data Source:

http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

Development of State Implementation Plans

According to the RHR, states and tribes must establish and meet reasonable progress goals for each federal Class I area to improve visibility on the 20% haziest days and to prevent visibility degradation on the 20% clearest days by reducing the human-caused emissions that contribute to haze. The national goal is to return visibility in Class I areas to natural background levels by 2064. Variability in volcanic emissions make it difficult to estimate natural conditions, but the State of Hawaii can reduce emissions from power plants and other sources to try to achieve the RHR goals. States must evaluate progress by 2018 (and every 10 years thereafter) based on a baseline period of 2000 to 2004 (Air Resource Specialists 2007). In 2012, the National Park Service Air Resources Division recommended that federally enforceable SO₂ limits be established for several large power plants on Maui, in addition to reductions required at other power plants in the State (National Park Service 2012).

Progress to date in meeting the national visibility goal is illustrated in Figure 4 using a uniform rate of progress glideslope. Although haze on the 20% clearest days shows essentially no change relative to the 2000-2004 baseline, haze on the 20% haziest days at HALE and HAVO shows increasing departure over time between the baseline and the glideslope of required progress toward natural background visibility by 2064. Although increases in haze are expected because of increased volcanic activity, the State of Hawaii might further evaluate the need to reduce emissions from human-caused sources.

Toxic Airborne Contaminants

Information on the potential impacts of air toxics on sensitive resources in the PACN is generally not available. Undoubtedly, toxic emissions from volcanic activity contribute to some degree.

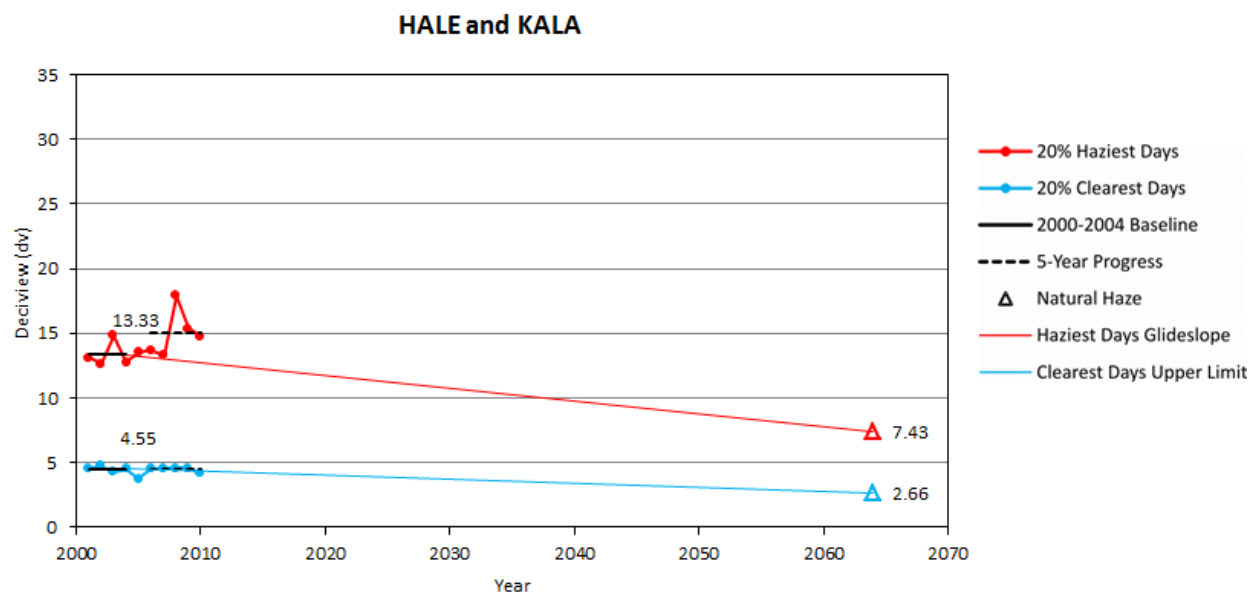


Figure 4a. Glideslopes to achieving natural visibility conditions by 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days for HALE and KALA (the sites have no data for the year 2000). Data for KALA are from HALE. In the Regional Haze Rule, the clearest days do not have a uniform 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. Data Source:

http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

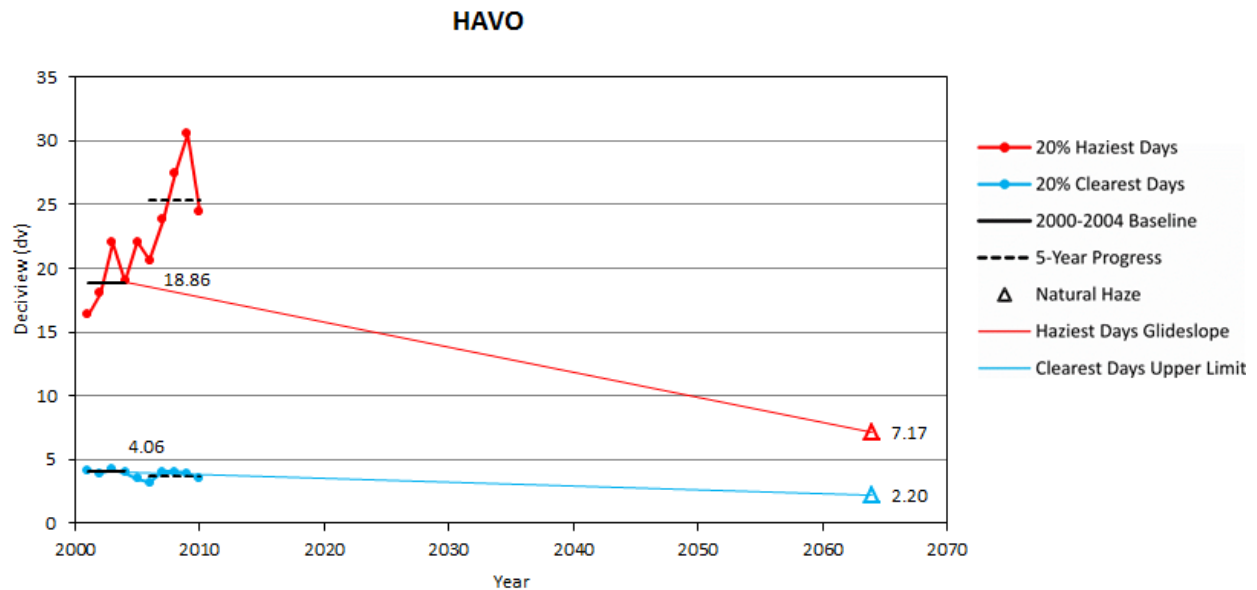


Figure 4b. Glideslopes to achieving natural visibility conditions by 2064 for the 20% haziest (red line) and the 20% clearest (blue line) days for HAVO (the sites have no data for the year 2000). Data for KALA are from HALE. In the Regional Haze Rule, the clearest days do not have a uniform rate of progress 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. Data Source: http://vista.cira.colostate.edu/improve/Data/IMPROVE/summary_data.htm

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