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Land Is Losing to the Poor's

People without property are moving onto the hillsides.

Special to The New York Times

WASHINGTON

ACTING out of desperation, many of the poorest people in the world are cutting down forests, razing grasslands and slowly destroying fragile ecosystems to survive, environmental researchers say.

Poor farmers in the Sudan clear trees at the headwaters of the Nile, and by destroying these valuable watersheds, cause floods up and down the river. Peasants in Brazil with no fields of their own hew down the Amazon rain forests and indirectly threaten the climate of the globe by reducing the production of oxygen.

"For centuries, there has been moral outrage about disparities in standards of living," said Alan Durning, a staff member of the Worldwatch Institute, an environmental research organization. "Today we find poverty is not just a moral issue, because we now have a situation where poor people endanger the well-being of the better-off."

'Landless People'

The poor in Costa Rica have dealt a heavy blow to the rain forests that once covered most of their country, said Sheldon Annis, a member of the Overseas Development Council, an organization that researches economic issues affecting developing countries.

In Costa Rica, as in most of Latin America, there are two types of poor, Mr. Annis said. Those in the first group have a small parcel of land or some community that helps sustain them. Though these people must fight daily for their food and livelihood, they are finding a political voice, he said.

But those in the second category live in despair, he said.

"These are landless people, children, deculturated tribal people," he said. "They are people whose lands have already been developed throughout the world. They are the ones who are moving up the sides of hills."

Excess in affluent communities drives most of the world's environmental problems, Mr. Durning said, but as the numbers of the impoverished have grown by more than 200 million people worldwide in the last decade, so has the detriment of starvation and homelessness to the environment.

To subsist, the poor must consume or shatter the very resources that give them life, he said. Mr. Durning is the author of a recent report "Poverty and the Environment: Reversing the Downward Spiral."

U.N. Efforts

The relationship between poverty and environment has been apparent to development workers at the United Nations for some time, said Paul Perry, director of the U.N.'s Development Program in Washington.

From 1976 to 1986, the budget for such projects as developing underground water reserves in Mali, cleaning up the Ganges in Bangladesh and expanding small farms in Zambia has nearly tripled, from $42.5 million to $123 million.

"We're not letting it drop," Mr. Perry said. But he added, "There's a need for more concerted effort."

People in some countries have begun their own efforts to r environmental damage, s Oberg, a field representati Inter-American Foundat foundation is a Governme that gives financial assi small development operati Caribbean and Latin Amer

Recently, it gave more th to farmers in Costa Rica trying to turn back the e their land by reforestation. ers themselves came up wit of reforestation, Mr. Oberg the foundation provided mo for seeds, salaries, tools ar costs.

"I happen to believe ther hope," Mr. Oberg said. ' Rica, we find a lot of peopl

Disease and Destru

THE koala, a furry marsupial that lives almost exclusively in eucalyptus trees in the wilds of Australia, is at risk of becoming an endangered species, environmentalists and zoologists say.

Over the last 50 years, the population of koalas has dwindled from more than several million to 400,000 and is continuing to decline, scientists say. The decline is mainly a result of destruction of the koala's natural habitat and unchecked spread of disease among the animals. Nearly 80 percent of the koala's natural habitat and food supply has been wiped out by human development along the eastern coast of Australia.

"If we don't sound the alarm now, it soon may be too late," said Dr. Werner Heuschele, director of the Center for Reproduction of Endangered Species at the San Diego Zoo. "Right now there is the potential for the development there to strip away the koala's habitat."

While scientists say the major threat is from the destruction of the animal's habitat and food supply, they note that about 40 percent of all koalas are infected with chlamydia, a type of venereal disease.

$5 Million Campaign

If it remains unchecked, chlamydia is likely to spread to an even larger portion of the koala population, said Debbie Tabart, director of the Australian Koala Foundation, which has begun a campaign to raise $5 million to help save the animal.

Preliminary research indictates that chlamydia among koalas can cause blindness, female infertility, pneumonia and bladder infections, scientists said.

Because of the uncontrolled spread of the disease, any large-scale relief effort will now require a quarantine of noninfected koalas, scientists said.

"There is finally some acceptance

Australian koala may be ad

that the koala has a problem Tabart said. "Unless we do thing about it now, we are g face some serious problems next 50 years."

The destruction of thousand

Fight for Short-Term Survival

The World Bank is urged to find economic solutions.

everse the said Keith tive for the tion. The ent agency sistance to tions in the erica.

than $40,000 ca who are erosion of n. The farm- with the idea erg said, and money to pay and vehicle

there is some d. "In Costa eople who are

discovering they're shooting themselves in the foot."

But Mr. Annis said: "All this stuff about grass roots development is overstated. It's wishful thinking. Credit programs and education programs don't work unless states are basically competent and do what they're supposed to do."

Financial institutions like the World Bank and the International Monetary Fund have to change their policies, Mr. Durning said. As the bank works with developing nations on ways for them to pay off their huge debts, he said, it should make sure that they do not try to come up with the money by cutting food subsidies indiscriminately or by taking money away from education and health care while leaving the military and other power structures intact.

The World Bank focuses on helping everyone in the developing world by giving blanket assistance to national economies, he said, but it needs to shift emphasis to helping the poorest people in those nations.

Because of its size and the size of its loans, the bank is not always able to reach the poorest of the poor, a staff member at the World Bank said.

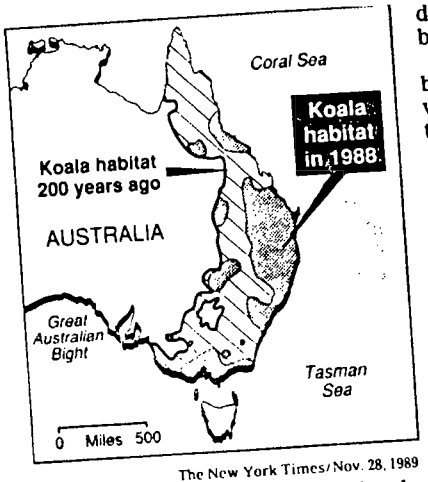
But the bank has begun to look at ways to reduce poverty along lines suggested in Mr. Durning's report. The staff is discussing devoting more money to projects that will provide jobs for more people.

Though Mr. Durning says much needs to be done, he is optimistic. "It's extraordinary how things can change suddenly," Mr. Durning said. "Look at Eastern Europe. Who could have predicted that? If we can make the case to people not only through humanitarian arguments but also with the threat to the environment that these problems have to be solved, then we may move in that direction much quicker."

uction of Habitat Are Killing Off Koalas

Australian Koala Foundation

a may be added to list of endangered species.



The New York Times/Nov. 28, 1989

The estimated range of the koala has shrunk over two centuries.

las a problem," Ms. Unless we do some- ow, we are going to ous problems in the

on of thousands of eu-

The koala, is a robustly built animal that is gray to gray-brown in color and is about two feet long. It , depends on a diet consisting almost entirely of the leaves and shoots of the eucalyptus tree. There are more than 600 species of the tree, but the koala eats only the leaves of about one-sixth of the species.

"A lessening of the available food source will lead to malnutrition, disease, poor survivability rates and poor reproductive ability," said Dr. Heuschele of the San Diego Zoo, which has 30 koalas, the largest exhibit of koalas in the United States.

The construction of resorts and housing developments in Australia is also fragmenting the koala's habitat, he said. "The koalas like to move from one place to another, and if you block their access, it limits their ability to find food and their ability to forage," he said.

In addition, he said, a recent study found that the most common cause of death of koalas is from being struck by automobiles.

With the exception of a small number of koalas in zoos around the world, the koala is found only in Australia.

Despite the popularity of the animal, scientists say much of the biology of the koala remains unknown. Koalas are primarily nocturnal animals, and spend most of the daylight hours sleeping in eucalyptus trees. The female usually gives birth to only one offspring during the annual breeding season, and the premature baby is nurtured in the mother's pouch for six to seven months before it is strong enough to set out on its own.

Koalas mature in about four years and live to be about 20 years old.

The relief effort led by the Australia Koala Foundation is seeking to raise money for research on chlamydia as well the preservation of large tracts of land for the koala. Other organizations taking part include the World Wildlife Fund and the Australian Conservation Fund.

Environmentalists have been mainly concentrating their efforts on encouraging local governments and businesses to set aside tracts of land for the koalas. In addition, further research on the eating and living habits of the koala is now under way.

"The east coast is some of the country's most beautiful territory," Ms. Tabart said. "Although people want to be there, there has been no provision made for the koalas. The trees that are being cut down are their homes and their kitchens."

While millions of koalas once populated nearly the entire Australian continent, settlers in the 19th century began killing them for their skins and by the late 1920's the animals had vanished from the wilds of South Australia.

calyptus trees, also known as gum trees, to make room for farmland, new homes and tourist development along Australia's east coast, has radically reduced the available food supply and habitable territory for koalas.

mon.
4/27

Alan - Envtl Studies Conf. 63300
Global Warming - effects on species
→ Rob Peters WWF
293-4800
*did an overview
effect on treelines
what habitats threatened.

uncertainty of feedback models →
how much warming to be expected

called 11/27 left msg.

Rob Peters:

Lynn Corn

~~Red + other~~

Oaks - hybridize & quickly
- endangered as "species"
= p. ambiguous here.

~~Hinckley~~ Oak - ~~Texas~~ - threatened.

[Adela Backiel x77263 -
ovipelis effectors plants]

Maple trees + beech trees

plankton UVB

antarctic winter - little light there ice →
algae begins on bottom of ice
as pack ice melts + release of
org. matl. into ocean
Spring → bloom (krill = shrimp)

all feeding on this fine layer cycles on this

if UV-B affects microorgs → disrupted
whole entire ecosystem

Orcas of blue whales depleted → they feed on krill.

Antarctica → 1991 Treaty up for amend.

Cards – list articles that appeared in journals

→ Selected Works

745.4880

Dan → Brody / Special Endangerment

Tim Pierce animals endangered due to human D:

Interaction of NEPA + Endangered Species

Forest Service Project (?) → Appalachian Project 13 mill acres fed funded. WVa + Va.

Role of FIFRA + End. Species
use a pesticide when → must survey F+WS.

less than 1 yr. to put it together (team of 6 or 7 people)

Task is divided to put together NEPA Stmt. Impact on species plants + animals.

fairly good timing

→ aerial spray →

Goal:
① slow/halt spread of gypsy moth
Us. 10-15 mi/yr.
② reduce adverse impacts

National Heritage Program — Have land-grant college.
go to F+W
Program to catalog all flora + fauna

Great Smokies:

in Ga — air toxics list admitted by Forest Service!
acid deposition → released to 80% descrip.
** flowering dogwood ** due to anthracnose disease attacks → sycamores, maples & flowers
** acid rain triggers the disease. **

** National Arboretum **

Frazier furs going in Smokies.
Smog, acid rain

Bald Eagle
thin shells due to DDT
Brown pelican

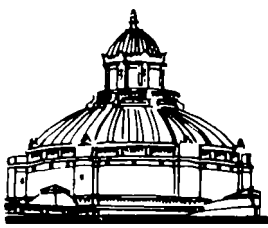
AIS

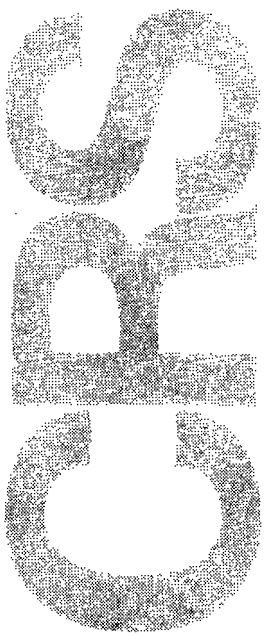
87-496 ENR

CRS REPORT FOR CONGRESS

OZONE AND PLANTS: A STATUS REPORT

Jeffrey A. Zinn, Specialist
Adela Backiel, Analyst
John Blodgett, Senior Analyst
Naomi Rush, Graduate Student Volunteer
Environment and Natural Resources Policy Division





CONGRESSIONAL RESEARCH SERVICE
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January 2, 1987

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ABSTRACT

Air quality research and control have traditionally focused on populated areas and health effects; recent concern about acid precipitation has motivated examination of ecosystem effects of air pollution. Despite nearly exclusive public focus on "acid rain," forest and ecosystem scientists are increasingly sounding alarm about the role played by ozone in forest decline. There is evidence that ozone damages some agricultural crops and trees, though its effects vary widely, by species and location. Economic assessments of this problem are inconclusive. Finally, ozone and acid rain both share nitrogen oxides (NOx) as a common precursor, and NOx pollution also plays a vital role in the breakdown of ozone. Controlling ambient ozone (circulating in the air now in many parts of the country at levels in excess of Federal standards), would appear to require reducing emissions of vapors from such sources as gasoline and solvents.

TABLE OF CONTENTS

ABBREVIATIONS

The following abbreviations are used in the text. These terms are listed in the order in which they appear:

CAA - Clean Air Act
NAAQS- National Ambient Air Quality Standard
NO_x - Nitrogen Oxides (Nitrogen Dioxide and Nitric Oxide mainly)
NO_2 - Nitrogen Dioxide
NO - Nitric Oxide
O - Oxygen
VOC - Volatile Organic Hydrocarbons
EPA - U.S. Environmental Protection Agency
NOAA - National Oceanic and Atmospheric Administration
TAPPI- Technical Association of the Pulp and Paper Industry
EPRI - Electric Power Research Institute
NPS - National Park Service
FRP - National Forest Response and Research Program
NAPAP- National Acid Precipitation Assessment Program
NCLAN- National Crop Loss Assessment Network
TVA - Tennessee Valley Authority
FS - Forest Service
NCASI- National Council of the Paper Industry for Air and Stream Improvement
NSF - National Science Foundation
RITS - Radiatively Important Trace Species
DOE - Department of Energy
ROPIS- Response of Plants to Interacting Stresses
CARB - California Air Resources Board
JAPCA- Journal of the Air Pollution Control Association
SIP - State Implementation Plan

OZONE AND PLANTS: A STATUS REPORT[1]

INTRODUCTION

Tropospheric ozone (O_3)--in the atmosphere and near the earth's surface--is a colorless gas that is one of the ingredients of photochemical smog.[2] Ozone occurs in relatively high concentrations in many cities, most notably Los Angeles. Ozone's damaging properties were first identified during the late 1940's and early 1950's when it was linked to the destructive cracking of rubber.[3] Subsequent investigations have shown ozone to be detrimental to human health if present in sufficient concentrations. It is also the only airborne chemical demonstrated to cause regionwide damage to vegetation.[4]

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[1]This report was researched and the initial draft was co-authored by Naomi Rush, an intern with CRS from the Yale University Graduate School of Forestry, under the supervision of the authors.

[2]Ozone also occurs in the stratosphere far above the earth. Recently, much attention in the scientific literature and the public press has focused on possible changes in stratospheric ozone, possibly as a result of human activities. Though cause for concern, stratospheric ozone is not a subject addressed in this report.

[3]Bradley, C.E. and A.S. Haagen-Smit. The Application of Rubber in the Quantitative Determination of Ozone. Rubber Chemical Technology, v. 24, 1951. p. 750-775.

[4]Ellis Cowling, North Carolina State University, Raleigh, N.C. pers. comm.; Izaac Walton League of America, Effects of Air Pollution on Farm Commodities. Proceedings of a symposium, Hyatt Regency Hotel, Washington, D.C. 1982; U.S. Environmental Protection Agency (EPA). Air Quality Criteria for Ozone and Other Photochemical Oxidants. Research Triangle Park, N.C. v. III, 1986. Pub. no. EPA-600/8--84-020cf.

Ozone is regulated as a "criteria" air pollutant under the Clean Air Act (CAA) (P.L. 91-604, sections 108 and 109). The primary National Ambient Air Quality Standard (NAAQS), which is to protect health, is currently set at 0.12 parts per million (ppm) (0.12 ppm not to be exceeded on more than one day per year in each specified area). The secondary NAAQS, which is to protect non-health values, including vegetation, is also 0.12 ppm; however, this level may be too high to protect all kinds of vegetation.[5,6] In addition to evidence that ozone can damage agricultural crops, some evidence has led many scientists to believe that ozone, which can be transported considerable distances, may be a more important factor in forest decline than acid rain.[7] The views of these scientists concern some policymakers interested in the health of the Nation's forests and in the productivity of croplands. Further, since some acid rain control strategies currently under consideration propose to reduce nitrogen oxides (NO_x), which act both as precursors to ozone and as agents breaking it down, the chemistry of ozone formation and destruction needs to be examined.

This report explores the current understanding of ozone formation and transport, reviews some of the scientific research about ozone damage to crops and forests, and points out policy questions raised by the evidence.

---

[5]At least one State, California, has set a lower standard of 0.10 ppm, but that same State is often out of compliance with the federal regulation. (Sylvia Champomier, California Air Resources Board (CARB), Sacramento, CA. pers. comm. June, 1986).

[6]U.S. EPA, as mandated under the Clean Air Act, has recently completed its criteria document on ozone, and is currently reviewing the primary and secondary NAAQS. It will revise them or reaffirm them as necessary.

[7]U.S. Congress. House. Committee on Agriculture. Subcommittee on Forest, Family Farms, and Energy. Review of the Effects of Acid Deposition and Other Air Pollutants on Forest Productivity. Hearings, 99th Congress, 2nd session. unpub. Hearings held May 13, 1986.

Included are discussions of what we know about the occurrence of ozone in ambient air and ozone-plant interactions and current levels of funding and manpower for various scientific research programs.

WHAT IS OZONE?

Ozone is a molecule of three oxygen atoms. Most ground-level ozone is produced when sunlight energizes emissions from the burning of fossil fuels, breaking down nitrogen dioxide (NO_2) to nitric oxide (NO) and oxygen (O). (The breakdown of NO_2 is by means of photolysis (chemical decomposition caused by radient energy); the atmospheric oxidation of volatile organic compounds and of NO is called photochemical oxidation, the source of the term "photochemical smog.") The ingredients, or precursors, to photochemical oxidant formation are NOx and reactive (non-methane) volatile organic compounds (VOCs).[8]

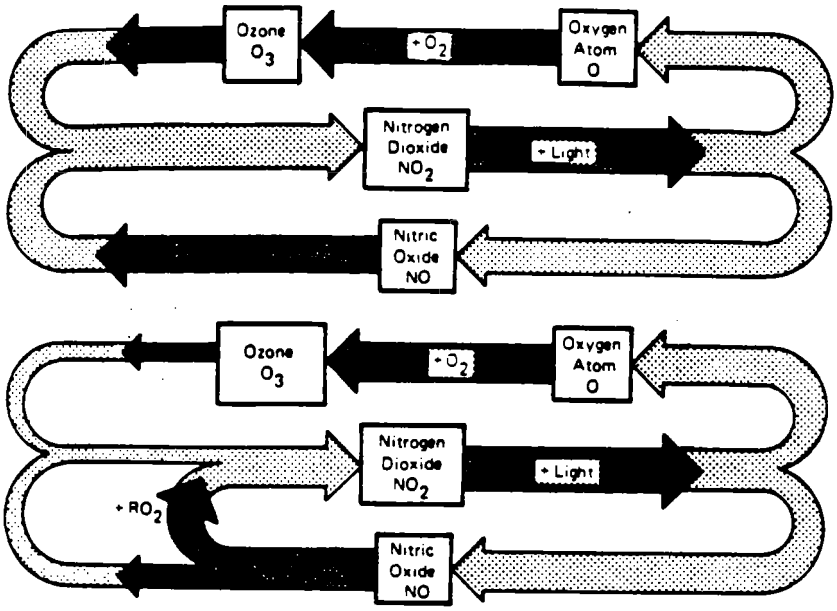
Figure 1 shows the cycle of reactions by which NOx is stripped of an oxygen molecule, which NO generally retrieves later in the day (degrading the ozone). The relationship between the two kinds of gaseous precursors to ozone is important for pollution control purposes because the amount of ozone produced is not linearly related to the amount of available NO_x and VOCs. While hydrocarbons are not necessary for ozone formation, when available they speed up the process, creating an amount of ozone that is in excess of the NO available to degrade the ozone.[9] Notice that the ozone box in the lower cycle is larger, because there is less available NO to degrade it.

---

[8]National Research Council. Committee on Medical and Biologic Effects of Environmental Pollutants. Ozone and Other Photochemical Oxidants. Washington, D.C.: National Academy of Sciences, 1977. p. 13-44; for more recent information on ozone formation and destruction, see U.S. EPA. Air Quality Criteria for Ozone. op. cit.

[9]Bob Lamb, Meteorologist, Environmental Protection Agency (EPA), Research Triangle Park, N.C. pers. comm., June 1986.

Figure 1.--The Ozone Cycle



The No-No_2-O_3 cycle in air contaminated with NO_x only (above) and with NO_x and hydrocarbons (below). Above, the dissociation of nitrogen dioxide by sunlight forms equal numbers of nitric oxide molecules and oxygen atoms. The latter are rapidly converted to ozone molecules. The ozone then reacts with the nitric oxide, again on a 1:1 basis, to reform nitrogen dioxide. Only a small steady-state concentration of ozone results from this cycle. Below, when hydrocarbons, aldehydes, or other reactive contaminants are present, they can form peroxy radicals that oxidize the nitric oxide, pumping it directly to nitrogen dioxide. This leaves very little of the nitric oxide to react with the ozone, so the ozone builds up to large concentrations.

Source: National Research Council. Committee on Medical and Biologic Effects of Environmental Pollutants. 1977. Ozone and Other Photochemical Oxidants. Washington, D.C. National Academy of Sciences, p. 19.

Relative proportions of NO_x and VOCs vary in urban and rural areas, making cities centers for both ozone formation and destruction. Ozone transported out into the countryside can persist, in relatively high concentrations because of the lack of NO there to react with it.

Most ozone measurements are taken in cities to see whether the health-based Federal primary standard of 0.12 ppm is being met. Data from the Environmental Protection Agency's (EPA) annual air quality reports suggest that both average levels and the number of times that ambient ozone exceeds regulatory limits are declining in most areas of the country, although the country as a whole, on average, is not meeting the standard. High peak levels continue to be registered in Southern California, the Texas Gulf, the Northeast Corridor and other heavily populated regions.[10] Readings as high as 0.28 ppm have been reported by the National Park Service (NPS) in the Santa Monica Mountains which lie in the Los Angeles basin; and even in remote Acadia National Park in Maine, levels of ozone at or above the standard have reportedly occurred for the past several years.[11] Many areas are likely not to be in compliance with the Federal standard when an EPA-extended December 31, 1987 deadline arrives.[12]

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[10]U.S. EPA. National Air Quality and Emissions Trends Report, 1984. p. 1-15.

[11]Napier, Shelton, ed. Pollution in Parks. Park Science. v. 6, n. 4. June, 1986. This special 24 page insert gives a good overview of the research activities of the National Park Service Air Quality Division.

[12]Ray Vogel, Coordinator, EPA Ozone Task Force, pers. comm. July, 1986.

OZONE PRECURSORS

This section examines the amounts and sources of the air pollutant precursors to ozone NO_x and VOCs. Most NO_x emissions come from high-temperature combustion of fossil fuels, in which the heating causes N_2 and O_2 to react. The largest sources of NO_x are shown in table 1.

Controls for NO_x already in place include more efficient equipment and precise adjustments of flames and air flows on equipment at stationary sources. Emissions of NO_x from mobile sources have been reduced because of catalytic converters, engine design modifications, and the use of lighter construction materials, all resulting in greater fuel efficiency. Nevertheless, NO_x emissions increased approximately 13 percent between 1970 and 1980

Table 1.--National Estimates of Emissions of Nitrogen Oxides, 1970 and 1983

Source Category	Weight of Emissions (in million metric tons/yr)	
	1970	1983
Transportation	7.6	8.8
Stationary Source Fuel Combustion	9.1	9.7
Industrial Processes	0.7	0.6
Solid Waste Disposal	0.4	0.1
Miscellaneous	0.3	0.2
Total	18.1	19.4

Source: EPA, 1984. National Air Pollution Emissions Trends Estimates, 1940-1983. Research Triangle Park, N.C.

because of increased amounts of fuel combustion in stationary sources, such as power plants, and because of increased vehicle use.[13,14] Regional differences in the total vehicle miles traveled and in the pattern of travel (stop and go driving versus driving at a constant speed, for example) can have dramatic conseqences for local air quality. Thus NO_x emissions in Los Angeles County, California increased sixfold from 1940 to 1970 compared to a threefold national increase; and in 1984, Los Angeles was the only area in the country to exceed ambient NOx standards.[15,16]

The other precursor of concern, volatile organic compounds (VOCs), are compounds that remain in the atmosphere long enough to participate in photochemical reactions. Anthropogenic VOCs--byproducts of human activity--vaporize from many products including gasoline and solvents.[17] Although VOC reduction is important to ozone control, the strategy of reducing ozone through reductions in VOC emissions is complicated by the diverse sources that emit relatively small amounts, as well as uncertainties about the roles of VOCs versus NO_x in ozone formation. Sources of anthropogenic VOC emissions are listed in table 2.

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[13]Council on Environmental Quality (CEQ). The Fourteenth Annual Report of the Council on Environmental Quality. Washington, 1981. p. 28.

[14]U.S. EPA. Air Quality Criteria for Ozone. op. cit. Vol. II, Table 3-9, p. 3-93.

[15]Ibid., p. 3-93.

[16]U.S. EPA. National Air Quality and Emissions Trends Report, 1984. p. 1-13.

[17]Volatile organic compounds, including hydrocarbons, are also natural products, but natural sources are not considered to be serious pollution problems because 70% of naturally emitted VOC is non-reactive methane, natural hydrocarbon emissions are evenly distributed over the globe, and some natural hydrocarbons react with ozone rather than producing ozone. See, for example, Altshuller, A.P. Review: natural volatile organic substances and their effect on air quality in the United States. Atmospheric Environment. vol. 17, 1983. p. 2131-2165.

Table 2.--National Estimates of Emissions of VOCs, 1970 and 1983

Source Category	Weight of Emissions (in million metric tons/yr)	
	1970	1983
Transportation	12.3	7.2
Stationary Source Fuel Combustion	0.9	2.1
Industrial Processes	8.7	7.5
Solid Waste Disposal	1.8	0.6
Miscellaneous	3.3	2.5
Total	27.0	19.9

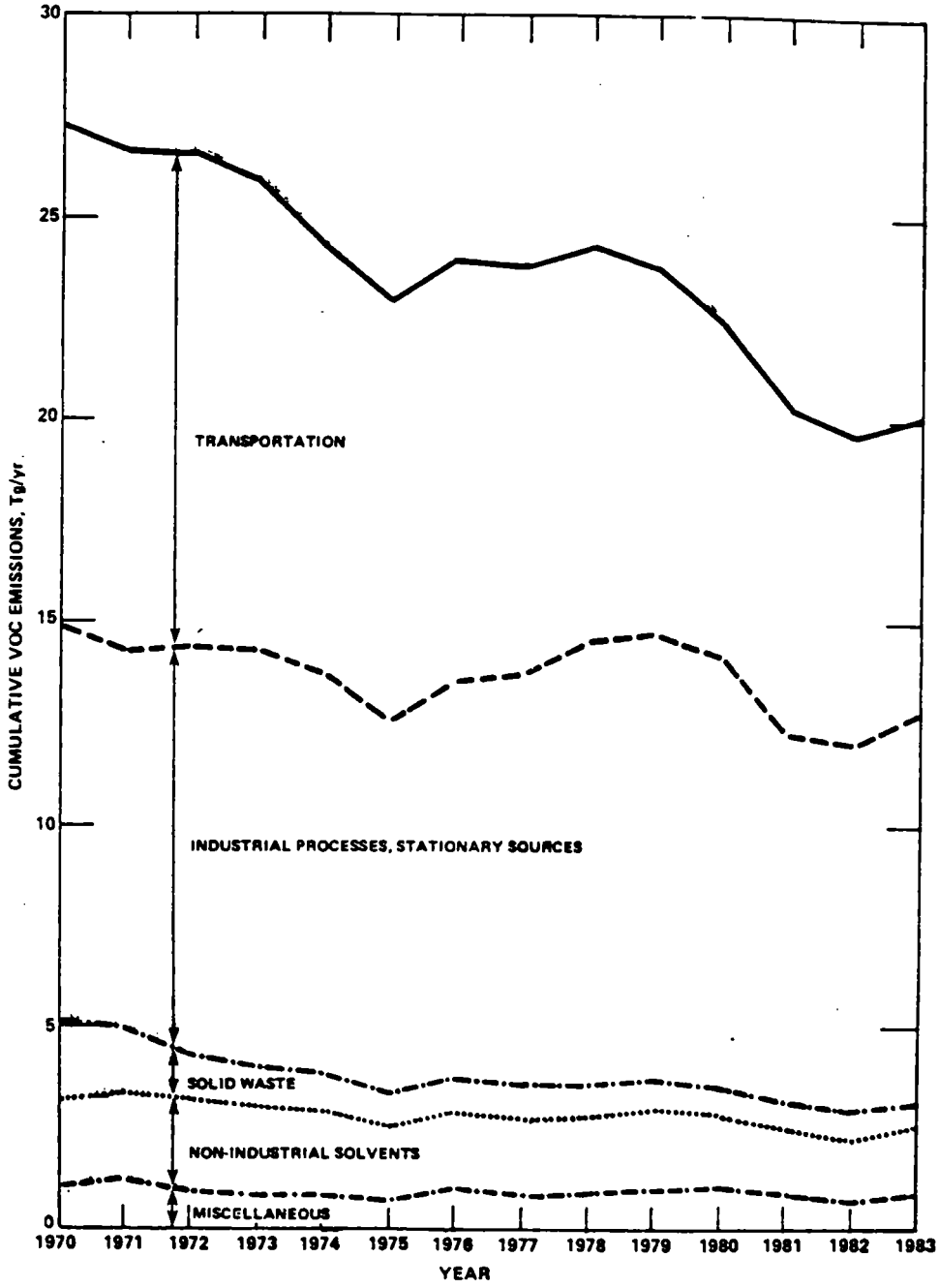
Source: EPA, 1984. National Air Pollution Emissions Trends Estimates, 1940-1983. Research Triangle Park, N.C.

The "gasoline cycle", which includes petroleum production and storage, gasoline distribution and marketing, and motor vehicle fueling and use, accounts for 50 percent or more of total VOC emissions.[18] Important stationary sources of VOC emissions include chemical plants; painting, printing and dry cleaning operations; and facilities releasing "fugitive emissions," such as waste dumps and waste water treatment plants.

National trends in NO_x and VOC emissions are shown in figures 2, 3 and 4. These trends indicate that despite the imposition of technically effective controls of VOCs, declines have been gradual, partly due to concurrent increases in vehicle use and power consumption.

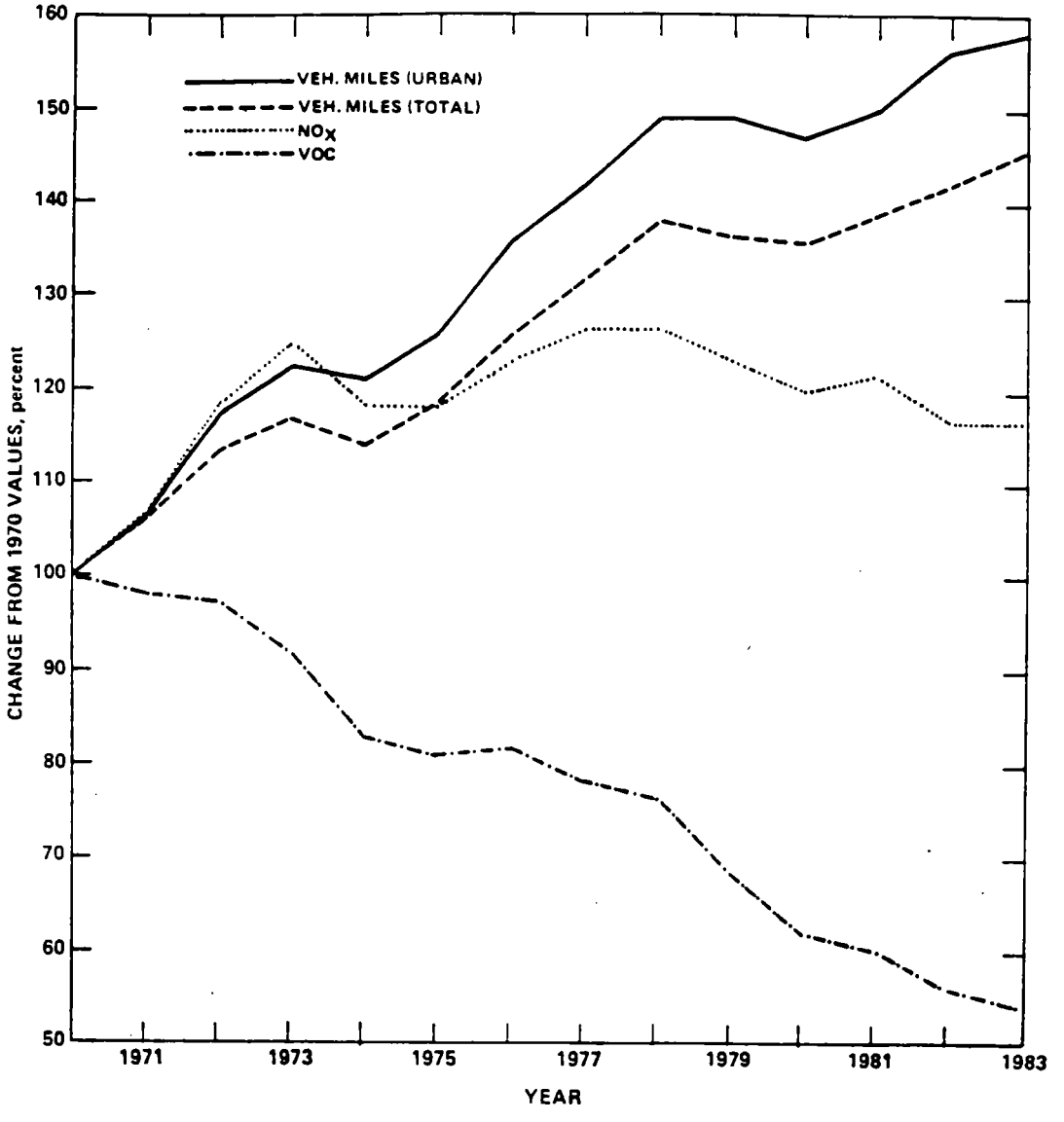
[18]Organization for Economic Corporation and Development. Photochemical Smog; Contribution of VOCs. 1982. p. 10.

Figure 2.--National Trend in Estimated Emissions of Volatile Organic Compounds, 1970 through 1983



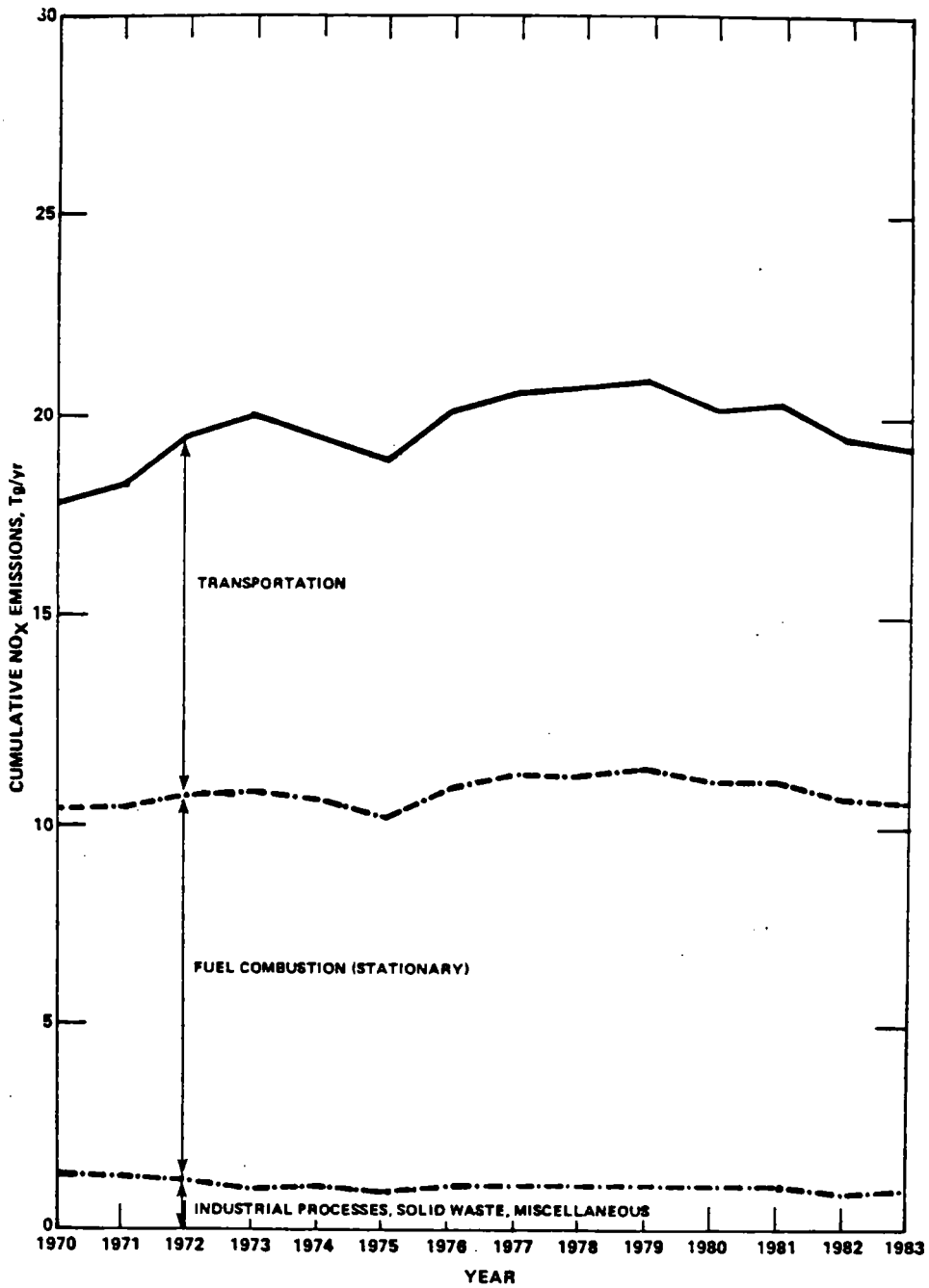
Source: U.S. EPA. Air Quality Criteria for Ozone and Other Photochemical Oxidants. 1986. Vol. II, p. 3-91.

Figure 3.--Comparative Trends in Highway Vehicle Emissions of Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOC) Versus Vehicle Miles Traveled, 1970-1983



Source: U.S. EPA. Air Quality Criteria for Ozone and Other Photochemical Oxidants. 1986. Vol. II, p. 3-92.

Figure 4.--National Trend in Estimated Emissions of Nitrogen Oxides, 1970 and 1983



Source: U.S. EPA. Air Quality Criteria for Ozone and Other Photochemical Oxidants. 1986. Vol. II, p. 3-94.

OZONE CONCENTRATIONS

Ozone is more complicated to control than some other air pollutants because its formation is affected by amounts of sunlight and other variable factors. Levels change daily and with the hour of the day, in response to the availability of precursors and weather conditions.[19] Ozone in urban areas shows fairly predictable diurnal fluxes, reaching its highest concentrations during sunny days several hours after morning rush-hour traffic.

High ozone concentrations are considered to have a "season," the length of which varies from place to place, and ozone monitors are operated 4 to 12 months of the year, depending upon geographic location and climate. Concentrations are generally highest during the sunniest times of the year (a function of solar radiation rather than temperature per se). While NO_x emissions per vehicle mile decrease as ambient temperatures increase, the number of vehicle miles travelled increases in the summer. Further, fossil fuel power plants produce an estimated 15 percent more NO_x in the summer than in the spring.[20] And although summer gasoline is engineered to be less volatile than winter gasoline, cars are filled with summer gasoline at warmer temperatures which increases the amount of VOC evaporation.[21]

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[19]U.S. EPA. Air Quality Criteria for Ozone. Op. cit. Vol. II, p. 5-2 and 5-3.

[20]Ibid., p. 5-3, p. 5-42 through 5-48, and p. 3-98.

[21]Fuller, H.B. Air Pollution Control Association Specialty Conference on Ozone/Oxidants--Interaction with the Total Environment. Proceedings. Dallas, Texas, March 10-12, 1976.

Local and regional variation in ozone levels is also significant. The highest peak (1-hour) measurements of ozone occur in cities but hourly readings in excess of 0.12 ppm (one value of 0.157 ppm was recorded in a 140-hour episode in 1977) have been measured at a remote station on Whiteface Mountain in upstate New York, at Shenandoah National Park, and at Mt. Mitchell in North Carolina.[22] In fact, average concentrations of ozone at upper altitudes in America and West Germany are reported to be higher than those at lower elevations.[23] In the U.S., increases in average concentrations of O_3 with increasing elevation have been reported for at least one area in the far West and one in the Northeast. In the San Bernardino Mountains in California, where O_3 damage to forests has been most thoroughly documented the best, higher average O_3 concentrations were observed at about 2,700 feet than at either 1,460 feet or about 4,000 feet, respectively.[24] A study in northwestern New Jersey showed that the 24-hour O_3 concentration was higher at 1,650 feet than at either 990 feet or 460 feet.[25] Concentrations in rural mountain areas can be high relative to urban areas at night, because

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[22]Dr. Paul Altshuller, Senior Science Advisor and Dr. Ronald Bradow, Physical Scientist, Atmosphperic Sciences Research Laboratory, U.S. EPA. Research Triangle, N.C. pers. comm., January, 1986.

[23]This is interesting since much of the known incidence of forest decline occurs at upper elevations. But stresses other than ozone pollution also increase in upper elevations, such as soil moisture stress, cloud acidity, wind and cold stress, etc. Ashmore M.R. et al, Forest Damage in West Germany and the Role of Ozone. Imperial College at Silwood Park, Ascot, Berkshire, SL5 7PY.

[24]Miller, P.R. , M.H. McCutchan, and B.C. Ryan. Influence of climate and topography on oxidant air pollution concentrations that damage conifer forests in southern California. Mitt. Forst. Bundesversuchsanst. Wien N. 97, 1972. p. 585-607.

[25]Wolff, G.T.; P.J. Lioy; R.S. Taylor. The Diurnal Variations in the Eastern United States. Journal of the Air Pollution Control Association. In press.

night-time ozone levels in cities drop down to near zero through the reaction of nitric oxide with ozone in urban places.[26]

The difficulties in controlling ozone are reflected in EPA's efforts to review and revise, as needed, a primary and secondary ambient air quality standard for ozone as mandated by the Clean Air Act.[27] The recently-completed EPA criteria document describes the scientific basis for a secondary ozone standard, and the agency is reviewing the data on agricultural crop damage and forest ecosystem damage as part of its considerations on the secondary standard. Although the first evidence of damage to plants dates back as far as 1944 in the Los Angeles basin, setting a standard is still difficult because current information about the severity and mechanism(s) of effects on vegetation is still inconclusive.

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[26]Bob Lamb, EPA Meteorologist, and Ray Vogel, EPA Ozone Task Force, pers. comm., June and July, 1986. (See also U.S. EPA. Air Quality Criteria for Ozone, op. cit., Vol. II. p. 5-49 and 5-50, and p. 5-15 through 5-25.)

[27]The Clean Air Act includes a provision for setting secondary standards (Section 109) to protect welfare, which includes air pollution "effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well being.

OZONE IN RURAL AREAS

Little is known about patterns of ozone distribution in rural areas because most air pollution research has been located in cities. Monitoring stations are located in populous areas because the primary standard is based on public health considerations, the gaseous precursors to ozone formation are predominantly emitted by man-made sources concentrated in urban areas, the maintenance of monitoring stations for purposes other than primary standard compliance is of low priority, and such stations are expensive to set up and maintain. To understand how ozone may be affecting crops and forests, however, one must know something more about ozone levels in rural areas. Given its various sources and the extent of ozone transport, ozone monitors in place can establish important baseline information.

The available evidence suggests that ozone does exist at fairly high levels in remote areas. To find out why, scientists at the National Oceanic and Atmospheric Administration (NOAA) are now studying ozone levels at upper elevation Colorado sites where VOCs are almost absent and where only the NOx precursors are found in significant amounts. Later these findings will be compared with measurements from rural locations in the Eastern United States.[28] Findings from these studies about the relative contributions of NO_x and VOCs may be critical for developing successful ozone control strategies.

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[28]Dan Albritten, Director, NOAA Aerometry Lab, pers. comm. July, 1986. NMHC measurements for 10 cities taken between 6 and 9 AM to get a sense of "background" levels showed that NMHC/NO_x ratios ranged from 5 to 16. U.S. EPA. External Review Draft of the Ozone Criteria Document. 1984. p. 3-102.

Some baseline information is already available. A recent investigation supported by the paper industry aggregated 1983 monitoring information about ozone levels for 12 States in the commercially important southern pine growing region. It concluded that:

> ...there can be considerable variability in O_3 concentrations measured at sites considered to be rural... even at sites located in the same geographic area. Seven hour means[29] for the hours [9 am to 4 pm] for the... growing season ranged from 0.032 to 0.058 ppm, the number of hours with concentrations of 0.07 ppm or greater varied from 20 to 965, the number of hours with concentrations of 0.10 ppm or greater[30] ranged from 0 to 52, and the maximum concentrations from 0.085 to 0.143. However, hourly average values of 0.12 or larger were recorded at [only 7 of 28 rural monitoring stations].[31]

A possible explanation for these and other unexpectedly high rural readings is that ozone can be taken up into the higher air layers by cool nighttime inversions, traveling up to hundreds of miles from its urban origins before daybreak, far from the presence of sources of NO that can scavenge ozone.[32] This ability to be transported in so-called "layers aloft" may also explain the high ozone readings at upper elevations noted above, as well as the very high ozone levels characteristic of places downwind from cities. Southern Connecticut, for example, receives overlapping plumes of

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[29]This is one way the secondary standard may be measured, since many of the recent experiments on agricultural crops used 7-hour-average O_3 concentration statistics in developing descriptive exposure-response models.

[30]The World Health Organization (European Division) recommends that a country's standard lie between 0.05 and 0.1 ppm. (These recommendations are, however, based on different assumptions and different rationales than those currently used in the United States.)

[31]Pinkerton, John and Allen LeFohn. Characterization of Ambient Ozone Concentrations in the Commercial Timberlands Using Available Monitoring Data. Technical Association of the Pulp and Paper Industry Journal. 1986, v. 69, n. 4. p. 58-63.

[32]Bob Lamb, EPA Meteorologist. pers. comm., June, 1986.

ozone traced from Washington, D.C., Baltimore, Philadelphia and New York, arriving up to a day later.[33]

Theories about the regional transport of ozone are being built into a mathematical computer model at EPA.[34] If the model turns out to be predictive (a discovery which will depend in part on adequate information from rural monitoring stations with which to validate the model) then scientists will have a new way to forecast ozone levels in rural areas.

Rural ozone monitoring is increasing. Stations are being established by research programs at the Electric Power Research Institute (EPRI), the National Park Service (NPS) the National Precipitation Assessment Program (NAPAP) and others. NOAA is also negotiating to establish approximately 20 rural ozone monitoring stations in other countries.[35]

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[33]Spicer, Chester et.al. Ozone Sources and Transport in the Northeastern United States. Environmental Science and Technology. 1979, v. 13, n. 8.

[34]Bob Lamb, EPA Meteorologist, pers. comm., June, 1986.

[35]Dan Albritten, Director, NOAA Aerometry Lab., pers. comm. July, 1986.

VEGETATIVE EFFECTS OF OZONE

During the 1950s and 1960s, foliage (leaf) injuries by ozone were observed in many crops, and in both deciduous and evergreen trees. While these injuries have not affected overall regional productivity, certain species in some areas have shown symptoms of ozone-induced injury. For example, Eastern White Pine has been shown to be sensitive to ozone injury in large parts of its natural range (much of the Blue Ridge mountain range and other parts of the East), and several species of conifers and certain hardwoods in the San Bernardino National Forest in California are known to suffer ozone injury (see figure 5).[36] Some foresters believe that these studies are evidence linking air pollution to forest decline.[37] Sophisticated research by both forest pathologists and crop scientists has begun to indicate that ozone, which has been shown to injure some plants in controlled experimental settings, may have even more significant effects in natural settings as it interacts with other stresses. For

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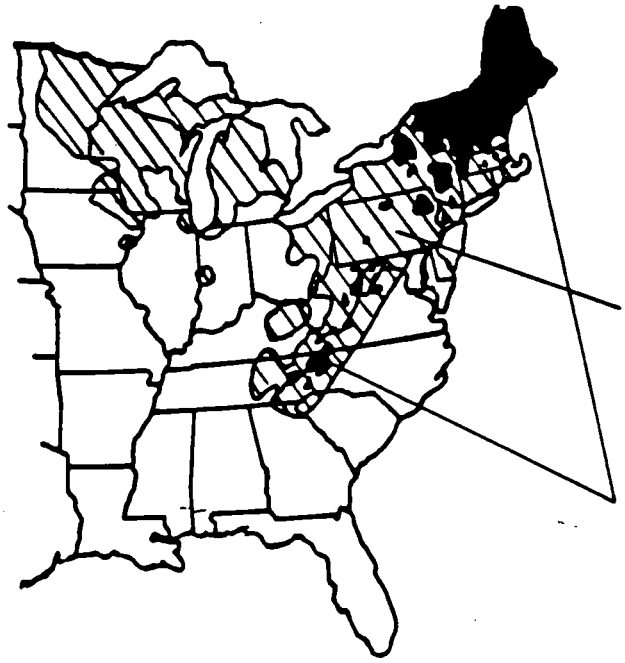
[36]Backiel, Adela and Alison L. Holt. Air Pollutant-Induced Stress to Forest Ecosystems--An Overview of Forest Damage. Washington, Congressional Research Service. 1986. 38 p. 86-560 ENR.

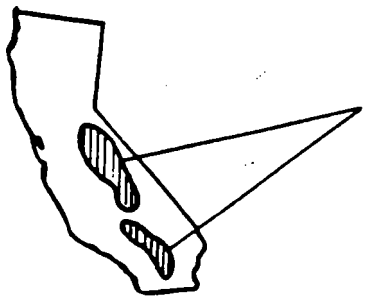
[37]U.S. Congress. House. Committee on Agriculture. Subcommittee on Forest, Family Farms,and Energy. Review of the Effects of Acid Deposition and Other Air Pollutants on Forest Productivity. Hearings, 99th Congress, 2nd session. Unpub. Hearings held May 13, 1986. Testimony of Ellis Cowling, North Carolina State University, Raleigh, N.C.

Figure 5.--Selected Areas of Suspected Air Pollution Damage to Selected U.S. Forests



Scattered growth declines, foliar damage, and mortality of eastern white pines have been clearly linked with ozone and other photochemical oxidants. Ozone concentrations are relatively high throughout the range of the species.

Coincident with a portion of the range of eastern white pine, the decline of red spruce in the Appalachian Mountains of the Eastern U.S. has been linked to air pollution by circumstantial evidence.



Damage of Jeffrey pine, white fir, ponderosa pine, and California Black oak in the San Bernardino, San Gabriel and Sierra Nevada Mountains of California has been definitively linked to damage from ozone and other photochemical oxidants. Some moderate to severe damage has been reported on the southern slopes of the western part of the San Gabriels, and in the western San Bernardinos, but damage is generally light, or nonexistent, in most parts of these mountain ranges.

Source: Adela Backiel and Francis Hunt. Acid Rain and Forests: An Attempt to Clear the Air. American Forests. February, 1986, p. 42.

example, there is evidence that ozone makes plants more sensitive to pathogens and insect attack.[38]

Symptoms

When ozone levels are raised frequently during the growing season, plant growth may be stunted.[39] Plant symptoms of ozone exposure are seen in discolored leaves in which cell injury has or may have interfered with basic biochemical processes like photosynthesis, by which plants transform the sun's energy into usable forms.

More specifically, the symptoms of foliar injury from ozone include: pigmented spots and angular shapes spread in some cases from vein to vein; blotchy bleaching of parts of leaves when cells inside collapse; white or orange-red discoloration of leaves; and chlorosis (yellow stippling or mottling) in some cases leading to early death in older leaves and needles. Particularly vulnerable areas include tips of young leaves and the centers of older leaves and near the base of the oldest leaves; veins are relatively resistant to ozone damage.

In addition to visible effects, ozone can cause physiological and biochemical changes which are not visible to the naked eye. Declines in crop yield, for example, are sometimes, but not always, associated with foliar damage.[40]

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[38]Walter Heck, U.S. Department of Agriculture, Agriculture Research Service,(USDA/ARS) and Professor of Botany, North Carolina State University, pers. comm., June, 1986. (See also, for example, C.R. Hibben. The Distinction Between Injury to Tree Leaves by Ozone and Mesophyl Feeding Leafhoppers. Forest Science. 1969, v. 15, p. 154-157; and U.S. EPA. Air Quality Criteria for Ozone, op. cit., v. II, p. 6-32 through 6-67.

[39]Jacobson, Jay and A. Clyde Hill. Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Pittsburgh: Air Pollution Control Association. 1970. p. B2.

[40]Tingey, David. The Impact of Ozone on Agriculture and its Consequences. Proceedings, International Acidification and Its Policy Implications. Conference in Amsterdam, the Netherlands, May 5, 1986. Unpublished draft.

Exposure conditions can alter the effects of ambient pollutant levels. For example, cereal crops and grasses are often injured along the portion of the stalk where the leaf bends, and one tobacco leaf may protect another lying in its shadow.[41] In general, very severe visual symptoms are usual before substantial declines in yield occur in row crops. But for several tree species, including southern pines and red spruce, growth may be inhibited before any visible symptoms appear.

Crops

Beginning in 1980-1981 an ambitious program of crop damage research was initiated to determine what dosage of ozone was needed to produce a measurable change, or response, in crops of national importance. The development of these dose/response functions, and many specific results of research by the National Crop Loss Assessment Network (NCLAN), is documented in a substantial body of published literature.[42]

NCLAN has developed mathematical interpolation techniques to estimate and map rural ozone loads, based on actual levels at as many as 401 stations

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[41]Jacobson, Jay and A. Clyde Hill. 1970. Recognition of Air Pollution Injury to Vegetation. op. cit. p. B2-3.

[42]NCLAN is a coordinated program of field and lab studies to model dose/response functions and to assess economic impacts of agricultural crop responses to air pollutants under realistic field conditions. The Research Management Committee, chaired by Walter Heck and O.Clifton Taylor, directs a team of nearly 20 senior scientists and a statistical consultant. NCLAN research has been performed at the Boyce Thompson Plant Research Institute at Cornell (Northeast region), North Carolina State University (Southeast), Argonne National Lab (Central) and University of California at Riverside (Southwest). In FY 1987, EPA is considering reallocating funds from future crop studies to forest effects research. U.S. Congress. House Agriculture Committee. Subcommittee on Forest, Family Farms and Energy. Hearing. Review of the Effects of Acid Deposition and Other Air Pollutants on Forest Productivity. Hearings held May 13, 1986. Unpublished testimony of Leonard Weinstein; David Tingey, U.S. EPA, Corvallis, OR. pers. comm. June, 1986.

maintained by EPA, EPRI, Tennessee Valley Authority (TVA), and NPS.[43] In experiments, doses replicating ambient ozone patterns during the growing season are applied.[44] Research designs mimic natural pollution fluxes by exposing vegetation in open field plots or in "open-topped chambers"; in the latter, plants are dosed with either clean filtered air or ambient air modified by varying levels of pollutants.[45]

Not all commercially grown plants are equally sensitivity to ozone exposure.[46] The most sensitive crops such as soybeans and citrus are severely injured even at low ambient levels of ozone. At 0.12 ppm (the current standard for ambient ozone), soybean crop production may be reduced by up to 40 percent. But production of other crops does not appear to be diminished by air containing high concentrations of ozone. Corn is resistant, while wheat is more sensitive than corn but less sensitive than soybeans (and other legumes).[47] Figure 6 shows the results of seven crop studies.

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[43]US EPA. National Crop Loss Assessment Network 1984 Annual Report. Draft. 1985. Corvallis, OR. Environmental Research Lab, Office of Research and Development. p.241. Much of this interpolation and mapping work was done by James Reagan, Atmospheric Sciences Research Laboratory, EPA, Research Triangle Park, NC.

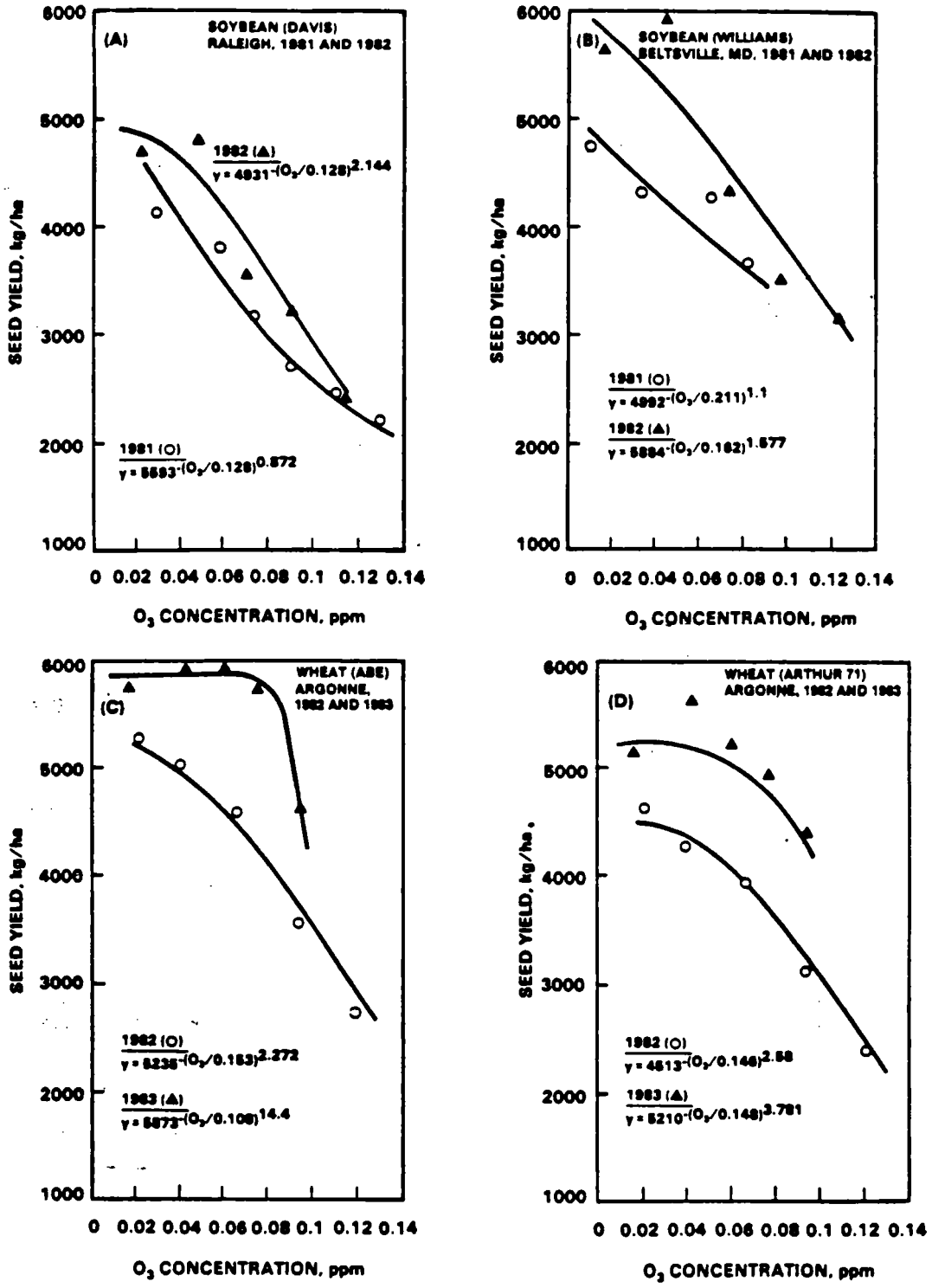
[44]Patricia Irving, NCLAN Senior Scientist. Meeting of the Department of Agriculture Subcommittee on Research and Education, June 19, 1986.

[45]U.S. EPA. Air Quality Criteria for Ozone. op.cit. Vol. III, p. 6-17 through 6-20.

[46]Different species of plants, different varieties or cultivars, or even different individual plants of the same species also show wide variations in ozone sensitivity. Effects of ozone are enhanced with certain light conditions, with increased relative humidity and with decreased soil moisture. Further, the presence of certain pollutants, chemical sprays and biological pests will also contribute to the extent to which plants respond to ozone.

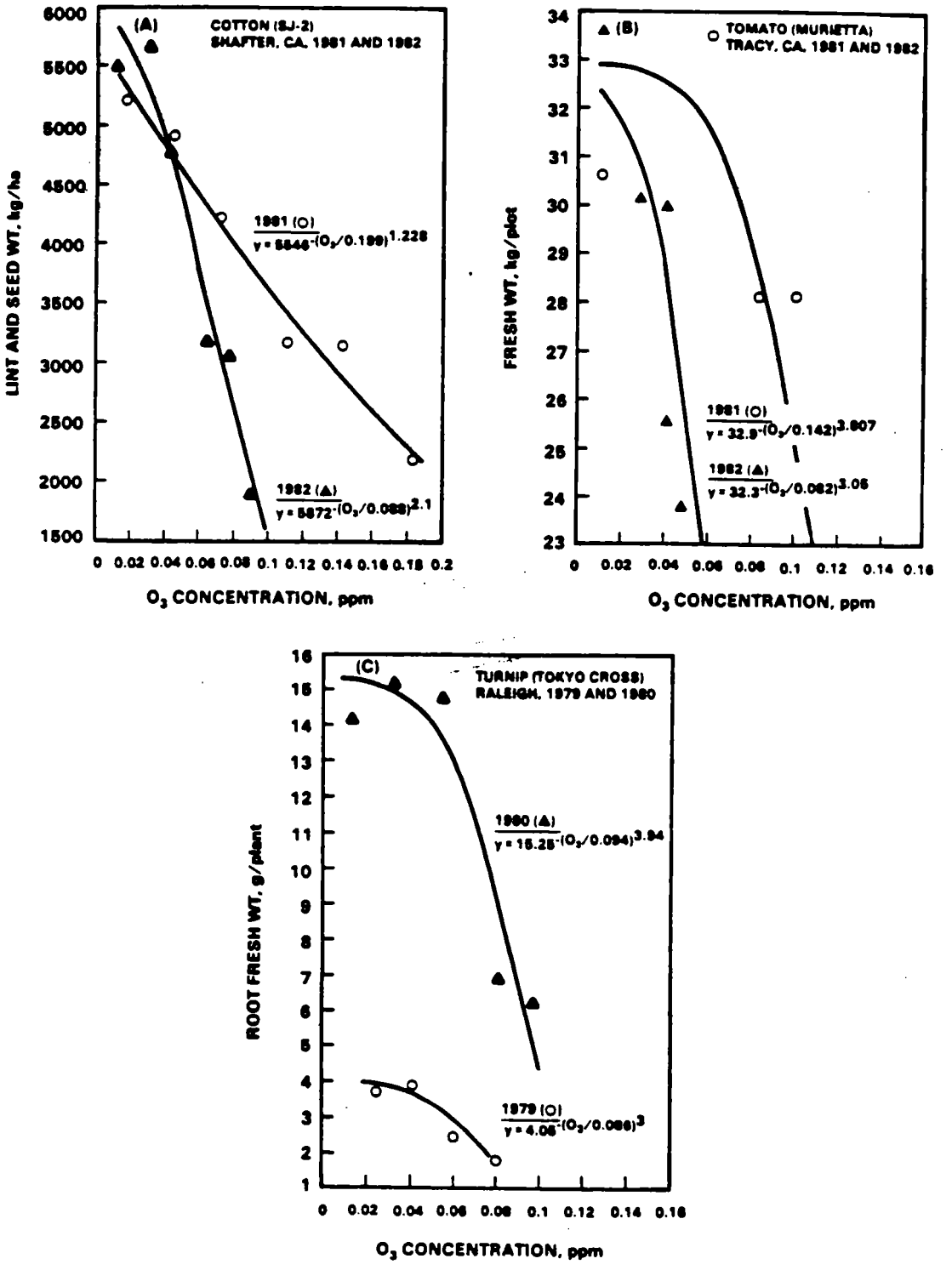
[47]U.S. EPA. Air Quality Criteria for Ozone. op. cit. Vol. III, p. 6-104 through 6-117.

Figure 6.--Effects of Ozone on Yields of Selected Crops



Source: U.S. EPA. Air Quality Criteria for Ozone and Other Photochemical Oxidants. Research Triangle Park, N.C. p. 6-229 and 6-230.

Figure 6 (cont).--Effects of Ozone on Yields of Selected Crops



Source: U.S. EPA. Air Quality Criteria for Ozone and Other Photochemical Oxidants. Research Triangle Park, N.C. p. 6-229 and 6-230.

It also indicates that the effect of ozone varies widely and from site to site, as shown in these charts for soybeans and wheat.

The timing and severity of pollution doses can produce radically different effects. For example, some experiments suggest that plants are most sensitive during reproductive stages, that is, during flowering, seed set and fruit maturation.[48] Other data indicate that plants can recover from several "peak" doses during the course of a season, but that if the peak doses come too often, carbon-dependent cell repair mechanisms cannot keep up and are overwhelmed.[49] The effects of the timing and severity of doses, called "exposure dynamics" are another research priority for NCLAN scientists, and also could have important implications for air pollution control efforts.[50]

Forests

In recent years, various stages of forest decline and tree death have been reported in many European countries. The primary causes of these declines are unknown, but do not appear to be insects or other known forest pathogens or climatic factors like drought. The widely-publicized decline

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[48]Walter Heck, USDA/ARS, North Carolina State University. pers. comm. June, 1986.

[49]See, for example, Effects of Air Pollution on Farm Commodities. Proceedings of a Symposium. Washington D.C. Izaac Walton League of America. 1982. Basic research on cell biochemistry and plant physiology may improve understanding of the mechanisms by which cells, plant and animal alike, are stressed and repair themselves.

[50]Irving, Patricia. Draft Summary Report of the National Acid Precipitation Assessment Program (NAPAP) Crop Response Workshop, Chicago, IL. April, 1986.

problems are increasingly being viewed as possibly resulting from a combination of stresses, including air pollution.[51] Symptoms of decline include increased yellowing and death of foliage, twig and crown dieback, deterioration of roots and their ability to resist infection or absorb nutrients, slowing rates of growth, and changes in forest structure following actual tree death.[52]

Forest decline has been defined by several foresters as a syndrome of deterioration and death of trees that results from several interacting stresses. One theory of forest decline suggests that air pollution can either predispose a tree to decline during extended periods of exposure or can incite decline during short-term attacks. Factors contributing to the ultimate death of trees can also include, among others, insects and pathogens, salt and drought.[53]

One expert who has numbered reported instances of regional forest decline at 21, says that five are most clearly related to air pollution, but that only two of these have been proved to be the result of air pollution stress. In both these instances, Jeffrey and Ponderosa pine in the San

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[51]Schutt, P. and E.B. Cowling. Waldsterbenn, a General Decline of Forests in Central Europe: Symptoms, Development, and Possible Causes. Plant Disease. 1985. v. 69. p. 548-558.

[52]For an overview of recent research on the subject see: McLaughlin, S.B. Effects of Air Pollution on Forests: A Critical Review. Journal of the Air Pollution Control Association. v. 35, May, 1985. p. 512-534; or Air Pollutants Effects on Forest Ecosystems. Proceedings. St. Paul, MN: Acid Rain Foundation. Proceedings. 1985; or Air Pollution and the Productivity of the Forest. proceedings. Washington, D.C.: Izaac Walton League. 1983.

[53]Manion, Paul. Factors contributing to the Decline of Forests, a Conceptual Overview. Air Pollutants Effects on Forest Ecosystems. Proceedings. St Paul, MN: Acid Rain Foundation. 1985. p. 64-74.

Bernardino Mountains of California and of White pine in the eastern, U.S., the pollutant identified as causing the decline was ozone.[54]

Forests are more difficult to study than annual crops, since they do not grow anew each year from seed, and the complex forest ecosystem cannot be controlled by the cultivator to the same degree as the experimental "agro-ecosystem". Influences in the natural forest can include wildlife; weather; and variations in slope, aspect, and altitude, which affect water, light, and nutrient availability. Being large and long lived organisms, the health of trees reflects many seasons of ambient air and other conditions. Forest scientists examine the consistency of the association between a stressing agent, such as ozone, and pathology observed in the forest by designing controlled experiments that test the observed association in greenhouses, and by designing field studies to produce better understanding of the natural ecology of the forest.

The effects of various doses of ozone on seedlings and young saplings can be easily studied in greenhouse settings. Greenhouse studies, however, are likely only to tell part of the story about ozone damage to trees.

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[54]In these cases, a) geographical gradients in damage are correlated with geographical gradients in ozone concentrations [notes]; b) the major symptoms (yellowing and necrosis of foliage, decline in rate of growth, and death of trees) can be reproduced by exposure to ozone, and c) genetic variation in susceptibility and resistance to damage in the field is correlated with genetic variation in susceptibility and resistance to ozone in controlled exposures [note]. Cowling, Ellis. Regional Declines of Forests in Europe and North America: the Possible Role of Airborne Chemicals. Aerosols. [S.D. Lee et. al., eds.] Chelsea, MI, Lewis Publishers, 1986. p. 1334-1343.

Field studies are also necessary to explore how natural factors--varying amounts of light, wind and water exposure reproductive activity, forest structure (the relative prevalence of different species at various life stages)--affect natural and ozone-exposed forests.

One theory about how ozone damages plants is that the presence of ozone increases the loss of magnesium, an essential metal that is part of the chlorophyll molecules, which are essential for photosynthesis. Chlorotic needles of trees damaged by ozone are often deficient in magnesium. Leaves stressed by acid rain can also lose magnesium.[55] These nutrient-deficient leaves then are more susceptible to natural stresses such as drought, frost and insect damage.

Another theory is that ozone enters the cell and initiates biochemical and physiological responses. Critical effects, including reduction in photosynthesis and a shift in the assimilation of photosynthate, lead to reduced biomass, growth, and yield. Visible injury results when ozone-induced cell injury and death adversely affects plant vigor.

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[55]Ashmore, M.R. et al. undated draft. "Forest Damage in West Germany and the Role of Ozone." Imperial College at Silwood Park. Ascot, Berkshire, SL5 7PY. 15 pp. and, Rehfuess, Karl E. 1983. "Walderkrankungen und Immissionen - eine Zwischenbilanz. Allg. Forstzeitsch, v. 38 p. 601-610. For further description of this and other hypotheses and of forest declines generally see Cowling, Ellis. Regional Decline of Forests in Europe and North America: the Possible Role of Airborne Chemicals. Aerosols. [S.D. Lee et al. eds.] Chelsea, MI: Lewis Publishers, 1986. p. 1334-1343; Schutt, Peter and Ellis Cowling. 1985. Waldsterben, a General Decline of Forests in Central Europe: Symptoms, Development, and Possible Causes. Plant Disease. v. 69, n. 7. p. 548-558; U.S.House of Representatives. Committee on Agriculture, Subcommittee on Forests, Family Farms and Energy. Effects of Air Pollution on Forests. Hearing unpublished. May 13, 1986. Testimony by Allen Torrenueva. Effects of Air Pollution on Forests: A Canadian Perspective; and Hugo von Sydow; Effects of Acid Deposition and Other Air Pollutants on Forest Productivity; Some Swedish Observations.

OZONE RESEARCH

Federal Research

Many Federal departments and agencies conduct research on effects of ozone pollution, including the EPA, the Forest Service (FS) in the Department of Agriculture, the National Park Service (NPS) in the Department of the Interior, and the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce.[56]

The National Acid Precipitation Assessment Program (NAPAP) is in charge of overseeing the many facets of Federal acid rain research, although not responsible for actual research projects. NAPAP is a 10-year program authorized by the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act (P.L. 96-294)) in 1980 to assess the effects of acid rain. NAPAP has begun to play a role in ozone research by suggesting research on other pollutants as well as acid rain to determine whether they are possible contributors to forest decline.

The Federal research programs of individual agencies are discussed briefly below.

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[56]In addition, at least one State government is supporting an ambitious program of ozone related research. The State of California with its severe ozone problem and its economically important agricultural sector devotes up to $8 million a year to research administered by the California Air Resources Board (CARB). Ozone and crops research alone in FY 86 received $.56 million from CARB (Sylvia Champomier, CARB, pers. comm. June, 1986).

The EPA is the lead Federal agency for ozone-related work. EPA research supports its regulatory obligation to set standards and monitor their effectiveness. The EPA budgets for ozone-related research for fiscal years 1984, 1985 and 1986, respectively, were approximately $13.7 million, $14.7 million and $14.0 million.[57,58]

The EPA dedicates some funds to improving pollution monitoring and control techniques. These funds support research contributing to the modeling of regional ozone transport, which should help to predict ozone levels in rural areas. Ozone monitoring in support of regulations is also funded by these monies. In addition, grants to the States, ranging from $5 million to $7 million, are dedicated to ozone related monitoring.[59]

In addition, EPA's Environmental Processes and Effects Program has supported the National Crop Loss Assessment Network (NCLAN) research on

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[57]U.S. EPA. Justification of Appropriation Estimates for Committee on Appropriations, FY 1986, p. A-10.

[58]In addition, ozone regulatory activities within EPA are allocated approximately $2.1 million under the President's budget for FY 1987. About $1 million of that total is dedicated to mobile and stationary source compliance and enforcement activities both at headquarters and in the regions, supporting approximately 12 staffers at headquarters and approximately 217 in the regional offices whose compliance work centers around ozone and VOCs. Those monies not allocated to compliance and enforcement go towards: wrapping up new source performance standards for VOCs (10.5 Full Time Equivalent workers (FTE) for $700,000); reviewing the ozone ambient standard (5.5 FTE for $250,000; helping States meet their air pollution control implementation plan (SIPs) goals for ozone control (11 FTE for $90,000) and modelling the movement and monitoring the amounts of ambient ozone (7.5 FTE for $45,000). Stan Meiburg, Air Quality Planning and Standards, EPA, pers. comm., June, 1986.

[59]Gregg Glahn. Office of Air Quality Planning and Standards, EPA. Durham, NC. pers. comm. July, 1986.

Table 3.--NCLAN Budget
(in thousand dollars)

Fiscal Year	Supplies & Equipment	R & D; Outside Contracts
1983	$816	$669
1984	1,023	1,629
1985	720	1,549
1986	704	1,300
1987	649	955

Sources: Bill Hoggsett, EPA Corvallis, OR. pers. comm. June, 1986, and Tom Murphy, NAPAP, EPA, Corvallis, OR. pers. comm. July, 1986.

ozone with $4.9 million (obligated) for FY 1985, $2.9 million (allocated) for FY 1986 and $1.7 million (requested) for FY 1987.[60] Funding support from FY 1983 through FY 1987 is shown in table 3. NCLAN research dedicated to generating national crop loss data on ozone for economic assessments is ending after 1987.

EPA is also working cooperatively with the FS in research on the effects of combined pollutants on forests, particularly as ozone relates to acid rain and other pollutants that may contribute to forest decline. This coordinated treatment of acid rain and ozone is predominantly managed by the EPA and the FS Forest Response Program as a part of the National Acid Precipitation Assessment Program.

[60]U.S. EPA. 1987 EPA Budget Estimate. A-21.

The foundation of the Forest Response Program is the establishment of five, 5-year research cooperatives--four of which focus research on specific regional problems while the fifth is a National Vegetation Survey. In support of the cooperatives, a Deposition Monitoring Program is managed by EPA as part of the Forest Effects Research Program. A short description of each cooperative with funding projections follows:

Spruce-Fir Cooperative. Severe dieback and mortality of spruce and fir has been reported in some areas of the northern and southern Appalachians. Funding for the cooperative to study this problem started at about $3 million in FY 1985 and $5.7 million in FY 1986; $4 million is proposed by the Administration for FY 1987.

Southern Pine Cooperative. Southern pine forests represent some of the major commercial forest lands in the eastern United States. Unexplained growth reductions have been found in the Piedmont and coastal plains. Funding began at $1 million in FY 1985, and jumped to around $4.8 million in FY 1986; $4 million is proposed for FY 1987.

Eastern Hardwoods Cooperative. Oak/hickory and maple/beech/birch forests comprise a majority of eastern forestlands. Large oak/hickory forests in the eastern United States coincide with the region of highest measured deposition of atmospheric pollutants; photoxodant damage has been reported for these forests. Maple and birch historically have exhibited growth declines. This cooperative was not funded until FY 1986 with about $1 million; approximately $2 million is proposed for FY 1987.

Western Conifers Cooperative. Studies of two major commercial forest species, Douglas-fir and Ponderosa pine began in FY 1986 with approximately $.8 million; $1.8 million is proposed for FY 1987.

The National Vegetation Survey. This broad-based survey is designed to give a better picture of the geographic extent of current problems, the magnitude of forest effects, and whether additional forests are at potential risk than the previous, more focused surveys indicated. Inventory information will help monitor changes in forest conditions and assess any current or past relationship between forest condition and atmospheric deposition. Data collection and analysis of eastern forest information is targeted for completion in 1989. The National Vegetation Survey was funded by the Forest Service at $2.3 million in FY 1985 and $154,000 in FY 1986; $154,000 is again proposed for the FY 1987 budget.

The Forest Service also conducts some additional research projects related to forest ecosystem effects of atmospheric deposition. For example, a project begun in 1985 is studying high elevation ecosystem effects in the Rocky Mountains. And one of the longest running research projects on forest effects from ozone and NO_x continues in the Sierra Nevada Mountains of California.

The findings from the Forest Response Program are scheduled to be released in two stages; the first release date is the end of 1988 and the second is in 1991.[61]

Work sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF) on an atmospheric chemistry program will help improve understanding of ozone formation, transport and destruction. NSF devoted approximately $1.2 to $1.9 million to relevant

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[61]NAPAP, et. al. Responses of Forests to Atmospheric Deposition: National Research Plan for the Forest Response Program. June, 1986. Draft.

research in FY 1986.[62] NOAA's Radiatively Important Trace Species program examines climatic and air quality issues by monitoring atmospheric constituents, looking at processes which form and remove them, and attempting to model and predict atmospheric changes and effects. About half the program budget of $1.5 million in FY 1986 (up to $200,000 from the previous year) was dedicated to ozone-related research.[63]

The Department of Energy (DOE) physiological ecology program supports several studies on how plants respond to ozone and other stresses including drought and other air pollutants. At least $400,000 goes to these studies.[64]

The National Park Service Air Quality Division spends $500,000 to $750,000 a year on ecological research, of which half to three-quarters is dedicated to ozone-related studies.[65] Having observed symptoms of ozone damage in 34 of 44 (or 77 percent) of national parks studied,[66] monitoring has become a high priority for this division, particularly in the East Coast where the damage appears to be severe.[67]

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[62]Jarvis Moyers, Director, National Science Foundation Atmospheric Chemistry Program, pers. comm. July 2, 1986.

[63]National Oceanic and Atmospheric Administration (NOAA) Environmental Research Laboratories. Radiatively Important Trace Species: Trends and Mechanisms; FY 1986 Budget and Research Plans. Washington, September, 1985.

[64]Janet Dorrigan, Department of Energy, Physiological Ecology Research Project Manager, pers. comm. June 1986.

[65]James Bennett, Ecologist, Air Quality Division, National Park Service, Denver, Colorado. pers. comm. June, 1986.

[66]Christiano, John. Letter from the Chief of the National Park Service Air Quality Division to David McKee, commenting on EPA's draft Staff Paper for the ozone NAAQS. Enclosure C. June 25, 1986.

[67]See, for example, U.S. Congress. House. Committee on Interior and Insular Affairs. Subcommittee on National Parks and Recreation. Impacts of Air Pollution on National Park Units. Hearings. 99th Congress, 1st session. Washington, U.S. Govt. Print. Off. 1985. 586 p.

This NPS program is notable for several reasons. One is that it is operating a small but increasing number of ozone monitors in rural and "remote" areas; another is that these monitors are recording levels of ozone in excess of the primary NAAQS at some of these sites, including sites at Sequoia and Kings Canyon National Parks in the high Sierras and at Acadia National Park in Maine.[68] Finally, some types of vegetation damage have been observed in "attainment areas," where ambient ozone levels are legally acceptable:

> "...NPS studies suggest that elevated levels of ozone in NPS units may have already brought about the elimination of sensitive genotypes of quaking aspen, a serious effect given the National Park Service's role as a genetic library. ... Injury in [the] ozone attainment areas sometimes reaches 90 per cent of the plants examined."

Shenandoah and Great Smoky Mountains National Parks, Saguaro National Monument, and Cuyahoga Valley National Recreation Area, are attainment areas where ozone damage has been found.

Private Ozone Research

The Electric Power Research Institute (EPRI) supports research on ozone and forests and crops, although ozone is a secondary emphasis in a program focused on acid precipitation effects. Its $17 million project called Response of Plants to Interacting Stresses will run through 1989, and its goal is to develop a general theory of how plants react to interacting stresses.[69] EPRI's Integrated Forest Study, which will help to establish the

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[68]Christiano, John. June 25, 1986. Letter from the Chief of the National Park Service Air Quality Division to David McKee, Office of Air Quality Program Standards, EPA, Durham, N.C., commenting on EPA's draft Staff Paper for the ozone NAAQS. p.2.

[69]John Huckabee, EPRI, pers. comm. Some utilities and NAPAP have expressed an interest in cofunding some of this work.

ecological significance of air pollutants, maintains ozone monitors at its study plots, which are widely dispersed in the U.S. and Norway. EPRI has also sponsored crop effects research in the U.S. and forest research in Sweden and Germany.

The National Council of the Paper Industry for Air and Stream Improvement (NCASI), the research arm of the pulp, paper, and forest products industry, began devoting approximately $1 million to forest research in 1985 and hopes to continue to do so for the length of a five-year program. This program is coordinated with the Forest Service and EPA Forest Effects Program, primarily in the Southeast forested States. NCASI has also supported the development of maps that show where the total of 500-800 ozone monitoring stations were located from 1978 through 1983, and characterize their seasonal readings.[70]

The oil, auto, and architectural coatings industries have invested in research on better and cheaper ways to regulate VOC emissions from each others' operations, reportedly in part to avoid capital investment associated with having to meet standards under the CAA.[71]

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[70]National Council of the Paper Industry for Air and Stream Improvement. Review of Available Ambient Ozone Monitoring Data for the Years 1978 through 1983. New York City, 1986. 15p. and appendices. Technical Bulletin No. 502.

[71]Taylor, Robert. Oil, Auto Industries Square Off in An Attempt to Deflect Burden of Meeting Gas Fumes Plan. Wall Street Journal. June 30, 1986. p. 54.

ECONOMIC IMPACTS OF OZONE POLLUTION

Economic analyses of the effects of the ozone problem on crops and forest resources are limited. The first studies of the possible economic significance to the forest products and recreational sectors will be completed soon by Resources for the Future and Energy Research Consultants, according to sources at EPA.[72] The estimated value of damages to National Park resources is also not known at this time.

Agricultural effects have been more extensively modeled using NCLAN data. These models explore effects of different levels of pollution on specific crops (dose/response functions). One recent assessment puts the benefits of increased agricultural production that would result from tightening the current ozone standard of 0.12 ppm to 0.09 ppm at $1 billion in 1978 dollars.[73],[74] Another study estimates that a 25 percent decrease in ozone levels (0.12 ppm down to 0.09 ppm) would result in $1.7 billion 1980 dollars in additional agricultural productivity and benefits to both

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[72]Mark Thayer, Economist, EPA Office of Policy Planning and Evaluation, pers. comm. June, 1986.

[73]This is close to the original EPA standard of 0.08 ppm for total oxidants which was promulgated in 1971. The current ozone standard of 0.12 ppm was promulgated in 1979.

[74]Kopp, Raymond et al. Implication of Environmental Policy for U.S. Agriculture: the Case of Ambient Ozone Standards. Journal of Environmental Management, v. 20, 1985. p. 321-331.

producers and consumers, while a 40 percent increase in ozone would result in a $2.4 billion loss to the U.S. agricultural economy.[75]

Some critics question the usefulness of these estimates because their reliance on NCLAN crop-loss functions is outdated by the short useful life of particular seed varieties. Some economists also complain that NCLAN chose to study especially sensitive varieties, and crops without significant economic value. NCLAN research plans of recent years have addressed these criticisms.[76]

Some critics also fault these studies for ignoring the costs to the Nation of large crop surpluses maintained by agricultural price supports.[77] One observer argues that any increased agricultural production resulting from cleaner air would be of questionable benefit because under current policies and conditions any surplus agricultural production of federally-supported crops would be purchased by the Government. For this and other reasons, it is argued that the net benefits to society of ozone reduction could be negative.[78] Others might question the logic of allowing air pollution to continue as a way to reduce crop subsidy payments.

Estimates of the cost of ozone damage to crops attribute to it a loss of 2 percent to 4 percent of the value of farm crop sales in 1985. Relative

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[75]Adams, Richard. An Assessment of the Economic Effects of Ozone on U.S. Agriculture. Journal of the Air Pollution Control Association. v. 35, 1985. p. 938-943.

[76]Patricia Irving, Senior Scientist, NCLAN and Walter Heck, Chair, NCLAN Research Management Committee, pers. comm. June, 1986.

[77]McGartland, Al. Implications of Ambient Ozone Standards for U.S. Agriculture: A Comment and Some Further Evidence. Journal of Environmental Economics and Management. (publication pending).

[78]This estimate only covers soybeans, corn, wheat, cotton and peanuts. Raymond Kopp, Economist, Resources for the Future. pers. comm., June, 1986.

to other threats to crop production, such as water stress and insect blights, air pollution problems appear to be relatively economically insignificant on a national scale, based on these research results.

Regionally, though, crop losses appear important. This is partly because of the regional variation in ozone distribution, and partly because of the relative sensitivity of certain crops like soybeans and citrus, which are grown in certain regions. One economic study estimates that damages to 33 crops in California were worth $100 million in 1978, with losses to both producers and consumers[79]. A model was updated during the summer of 1986 with 1984 NCLAN dose/response functions for 20 crops planted throughout the state; the results will help California Air Resources Board (CARB) decide which crops warrant immediate further study.[80]

Given the importance of regional impacts, it may be worth noting that the economic model of ozone-induced crop damage due to be completed for the EPA (by Resources for the Future) during 1986 is made up of regional data from 250 areas. Although initial results will look at the aggregated impact, it would be possible to examine the possible benefits of targeted regional control using this model, if the agency choses to do so.[81]

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[79]Rowe, Robert and Lauraine Chestnut. Economic Assessment of the Effects of Air Pollution on Agricultural Crops in the San Joaquin Valley. Journal of the Air Pollution Control Association, v. 35, 1985. p. 728-734. See also Adams, R.M. et al. An Economic Assessment of Air Pollution Damages to Selected Annual Crops in Southern California, JEEM, v. 9, 1982. p. 42-58 and Howitt, Richard, et al. Effects of Alternative Ozone Concentrations and Response Data on Economic Assessments: The Case of California Crops. JAPCA v. 34, 1984. p. 1122-1127.

[80]Sylvia Champomier, Research Division, California Air Resources Board and O. Clifton Taylor, Professor of Plant Sciences, University of California, Riverside. pers. comm. June, 1986.

[81]Raymond Kopp, Economist, Resources for the Future, pers. comm. June, 1986.

OZONE CONTROL

Ozone is regulated as a "criteria" air pollutant under sections 108 and 109 of the Clean Air Act (P.L. 91-604, and amendments). Criteria air pollutants are those for which the Environmental Protection Agency has set national ambient air quality standard (NAAQS), which represent the maximum acceptable level of a pollutant in ambient air. The CAA provides for two kinds of NAAQS: primary ambient air quality standards, set at a level to protect health with an adequate margin of safety; and secondary ambient air quality standards, set at a level to protect welfare values, which include vegetation, visibility, and materials (any non-health effects).

For ozone, EPA has set both the primary and secondary NAAQS at 0.12 parts per million (ppm), not to be exceeded more than once a year. Many experts believe, however, that current evidence would justify a more stringent standard to protect health and/or vegetation. At least one State, California, has set a lower standard of 0.10 ppm.

The CAA requires that EPA review the primary and secondary standards every five years to reaffirm or revise current standards. The EPA, as mandated under the CAA, has recently completed a new "Criteria Document" on ozone,[82] and is currently reviewing the primary and secondary NAAQS. This review could result in proposals to change the ozone NAAQS.

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[82]Environmental Protection Agency. Air Quality Criteria Ozone and other Photochemical Oxidants. 1986. Five volumes; volume three contains discussions of the effects of ozone on vegetation and on ecosystems.

Once the EPA sets a NAAQS, the States, through State Implementation Plans (SIPs) for local areas called air quality control regions, are responsible for attaining and maintaining the NAAQS.[83] The present focus of ozone regulation is on some 73 air quality control regions which may not achieve the NAAQS for ozone by the statutory deadline of December 31, 1987.[84] About one-third of these regions may improve enough by the deadline to comply; another one-third to one-half probably cannot comply by the deadline but might, with more stringent control measures, comply within a number of years. Several areas are not expected to meet the current standard at any time in the foreseeable future without taking controversial measures that would significantly affect business, transportation, and lifestyle. Strategies for controlling ozone are under active debate.[85]

Regions not meeting the deadline face the possibility of strong sanctions, which could include withholding Federal funds for highway construction, withholding EPA grants for environmental programs, and imposing moratoria on construction of pollutant-emitting sources. There is some disagreement about the conditions under which sanctions might be imposed or avoided.

While concerns about the impact of ozone on vegetation--either by itself or in conjunction with acid precipitation--will surely continue as EPA evaluates the ozone NAAQS, the immediate stimulus for congressional concerns about ozone will arise from the pressure of the deadline for attainment.

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[83]The CAA sets a firm deadline for attaining primary NAAQS, while requiring that secondary NAAQS be attained in a reasonable time. This distinction, although important for some air pollutants, is not relevant for ozone at this time since the primary and secondary standards are identical.

[84]Congressional Research Service. IB 87066. Clean Air Act: Ozone Nonattainment. Continually updated.

[85]Thomas, Lee M. A Strategy for Controlling Ozone. Journal of the Air Pollution Control Association. v. 36, n. 9, September 1986. p. 997-1000.

But if EPA concludes that the ozone standard should be tightened, then the problems posed by nonattainment will be made even more difficult: regions out of compliance will need to take even stronger control actions than already required, and additional regions will be out of compliance and also need to tighten controls to abate ozone pollution.[86]

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[86]The actual impact of tighter standards would vary depending on whether the primary and secondary standards stayed the same. If EPA were to make the secondary standard more stringent than the primary standard, the statutory deadline would apply only to the latter, with States having a "reasonable" time to achieve the secondary standard.

Annual Bird Counts Are Starting to Yield Scientific Insights

Bird watchers span the continent to monitor species.

By JANE E. BRODY

WHAT began in the last century as a Christmas hunting contest has become an annual count of North American birds that provides scientists and conservationists with incomparable data about hundreds of species.

Now in its 90th year, the annual Christmas bird count began last Saturday as the first of 42,000 volunteers went out to record sightings. Under the auspices of the National Audubon Society, and aided by dozens of local nature groups, bands of bird watchers across the continent will count all the wild birds they find in a day. They will separate into more than 1,500 groups, each of which will cover a circular area about 15 miles in diameter. Before the count ends on Jan. 3, experts expect to record more than 66 million birds.

For most participants, the Christmas bird count is just a fun way to spend a winter day. But growing numbers of scientists and environmentalists are finding a wealth of important facts among the data generated by the winter bird watchers.

More than 200 papers based on results of Christmas counts have been published, most in the last 15 years. And scores of studies are under way, all made possible by the recent computerization of 28 years of bird count data.

One of the most recent studies, done last year at the Cornell Laboratory of Ornithology, examined 20 of the 30 birds on a list of species that could become endangered. This early warning list was compiled by the United States Fish and Wildlife Service. The Christmas counts indicated that 7 of the 20 species appeared to be declining rapidly, said Gregory S. Butcher, director of the laboratory's population studies.

Pesticides Called a Threat

For example, Dr. Butcher said, the loggerhead shrike, which once had a huge range over North America, is now declining drastically all over its range. While experts had expected this because the hedgerows, woodlots and brushy fields favored by the bird are shrinking, the population is declining much faster than anyone would have predicted. Dr. Butcher suggested that exposure to pesticides may be an important factor in its decline.

He also found that the seaside sparrow, which breeds on Long Island and winters in salt marshes in Florida, is declining dramatically as humans encroach on its wintering grounds.

In addition, the study raised concerns about the spotted owl and Henslow's sparrow, a species that favors abandoned agricultural fields. These species "may be in the most danger of extinction and should be top candidates for special research programs and for conservation action," the study said.

Such information is being used to alert agencies and groups like the United States Forest Service, the Nature Conservancy, the Bureau of Land Management and the National Park Service to the need for land management practices that would encourage the birds now in decline.

"The idea is to get the word out and get something done about it before the species have totally fallen apart," Dr. Butcher said. For example, he explained, the state parks and national forests might start a mowing schedule that would provide a desirable place to breed for the Henslow's sparrow and other species that prefer grasslands.

Some Species Show Increases

At the same time, the study showed that two birds that had been on the early warning list, the trumpeter swan and the white-faced ibis, are now increasing significantly, and that the Harris hawk, which had dropped in numbers in the early 1980's, is also bouncing back.

Terry Root, an ornithologist at the University of Michigan's School of Natural Resources, used 10 years of Christmas count data to produce "The Atlas of Wintering North American Birds." The book, published last year by the University of Chicago Press, maps the distribution and abundance patterns for more than 250 species of birds.

Just after dawn on Saturday at Montauk Point on Long Island,

Census offers researchers a we of data on the st and needs of bir

By superimposing maps mental variables like ter vegetation and precipitati bird distribution maps, sh to show that the limits of cies were determined b ture.

Migration and Metabolic

"These species go only as 2.5 times their basa rate," she said, meaning tain body temperature ir er, the birds will not rai of burning fuel more th their usual metabolic r temperatures.

Dr. Root said she is use the bird count data tal scale to study the ef warming.

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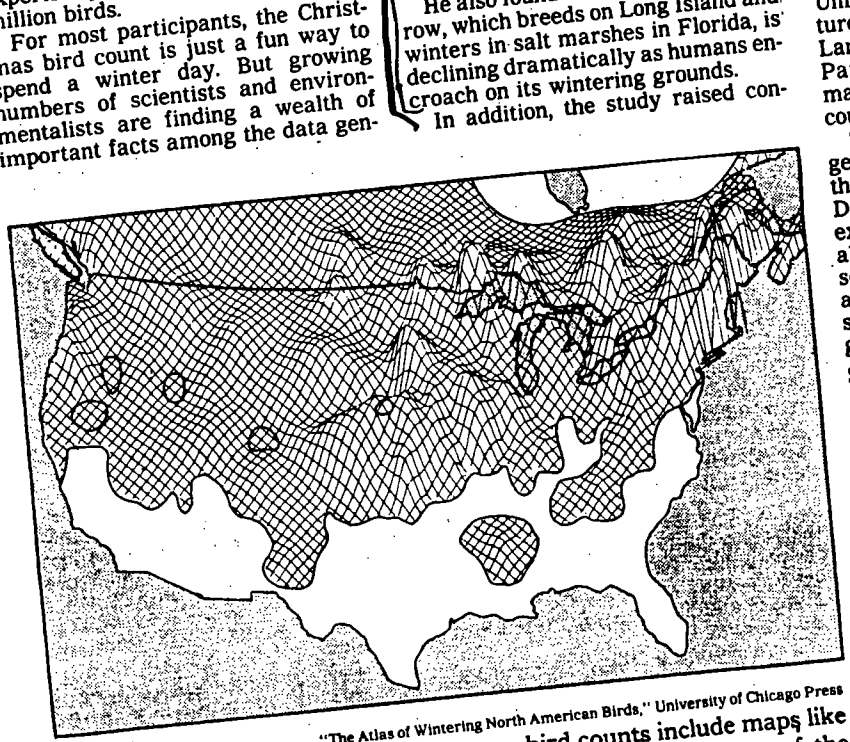

"The Atlas of Wintering North American Birds," University of Chicago Press

The scientific fruits of years of Christmas bird counts include maps like this one, which shows the winter distribution and abundance of the black-capped chickadee in the form of peaks and valleys.

The New York Times/Rameshwar Das

on Saturday at Montauk Point on Long Island, a team began its annual bird count.

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By superimposing maps of environmental variables like temperature, vegetation and precipitation over the bird distribution maps, she was able to show that the limits of some species were determined by temperature.

Migration and Metabolic Rate

"These species go only as far north as 2.5 times their basal metabolic rate," she said, meaning that to maintain body temperature in cold weather, the birds will not raise their rate of burning fuel more than 2.5 times their usual metabolic rate at higher temperatures.

Dr. Root said she is now trying to use the bird count data on a continental scale to study the effects of global warming.

"If temperatures rise, the species that are limited by winter lows will be able to move north rapidly," she said. "But those limited by vegetation will have to wait until the vegetation they depend on grows up. This will tear apart existing bird communities and create new ones, to what effect no one yet knows."

Dr. Root said her data can also be used by conservationists as a guide to establish preserves to protect threatened species. Since the maps show relative abundance of a species in different parts of its range, conservationists can protect areas where a bird is doing the best, rather than the edges of its range.

Although Christmas counts have been available for nearly a century, scientists have been wary of using the data, in part because they were regarded as unscientifically gathered. The experts were concerned that in a race for the most birds, the thousands of amateurs might overcount or misidentify species.

More Reliance on the Count

But attitudes changed recently as more stringent counting rules and data checks were introduced and scientists began to realize that the count is "the most extensive, longest-term, continuous and most geographically comprehensive data set in American ornithology," as Susan Roney Drennan put it. Ms. Drennan, a mathematician, is editor of American Birds, the scientific publication of the National Audubon Society. The society corroborates, compiles and publishes the annual bird count data.

Other scientists share her assessment and have come to rely on the data base, which is far larger and more comprehensive than any individual scientist could hope to gather even with an enormous research grant.

Carl E. Bock, professor of biology at the University of Colorado in Boulder, said the Christmas count data are "ideally preadapted to address questions of why certain birds appear in particular places some years and not others."

Dr. Bock and a graduate student computerized a decade of data, under a National Science Foundation grant. In analyzing the data, Dr. Bock found that wintertime "eruptions" in the United States of birds that normally live in the evergreen forests of Canada were driven by feed crop failures in the forests. When the trees failed to produce cones for reasons not yet understood, birds that eat the conifer seeds came into the United States for winter food. These birds include the red poll, pine siskin, evening grosbeak, purple finch, red-breasted nuthatch and crossbills.

In comparing the North American bird counts with data from Europe, Dr. Bock found that the southern movements of birds from northern forests seem to be synchronized worldwide, suggesting that some global climactic changes may be involved.

Dr. Bock, who has done two dozen other studies using Christmas counts, sees a bright future for what is unquestionably the largest data base in the animal kingdom.

"The counts tells us two fundamental things about birds: their patterns in space and their patterns in time," he said. "For no other kinds of animals do biologists have data like these."

From Hunting To Counting

In the 19th century, teams of hunters traditionally competed on Christmas Day to shoot the largest number of wild birds and mammals. Disgusted by the killing, Frank M. Chapman, an ornithologist who spent 56 years at the American Museum of Natural History, organized a Christmas bird count as an alternative.

On Dec. 25, 1900, 27 bird watchers in the first count covered 26 locations. Last year 42,671 volunteers counted birds in 1,563 locations (40 of them in Central and South America). The counting parties are organized to minimize the chances of misidentification and limit the possibility that any bird will be counted more than once. Unusual sightings or inordinately large numbers of birds are checked by regional compilers before the data are sent to the National Audubon Society.

When scientists use the Christmas count data to calculate the size of bird populations, they try to standardize the figures by taking into account the number of observers in each party and how much time was spent in the field.