5-2003

An Analysis of Air Pollution from Recreational Vehicle Use in Maine

Erin R. Bock

AN ANALYSIS OF AIR POLLUTION FROM RECREATIONAL VEHICLE USE IN MAINE

By

Erin R. Bock

B.S. Western Carolina University, 1998

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Resource Economics and Policy)

The Graduate School

The University of Maine

May, 2003

Advisory Committee:

Jonathan D. Rubin, Associate Professor of Resource Economics and Policy, Advisor

Mario Teisl, Associate Professor of Resource Economics and Policy

Deirdre Mageean, Associate Professor of Resource Economics and Policy

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Thesis Advisor: Dr. Jonathan D. Rubin

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Recreational vehicles produce a significant amount of air pollution. Despite this fact, only recently has regulation been placed into effect by the EPA on air emissions from these sources. Maine has a high amount of recreational vehicle use, and many people travel from out of state to utilize Maine's resources in this manner. Until now, there has been no research done to examine the impact of Maine's recreational vehicle sector on air pollution.

This thesis focuses on air emissions from several types of recreational vehicles. These are gasoline-powered snowmobiles, all-terrain vehicles (ATVs), and non-commercial watercraft. There were several goals that were accomplished by this research. First, exhaust emissions from these sources were estimated using emissions modeling software developed by the EPA. This was used in conjunction with data collected from three gasoline-consumption surveys for recreational vehicle use conducted by the Margaret Chase Smith Center for Public Policy at the University of Maine.

Emissions estimates were obtained for the years 2000, 2010, and 2020. The emissions results obtained using the survey data were much different then the results obtained using EPA's data provided for use by the computer model.

Another objective of this research was to examine the effects of emission regulations placed on these vehicles by the EPA for the State of Maine. A recent rulemaking covered exhaust and evaporative emissions for snowmobiles and ATVs, and a 1996 ruling covered exhaust emissions from several types of watercraft. Using the costs predicted by the EPA for complying with these regulations, effects on sales of the regulated vehicles, and cost-per-ton estimates for the reduction of pollution from these vehicles were examined.

It was found that cost-per-ton estimates using the EPA's data as opposed to the survey data were significantly higher. This is an important result, as it shows the sensitivity of the emissions model to small differences in data, and the consequences this can have when estimating associated costs.

ACKNOWLEDGEMENTS

I would like to thank the individuals on my thesis committee for their patience and time throughout the process of conducting and writing up this research. I would especially like to thank Dr. Jonathan Rubin for his guidance and input during this time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION AND BACKGROUND

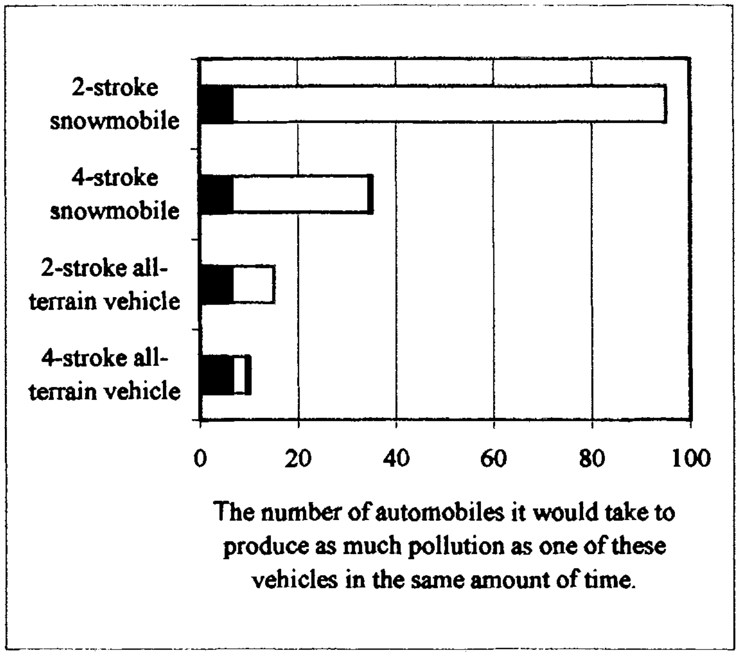
Introduction

Air pollution is a continuing problem in the U.S. and elsewhere due to its negative effects on human health and the environment. Air pollution can affect public health by aggravating respiratory ailments such as asthma, and by contributing to increased mortality rates resulting from cardio-pulmonary effects (EPA, 2001a). Public welfare is adversely affected by problems resulting from air pollution, such as acid rain deposition and decreased visibility, which are especially harmful in our wilderness areas and national parks.

The EPA classifies anthropogenic sources of air emissions into the three broad categories of mobile, stationary (point), and area (non-point) sources (EPA, 2002a). The mobile source category is further disaggregated into the sub-categories on-road (highway), and nonroad (off-highway), with the nonroad sector being comprised of a broad collection of engines and vehicles, including recreational vehicles, farm and construction equipment, and commercial transportation (EPA, 2002b). Although highway engines are heavily regulated for air emissions, much of the nonroad sector remains unregulated.

Recreational land and marine-based vehicles contribute significantly to air pollution in this country. Many of these vehicles have two-stroke instead of four-stroke engines, which are more inefficient in terms of fuel usage, and thereby produce much higher levels of air pollution. Figure 1.1 outlines how many cars it would take to produce the same amount of smog-forming pollution as one of the recreational vehicles listed on the vertical axis in the same time period.

Figure 1.1: Comparison of HC+CO+NOx from Recreational Vehicles and Automobiles



Source: EPA, 2002a

Objectives and Organization

This research focuses on exhaust emissions from recreational vehicles - specifically gasoline-powered snowmobiles, all-terrain vehicles (ATVs), and non-commercial watercraft, in the State of Maine. Maine's economy relies heavily on the tourism industry, with a large part of this industry dependent on the state's quality sources of recreation. Maine has more mileage of coastline than any other state, making it a prime area for all types of water-based recreation. It also has the highest mileage, over 3000 miles of International Trail System (ITS) trails and over 15,000 miles of smaller/private trails, of snowmobile trails in the Eastern U.S. (MSA, 2001). Intensive recreational vehicle use imposes a significant environmental impact where these vehicles are used.

A study on the air pollution impact of Maine's recreational vehicle sector has never been done. This research examines air emissions from, and regulations pertaining to gasoline-powered snowmobiles, ATVs, and non-commercial watercraft in Maine. The first objective of this research is to estimate Maine's emissions from these sources in the year 2000, and to predict future emissions for the years 2010 and 2020. The second objective is to examine what effects the existing regulations on these vehicles will have on future emissions from these vehicles, as well as on future sales of these vehicles in the state. Finally, we would like to obtain Maine-specific cost-per-ton estimates for the reduction in exhaust emissions due to current regulations on these vehicles.

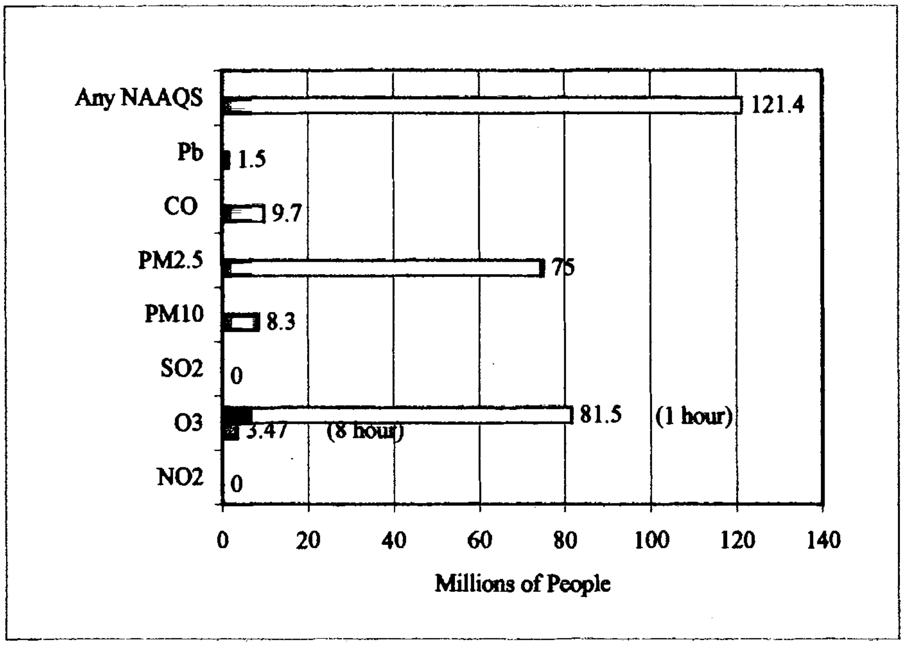
Literature Review

Air Pollution and Human Health

Recreational vehicles produce several types of air pollution, including criteria pollutants, greenhouse gases, and air toxics. The implications for the environment and human health from these sources are various. In this section of this report, specific types of air pollution and their associated effects will be discussed.

The EPA sets the National Ambient Air Quality Standards (NAAQS) for seven pollutants termed criteria pollutants (EPA, 2002c). These are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), particulate matter size 10 microns or smaller (PM_{10}), particulate matter size 2.5 microns or smaller ($PM_{2.5}$), and sulfur dioxide (SO_2). Primary standards are those which set limits to protect human health, and secondary standards are set to protect public welfare. Areas of the country where air pollution levels consistently exceed the NAAQS are deemed "non-attainment" areas. Figure 1.2 outlines the number of people in the U.S. living in non-attainment areas for the seven criteria pollutants in the year 2000.

Figure 1.2: Number of People Living in Counties with Air Quality Concentrations Above the Level of the NAAQS in 2000



Source: EPA, 2000a

Ozone is formed by a series of reactions involving volatile organic compounds (VOC), and nitrogen oxides (NOx), which are both emitted by mobile sources (EPA, 2002a). Hydrocarbons (HC) make up a large subset of VOC, so much of the regulation on exhaust emissions for the reduction of ozone from mobile sources is based on reducing levels of HC. Heat and sunlight are catalysts in the reaction, making ozone formation highly dependent on temperature and time of year. Ozone tends to be considerably more prevalent in the summer months, due to both increased traffic and warmer temperatures. There exists a high correlation between elevated ozone levels and hospital visits for respiratory and pulmonary ailments. Ozone has also been shown to cause permanent lung damage with cumulative exposure. In addition to deleterious human health effects caused by exposure to ozone, the natural environment can also be affected by means of decreased absorption of sunlight in plants.

Carbon monoxide (CO) is produced by the incomplete combustion of fuel, which is especially a problem with two-stroke engines (EPA, 2001a). Health effects due to CO are mainly a concern for those who suffer from cardiovascular disease, because it reduces necessary oxygen delivery within the body's system. Carbon monoxide can also contribute to ground level ozone production by forming a reaction with compounds that would otherwise bond with volatile organic compounds. This leaves a greater amount of VOC available for ozone formation.

Particulate matter (PM) is generally classified as one of two types, depending on its size (EPA, 2001a). PM_{10} refers to particulate matter with a size equal to or less than 10 microns, while $PM_{2.5}$ refers to particulate matter that are equal to or less than 2.5 microns. Adverse health effects caused by the presence of PM are mostly related to the aggravation of respiratory and cardiovascular disease, which in severe cases can lead to premature mortality. Particulate matter affects public welfare by causing decreased visibility and by contributing to acid rain deposition from particles that contain nitrogen or sulfur.

In addition to criteria pollutants, nonroad sources produce greenhouse gas emissions such as carbon dioxide, and other air pollutants known as air toxics (EPA, 2001a). Air toxics include such pollutants as benzene and formaldehyde, and have been shown to have carcinogenic and other negative health effects. Greenhouse gases contribute to global warming, which has the potential to produce a series of harmful effects for both human health and the environment.

The EPA examined the health costs of air pollution for the final draft of a regulatory support document for a recent rulemaking that covers several categories of nonroad vehicles, including snowmobiles and ATVs (EPA, 2002e). They estimated these costs in detail for two types of particulate matter - NOx-containing PM and basic PM. The total cost estimates for health incidences/ton of pollution in 2001 were $10,193, and $142,867 for NOx-containing PM, and basic PM, respectively. These costs do not include costs such as loss of visibility or other non-quantifiable welfare effects from these pollutants.

Contributions to Air Pollution by Source

In Table 1.1 and Figure 1.3, the mobile source category has been disaggregated into on-road and nonroad categories for the purpose of viewing what each of these contributed to national levels of six major air pollutants in 1999. Nonroad engines contribute significantly to air pollution in this country, making up 26% of the CO, 5% of the SO_2, 22% of the NOx, and 18% of the VOC emissions produced in 1999 (EPA, 1999a). Within the mobile source category, nonroad engines produced 33% of CO, 72% of the SO_2, 39% of the NOx, 38% of the VOC, and 62% of the PM emissions.

Table 1.1: National Anthropogenic Air Emissions by Source, 1999

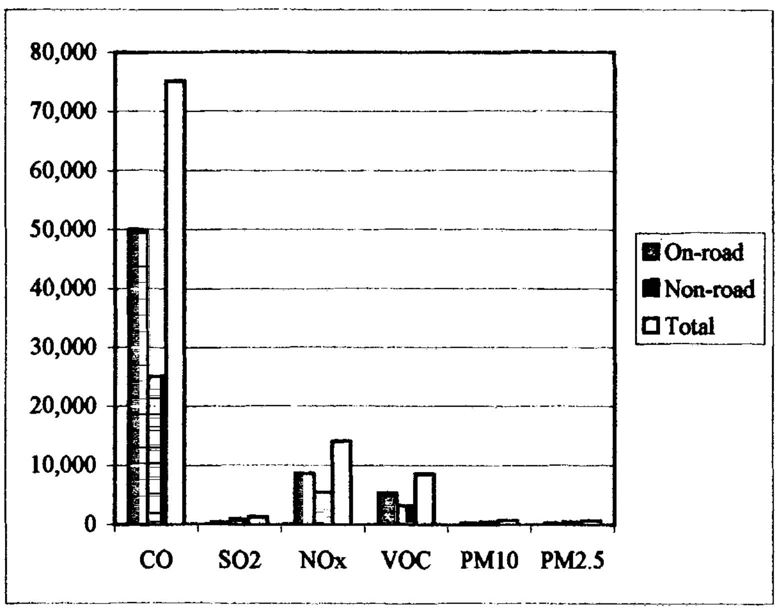
(1000's short tons)

	Misc.	Industrial Processes	Fuel Combustion	Mobile Sources		Total
				On-road Vehicles	Nonroad Engines and Vehicles	
CO	9,378	7,590	5,322	49,989	25,162	97,441
SO_2	12	1,465	16,091	363	936	18,867
NOx	320	942	10,026	8,590	5,515	25,393
VOC	716	7,996	904	5,297	3,232	18,145
PM_{10}	20,634	1,263	1,029	295	458	3,045
$PM_{2.5}$	4,454	913	766	229	411	7,655

Source: EPA, 1999a

Figure 1.3: National On-road, Nonroad and Total Mobile Source Air Emissions, 1999

(1000's short tons)



Source: EPA, 1999a

Maine's estimated air emissions in 1999 follow a similar trend to what was exhibited at the national level, with the percentages of nonroad CO and VOC emissions being somewhat higher, and the percentage of nonroad NOx being somewhat lower than what was exhibited nationally. The nonroad engine and vehicle sector produced 33% of the CO, 16% of the NOx, 5% of the SO_2, and 33% of the VOC emissions in the state in 1999. In Maine, nonroad sources produced 38% of the CO, 60% of the SO_2, 23% of the NOx, 60% of the VOC, and 64% of the PM emissions from mobile sources in 1999.

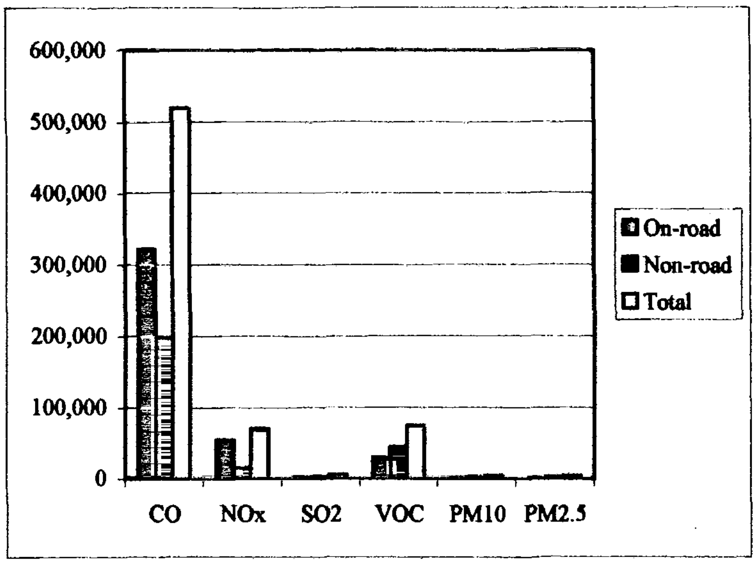
Table 1.3 breaks down the air pollution contribution from nonroad sources by engine category for four air pollutants in the year 2000. These numbers are estimates based on air emissions modeling conducted by the EPA. The categories relevant to this research are the recreational spark-ignition (SI) category, which includes gasoline-powered snowmobiles, ATVs, and off-road motorcycles, and the marine SI category, which includes gasoline-powered outboard, inboard/sterndrive, and personal watercraft engines. A more detailed description of these vehicles will be given in the next section.

Table 1.2: Maine's Anthropogenic Air Emissions by Source, 1999 (1000's short tons)

	Misc.	Industrial Processes	Fuel Consumption	Mobile Sources		Total
				On-road Vehicles	Nonroad Engines and Vehicles	
CO	705	20,742	64,045	321,439	198,573	605,504
NO_x	20	4,560	25,933	54,203	16,039	100,754
SO_2	1	1,427	33,915	1,988	3,032	56,905
VOC	232	44,158	14,251	29,941	44,639	133,221
PM_{10}	46,811	5,899	86,378	1,754	2,955	143,807
$PM_{2.5}$	9,684	4,811	85,168	1,390	2,711	103,763

Source: EPA, 2002d

Figure 1.4: On-road, Nonroad, and Total Mobile Source Air Emissions in Maine, 1999 (1000's short tons)



Source: EPA, 2002d

Table 1.3: Modeled Annual Emission Levels for Mobile-Source Categories in 2000 (thousand short tons)

Category	NOx		HC		CO		PM	
	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent mobile source	1000 tons	percent of mobile source
Total for engines subject to today's standards*	547	8.80%	1,305	24.10%	4,866	5.60%	34.1	5.20%
Highway Motorcycles	14	0.20%	142	2.60%	572	0.70%	0.8	0.10%
Non-road Industrial SI > 19 kW*	472	7.60%	318	5.90%	2,336	2.70%	2.3	0.40%
Recreational SI*	14	0.20%	985	18.20%	2,521	2.90%	30.2	4.60%
Recreational Marine CI*	61	1.00%	2	0.00%	9	0.00%	1.6	0.20%
Marine SI Evaporative	0	0.00%	114	2.10%	0	0.00%	0	0.00%
Marine SI Exhaust	58	0.90%	284	5.20%	1,985	2.30%	28	4.30%
Non-road SI < 19 kW	106	1.70%	986	18.20%	27,352	31.70%	77	11.80%
Non-road CI	1,791	28.80%	142	2.60%	1,462	1.70%	261	40.00%
Commercial Marine CI	819	13.20%	35	0.60%	160	0.20%	46	7.00%
Locomotive	611	9.80%	35	0.60%	119	0.10%	21	3.20%
Total Non-road	3,932	63%	2,901	54%	35,944	42%	467	71%
Total Highway	2,050	33%	2,276	42%	48,906	56%	145	22%
Aircraft	232	4%	238	4%	1,387	2%	43	7%
Total Mobile Sources	6,214	100%	5,415	100%	86,237	100%	655	100%
Total Man-Made Sources	16,190	--	15,475	--	109,905	--	3,039	--
Mobile Source percent of Total Man-Made Sources	38%	--	35%	--	79%	--	22%	–

Source: EPA, 2002

Regulation of Air Emissions from Recreational Vehicles

For regulatory purposes, the EPA groups nonroad engines into several categories. The recreational vehicles we are interested in fall within two of these categories – recreational SI, and marine SI. Recreational spark-ignition vehicles are those recreational vehicles that use spark-ignition technology to start their engines[1]. This category contains both gasoline-powered snowmobiles and ATVs. For the purpose of regulating these vehicles, EPA groups off-road motorcycles with ATVs. Although we are not particularly interested in off-road motorcycles in this study, this is not of large concern, because off-road motorcycles only made up around 3% of the total population when grouped with ATVs according to Maine registration data for the year 2000 (Margaret Chase Smith Center, 2001b).

Most snowmobiles currently sold in the U.S. contain two-stroke engines, which are highly inefficient, leaving up to 25 percent of the fuel exiting the cylinder unburned (EPA, 2000b). Currently, about 15% of the ATVs sold in the U.S. have two-stroke engines, while the rest contain four-stroke engines (EPA, 2002e). The recreational SI category contributes about 18% of the HC emissions from mobile sources in the U.S. (Table 1.3). Snowmobiles, in particular, produce high levels of CO, which can endanger individuals while riding and contribute to ambient levels of CO in CO non-attainment areas.

The second category of recreational vehicles we are interested in is the marine spark-ignition vehicle category. This category contains gasoline-powered outboard, inboard and sterndrive, and personal watercraft engines. Inboard and sterndrive boats

[1] The main difference between spark-ignition (SI) technology and compression-ignition technology (CI) is that SI engines use gasoline and CI engines use diesel.

have engines that are enclosed within the boat's body. Most of these engines are four-stroke, and are typically modified versions of automotive engines. Outboard engines are detachable engines, which operate outside the main body of the boat. Personal watercraft engines (PWC) include jetskis and jetboats. Most of the spark-ignition outboard and PWC engines use two-stroke technology at this time. Marine spark-ignition engines, as a whole, are accountable for over 8% of the HC emissions from mobile sources (Table 1.3).

Recreational SI

Recreational SI engines are covered in a new EPA rulemaking that was signed in September, 2002 (EPA, 2002e). This regulation focuses on reducing overall levels of HC, CO, PM, and NOx from a variety of nonroad engines, and presents a three-phase program for snowmobiles, and a two-phase program for ATVs and off-road motorcycles. The first phase for both types of recreational vehicles is set to go into effect in 2006. The second phase for recreational vehicles will be phased-in in 2007, and the third (which covers snowmobiles only), is set to occur in 2010. Reductions in emissions will be met in a variety of ways, with many of these decisions based on the manufacturers of these vehicles. The two main ways that reductions in emissions can be made are through engine replacement and engine modification.

Table 1.4: Recreational Vehicle Exhaust Emission Standards

Vehicle	Model Year	Emission standards		Phase-in
		HC g/kW-hr	CO g/kW-hr	
Snowmobile	2006	100	275	50%
	2007-09	100	275	100%
	2010	75	275	
	2012*	75	200	
		HC+NOx g/km	CO g/km	
ATV	2006	1.5	35.0	50%
	2007 and later	1.5	35.0	100%

*the long term program includes a provision which acts to cap NOx emission rates
Source: EPA, 2002e

The regulatory support document for the final rulemaking for these engines provides the estimated average costs for the implementation of this regulation. For the purposes of this report, we are assuming that these costs are passed to consumers in full, although in reality the extent to which these costs are passed on to consumers will depend on demand and supply elasticities for the affected vehicles. Both long and short-term costs are given, with the difference being due to the retirement of fixed costs, and assumed reductions in costs due to learning-by-doing.

Table 1.5: Total Average Per Unit Costs and Fuel Savings

	Snowmobile Phase 1	Snowmobile Phase 2	Snowmobile Phase 3	ATVs
near-term costs	$80	$131	$89	$87
long-term costs	$47	$77	$54	$45
fuel savings (NPV)	($67)	($286)	($191)	($29)

Source: EPA, 2002e

Table 1.6 outlines the estimated reductions for four pollutants from snowmobiles and ATVs in the years 2010 and 2020 due to the implementation of regulation on these vehicles. Levels of NOx actually increase, especially for snowmobiles, because in order to meet the requirements, many engines will be converted to four-stroke from two-stroke engines. This causes a slight increase in NOx emissions due to a technical difference in how the engines process fuel.

Table 1.6: Reductions in Exhaust Emissions for Snowmobiles and ATVs due to Regulation

Vehicle	Year	% Reduction			
		HC	CO	NOx	PM
ATVs	2010	32%	5%	(11%)	32%
	2020	86%	13%	(25%)	86%
Snowmobiles	2010	15%	15%	(16%)	4%
	2020	57%	46%	(101%)	42%

Source: EPA, 2002e

Marine SI

Exhaust emissions were addressed for outboard and personal watercraft engines in a 1996 ruling (EPA, 1996a). At this time, the final standards were set for outboard and personal watercraft engines, but sterndrive and inboard engines remain unregulated for exhaust emissions. The final rule for outboard and personal watercraft engines allows for a nine-year phase in of new technologies that started in 1998, and will result in an estimated 75% reduction in HC production by these engines in the year 2006, with a slight increase in NOx emissions.

Table 1.7: Average Consumer Cost Components per Engine Estimated per Engine Consumer Cost Increase

Year	Fixed Cost	Variable Cost	Dealer Cost	Fuel Savings	Maintenance Cost	Admin. Cost	Total Cost
1998	$10	$20	$5	($67)	$50	$14	$32
1999	$20	$39	$9	($135)	$115	$7	$55
2000	$29	$108	$25	($176)	$151	$7	$143
2001	$46	$189	$44	($227)	$203	$7	$261
2002	$52	$250	$58	($267)	$219	$7	$319
2003	$68	$301	$69	($327)	$284	$7	$402
2004	$84	$386	$89	($394)	$349	$7	$520
2005	$95	$438	$101	($429)	$380	$7	$591
2006	$103	$511	$118	($478)	$434	$7	$695

Source: EPA, 1996

Chapter 2

DATA AND METHODS

Estimating Maine's Current and Future Recreational Vehicle Emissions

This section presents the methods used to estimate Maine's air emissions from the three types of recreational vehicles discussed earlier. In order to estimate emissions from these vehicles, data from three gasoline consumption surveys that were conducted in Maine were used in conjunction with an EPA computer model that models emissions from nonroad sources to obtain emissions estimates for the years 2000, 2010, and 2020.

Gasoline Consumption Surveys

A series of three surveys was conducted by the Margaret Chase Smith Center for Public Policy at the University of Maine in 2001. The primary objective reached by these surveys was to determine gasoline usage for three types of recreational vehicles in Maine - ATVs, snowmobiles, and gasoline-powered watercraft. The surveys were conducted in the year 2001, but the questions pertained to gasoline consumption in the year 2000. Additional questions included information on vehicle make and model, engine size, frequency of use, and other factors that were helpful in estimating air emissions from these vehicles. A synopsis of what these surveys found is presented below.

Table 2.1: Summary of Findings from the Maine Gasoline Consumption Surveys

	# of Vehicles Registered	# of People Surveyed	Ave. Gas Used/Vehicle	Total Gas Used
Snowmobiles	95,334	635	87.4 gal.	8,336,275 gal.
ATVs	39,643	671	43.6 gal.	1,664,497 gal.
Motorboats	117,021	647	69.3 gal.	8,105,728 gal.

Source: MCSCPP, 2001

EPA's Nonroad Vehicle and Engine Emissions Model

As part of the rulemaking process for nonroad engines, the EPA developed a model used to estimate emissions from nonroad sources. This model can estimate air emissions from all of the nonroad equipment and engine categories set by the EPA, with the exception of commercial marine, locomotive, and aircraft engines (EPA, 1998b). It covers 340 types of nonroad equipment, and can calculate emissions for the six exhaust pollutants HC, NOx, CO, CO_2, SOx, and PM. HC can be reported as one of five types, and PM can be reported as either $PM_{2.5}$ or PM_{10}.

The model can calculate emissions at the national, state, county, and sub-county levels. It calculates emissions temporally by year, one of four seasons, or any particular month, and can predict future and past year emissions. Emissions for the period selected are estimated for the total period or a particular day (weekday or weekend), during that period. The nonroad model uses a basic equation to determine exhaust emissions for a single year from off-highway engines (EPA, 1998a):

Emissions = $\sum$(population * power * load * annual use * emissions factor)

Where:

Population = number of engines estimated to be in the U.S. (or the particular area you are interested in) in a given year

Power = population-weighted average rated power for a given horsepower range

Load factor = ratio between average operational power output and rated power

Annual use = average hours of operation per year

Emissions factor = weighted value between levels from baseline (no regulation) and controlled engines operating in a given calendar year

Many of the basic model inputs are variable, and can be replaced with local data when it is available. For this research, the basic model inputs that will be changed for each of the three vehicle types are population of vehicles and activity in hours of use per year.

Modeling Emissions for Snowmobiles and ATVs

The populations of snowmobiles and ATVs were obtained from Maine registration data for the year 2000. Both populations were divided into two groups based on the survey data, depending on whether they had two-stroke or four-stroke engines. The data file for population used by the nonroad model places vehicles into categories based on whether they have two-stroke or four-stroke engines, and based on horsepower range. For snowmobiles and ATVs, information on horsepower range was not obtained in the survey. In order to divide our data up into horsepower ranges, we used the percentages of vehicles within the given ranges, as listed in the default Maine population file for the year 2000 used by the model. We created a new data file by applying these percentages to our data in order to divide up our population by horsepower range, and then used these numbers to replace the default values that would normally be used by the model.

Data relating the activity of these vehicles in hours of use for the year 2000 was not obtained by the gasoline consumption surveys for snowmobiles and ATVs. The survey data did relate activity values for gallons of gasoline used per year, however. In order to use this data in the nonroad model, we converted it into hours of use per year following a procedure used by the EPA (EPA, 1997a). This procedure is given below:

Activity (hrs/year) = (FC)/[(E)*(Hp)*(LF)*(BSFC)]

Where:

FC = yearly fuel consumption,

E = the number of engines

Hp = the average horsepower

LF = average load factor

BSFC = the brake-specific fuel consumption

Average fuel consumption per engine was determined by the surveys, and average horsepower was calculated after applying EPA's percentages to Maine's population of these vehicles. Load factor could be found in the activity data files used by the nonroad model, and brake-specific fuel consumption could be determined using a chart given in the technical document, which provided this value for a range of horsepower values (EPA 1997a).

Tables 2.2 and 2.3 compare the activity values we obtained from the surveys with the default activity values normally used by the nonroad model. For snowmobiles these values are very similar, whereas for ATVs they were significantly different. These tables also show the default populations broken down into the respective horsepower ranges. The Maine Data column represents our population of each of the vehicles broken down into the respective horsepower ranges based on the percentages given by the Model Default data.

Table 2.2: Inputs for Snowmobiles in the Nonroad Model

<table>
<tr><td colspan="5">Snowmobiles</td></tr>
<tr><td></td><td>all</td><td>2-stroke</td><td colspan="2">4-stroke</td></tr>
<tr><td># Registered (survey)</td><td>95,334</td><td>86,868</td><td colspan="2">8,466</td></tr>
<tr><td>% Engine Type (survey)</td><td>100%</td><td>91.12%</td><td colspan="2">8.88%</td></tr>
<tr><td>Ave. Gas/yr (survey)</td><td>87.4</td><td>87.4</td><td colspan="2">87.4</td></tr>
<tr><td>Ave. Hrs/yr (survey)</td><td>32.76</td><td>32.76</td><td colspan="2">32.76</td></tr>
<tr><td>Ave. Hrs/yr (EPA)</td><td>30</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="3">Hp ranges:</td><td colspan="4">Population</td></tr>
<tr><td colspan="2">Model Default (EPA)</td><td colspan="2">Maine Data (survey)</td></tr>
<tr><td>2-stroke</td><td>4-stroke</td><td>2-stroke</td><td>4-stroke</td></tr>
<tr><td>1 to 3</td><td>301 (0.41%)</td><td></td><td>356</td><td></td></tr>
<tr><td>3 to 6</td><td>144 (0.19%)</td><td>34 (5.56%)</td><td>165</td><td>471</td></tr>
<tr><td>11 to 16</td><td>2,268 (3.06%)</td><td></td><td>2,658</td><td></td></tr>
<tr><td>16 to 25</td><td>15,030 (20.29%)</td><td></td><td>17,626</td><td></td></tr>
<tr><td>25 to 40</td><td>13,470 (18.18%)</td><td></td><td>15,793</td><td></td></tr>
<tr><td>40 to 50</td><td>9,981 (13.47%)</td><td>577 (95.44%)</td><td>11,701</td><td>8,080</td></tr>
<tr><td>50 to 100</td><td>30,593 (41.29%)</td><td></td><td>35,868</td><td></td></tr>
<tr><td>100 to 175</td><td>2,600 (3.51%)</td><td></td><td>3,049</td><td></td></tr>
</table>

Table 2.3: Inputs for ATVs in the Nonroad Model

ATVs			
	all	2-stroke	4-stroke
# Registered (survey)	39,643	11,425	28,218
% Engine Type (survey)	100%	26.82%	73.18%
Ave Gas/yr (survey)	43.6	43.6	43.6
Ave Hrs/yr (survey)	51.11	51.11	51.11
Ave Hrs/yr (EPA)	34		

Hp ranges:	Population			
	Model Default (EPA)		Maine Data (survey)	
	2-stroke	4-stroke	2-stroke	4-stroke
1 to 3	202 (2.04%)	3,792 (12.24%)	233	3,454
3 to 6	1,619 (16.32%)	8,848 (28.56%)	1,865	8,059
6 to 11	1,619 (16.32%)	7,157 (23.10%)	1,865	6,518
11 to 16	607 (6.12%)	7,157 (7.96%)	699	2,246
16 to 25	2,291 (23.10%)	1,239 (4.0%)	2,639	1,129
25 to 40	2,291 (23.10%)	2,788 (9.0%)	2,639	2,540
40 to 50	397 (4.0%)		457	
50 to 100	893 (9.0%)		1,028	

Modeling Marine SI Emissions

In order to most accurately estimate marine emissions in the year 2000, the default activity and population data to be used by the model for the State of Maine were changed to fit more accordingly with the survey data for gasoline-powered watercraft. From the survey, we were able to obtain the information needed to place Maine's watercraft population into the given horsepower ranges found in the nonroad data file. The default data was replaced with this population data for the three types of watercraft engines. Activity was available from the survey data in hours of use per year and did not have to be calculated using an equation as with snowmobiles and ATVs.

Table 2.4: Inputs for Marine SI in the Nonroad Model

	Outboard:			Inboard/Sterndrive:			Jet Drive:		
	All	2-stroke	4-stroke	All	2-stroke	4- stroke	all	2-stroke	4-stroke
# Registered (survey)	96,652			18,572			1,802		
% Total Watercraft (survey)	82.59%	73.38%	9.22%	15.87%	2.05%	13.82%	1.54%	0.85%	0.68%
% Engine Type	100.00%	88.84%	11.16%	100.00%	12.90%	87.10%	100.00%	55.56%	44.44%
Ave Gas/yr (survey)	56.33	55.24	64.94	145.03	131.5	147.04	79.67	103.4	50
Ave Hrs/yr (survey)	63.8	65.72	48.53	87.67	95.42	86.52	74.28	52.5	101.5
Ave Hrs/yr (EPA)	45			75			73		

Hp ranges:	Outboard Population		Inboard Population		Jet Drive Population	
	Model Default (EPA)	Maine Data (survey)	Model Default (EPA)	Maine Data (survey)	Model Default (EPA)	Maine Data (survey)
3 to 6	2,738 (1.63%)	7,191 (7.44%)	15 (0.04%)	201 (1.08%)		
6 to 11	31,903 (19.01%)	17,571 (18.18%)	10 (0.03%)	459 (2.47%)		
11 to 16	27,471 (16.78%)	30,948 (32.02%)	6 (0.02%)	201 (1.08%)		
16 to 25	9,895 (5.9%)	6,186 (6.40%)			133 (0.59%)	0
25 to 40	26,263 (15.65%)	8,186 (8.47%)	27 (0.08%)	9,585 (51.61%)	1,634 (7.20%)	772 (42.84%)
40 to 50	17,165 (10.23%)	11,579 (11.98%)			1,639 (7.22%)	0
50 to 100	8,838 (5.27%)	3,798 (3.93%)	234 (0.67%)	6,390 (34.41%)	14,966 (65.96%)	515 (28.58%)
100 to 175	16,281 (9.7%)	15,174 (15.7%)	23,434 (66.77%)	999 (5.38%)	4,317 (19.03%)	515 (28.58%)
175 to 300	20,144 (12.0%)	6,186 (6.40%)	10,920 (31.11%)	201 (1.08%)		
300 to 600	7,1364 (4.25%)	2,001 (2.07%)	451 (1.29%)	201 (1.08%)		

In Table 2.4, the calculated values that were used in the model are listed for each type of motorized watercraft. The default population values used by the model were in most cases larger than those obtained from the survey data. EPA's activity values were very similar to ours for jetboats, but less so for outboard and inboard/sterndrive engines.

Modeling Future Emissions from Recreational Vehicles

To estimate future emissions from nonroad vehicles, the model uses a base year (2000 in this case), and applies a growth and scrappage function to get future populations (EPA, 1998a). The data files also contain cues for regulation phase-ins, allowing the model to estimate emissions with the predicted reductions due to the regulations. The nonroad model was released in 2000; therefore the regulations for watercraft are incorporated into the main data files. The regulations for snowmobiles and ATVs were released this September, so no cues for these regulations exist in the data for this version of the model. Therefore, the future emissions estimates for ATVs and snowmobiles do not include reductions in emissions that will take place due to the newly-implemented regulation. In order to look at the effects of the regulation on future emissions from these vehicles, reductions in emissions from snowmobiles and ATVs had to be estimated by applying the percentage reductions found in Table 1.6 to the emission estimates found for the years 2010 and 2020.

Modeling Recreational Vehicle Sales

In order to estimate the effects of regulation on future recreational vehicle sales, two steps were taken. First, price elasticity estimates were obtained using OLS regression analysis. These estimates were then used along with estimated future sales based on past sales data in order to predict the regulation effects. Because we were unable to obtain price data for ATVs, the sales modeling could only be done for snowmobiles and the three types of watercraft. Interestingly, although the emissions effects due to the regulations on watercraft have been incorporated into the data files for the nonroad model, the price effects on the sales (and therefore populations) of these vehicles has not. In order to take price effects into account, the growth and scrappage function currently used by the model would have to be changed.

Obtaining Price Elasticity Estimates

We obtained price elasticity estimates for snowmobiles and the three types of watercraft. In order to do this, we modeled annual sales of these vehicles in Maine using the equation:

$$\ln S_y = \ln Inc_y + \ln Pop_y + \ln Int_y + \ln Po_y + \ln Pi_y + \ln Pj_y + \ln Ps_y$$

Where:

S_y = sales of particular vehicle type in year y

Inc_y = per capita income in Maine in 2001 dollars in year y

Pop_y = Maine's total population in year y

Int_y = real interest rate in year y

Po_y = average price of an outboard watercraft in year y in 2001 dollars

Pi_y = average price of an inboard watercraft in year y in 2001 dollars

Pj_y = average price of a personal watercraft/jetboat in year y in 2001 dollars

Ps_y = average price of a snowmobile in year y in 2001 dollars

All recreational vehicles are represented in the same equation in order to provide more observations for the econometric modeling. Because we only had complete information for the period 1992-2001, dummy variables were used for price, allowing for a larger number of observations to be used in the estimation (see Appendix D). In a log-linear demand model, the parameters for price are the price elasticities. By examining these parameters, price responsiveness to a change in price for any of the vehicles can be examined. This is useful information when examining future sales and their effects due to regulations. Because future regulation costs will be incurred, these parameters will allow us to estimate the effect of regulation on future sales of these vehicles in the State of Maine.

Predicting Future Sales

To predict the effects of the regulations on future sales, the elasticity estimates found using OLS could be used look at the effects of regulations on the sales of controlled engines. We assume that price remains constant over time for purposes of this analysis. The equation used to determine the effect of the controls on sales using the elasticity values obtained is:

$$S_y^c = S_y + e_p * (P_y^c / P) * S_y$$

Where:

S_y^c = sales of vehicles under regulation in year y

e_p = price elasticity

P_y^c = cost of regulation in year y

P = ave. price of the vehicle

S_y = estimated sales in year y

Obtaining Cost-per-ton Estimates for the Pollution Reductions

The cost per ton estimates for HC, CO and PM were calculated for snowmobiles by multiplying the costs of the regulation by the estimated number of snowmobiles to be sold in the specified year for the years 2010 and 2020[2], and then dividing this number by the tons of each pollutant reduced in that year according to the reduction estimates by the EPA (Table 1.6). Because values for reductions in pollution for watercraft could not be obtained, cost-per-ton estimates were not obtained for the three types of watercraft. This is due to the fact that the model already incorporates these reductions in the estimated future emissions output. In order to look at what emissions from these sources would be in lieu of regulation, we would have to change certain data files relating emission factors for these engines. We did not have the resources needed to do this.

[2] We used the estimated number to be sold prior to taking price effects of the regulation into account.

Chapter 3

RESULTS AND DISCUSSION

Emissions Modeling

Recreational SI

Snowmobiles

The results of the emissions modeling for snowmobiles in the years 2000, 2010 and 2020 can be seen in Table 3.1. The Model Default values are the results that were obtained using the default activity and population data files that are normally used by the model for the State of Maine. The Maine Data values are the estimates that were obtained using the activity and population files we created based on the survey data.

The differences between the values obtained using the default data and the values obtained using the survey data were varied for the different pollutants. Because the population and activity values we obtained from the survey information were both somewhat higher than what the EPA had for its defaults, we expected the results using our data to be slightly higher than those using the default data, which is what we found. Some of the differences between the two sets of results were quite significant. For example, NOx emissions were 45% higher using the survey data in the model. This was true for all three years being examined. For the remaining six pollutants, the difference were between 20 and 30 percent for all three years, with the results using EPA's data being the lower of the two sets of results.

ATVs

As with snowmobiles, the results obtained using our data differ from the results obtained using the default data. Again, our population and activity values were higher than those provided by the EPA, resulting in higher emissions estimates for the three years being examined. The differences in this case were greatest for HC and PM ($PM_{2.5}$ and PM_{10}). The results using the survey data were around 40% higher for these three pollutants for all three years. The difference in NOx emissions was significantly lower than that for snowmobiles. For ATVs, the NOx emissions were found to be around 14% higher using the survey information in every time period.

Marine SI

The emissions modeling results for watercraft can be seen in Tables 3.3, 3.4, and 3.5. The Maine Data results are lower than the Model Default results for the three years being examined. This is due to the fact that our data showed a much a smaller population size than the default data file. As mentioned in the methods section, our activity values were somewhat higher than the values that the EPA had for activity values. The difference in population size was apparently significant enough to outweigh these effects.

The differences in emissions results are interesting. For several types of pollutants, this difference is decreasing over the three time periods examined. This is most likely due to the fact that the model takes regulation effects into account for marine SI vehicles. Exhaust HC, PM_{10} and $PM_{2.5}$ show a significant decrease in the differences over the three time periods. This is different from the results for snowmobiles and ATVs, where the differences remained pretty constant over time.

The two sets of results were largely different for this particular category of recreational vehicles. All were higher than 40% for the eight pollutants in the year 2000. For more than half of the pollutants, these differences stayed above 40% for the years 2010 and 2020.

Table 3.1: Emission Modeling Results for Snowmobiles (tons of exhaust pollutants)

Snowmobiles 2000	Engine Type	Exhaust HC	Exhaust NOx	Exhaust CO	Exhaust $PM_{2.5}$	Exhaust PM_{10}	Exhaust SOx	Exhaust CO_2
Model Default (EPA data):	2-Stroke	4,974.80	35.09	13,554.45	112.34	122.11	51.66	98,020.26
	4-Stroke	2.96	1.38	184.92	0.03	0.03	0.25	410.75
	Total:	4,797.80	36.47	13,739.37	112.37	122.14	51.91	98,431.01
Maine Data (based on survey):	2-Stroke	6,423.52	45.26	17,501.48	145.05	157.67	66.61	126,416.97
	4-Stroke	45.68	21.33	2,855.96	0.45	0.49	3.89	6,326.84
	Total:	6,469.20	66.59	20,357.44	145.50	158.16	70.50	132,743.81
Difference in Totals:		1671.40	30.12	6,618.07	33.13	36.02	18.59	34,312.80
% Difference:		26%	45%	33%	23%	23%	26%	26%
2010	Engine	HC	NOx	CO	$PM_{2.5}$	PM_{10}	SOx	CO_2
Model Default (EPA data):	2-Stroke	5,360.49	37.84	14,605.39	121.05	131.58	55.70	105,687.19
	4-Stroke	3.18	1.49	199.10	0.03	0.03	0.27	442.88
	Total:	5,363.67	39.33	14,804.49	121.08	131.61	55.97	106,130.07
Maine Data (based on survey):	2-Stroke	6,922.06	48.80	18,859.90	156.31	169.91	71.82	136,305.03
	4-Stroke	49.19	22.99	3,075.60	0.49	0.53	4.20	6,821.71
	Total:	6,971.25	71.79	21,935.50	156.80	170.44	76.02	143,126.74
Difference in Totals:		1607.58	32.46	7,131.01	35.23	38.83	20.05	36,996.67
% Difference:		23%	45%	33%	22%	23%	26%	26%
2020	Engine	HC	NOx	CO	$PM_{2.5}$	PM_{10}	SOx	CO_2
Model Default (EPA Data):	2-Stroke	5,769.65	40.73	15,720.22	130.29	141.62	59.96	113,755.71
	4-Stroke	3.43	1.61	214.30	0.04	0.29	0.29	476.69
	Total:	5,773.08	42.34	15,934.52	130.33	141.91	60.25	114,232.40
Maine Data (based on survey):	2-Stroke	7,450.78	52.23	20,300.44	168.25	182.88	77.31	146,711.02
	4-Stroke	52.95	24.75	24.75	0.53	0.57	4.52	7,127.94
	Total:	7,503.73	76.98	20,325.19	168.78	183.45	81.83	153,838.96
Difference in Totals:		1,730.65	34.64	4,390.67	37.92	41.54	21.58	39,606.56
% Difference:		23%	45%	22%	23%	23%	26%	26%

Table 3.2: Emission Modeling Results for ATVs (tons of exhaust pollutants)

ATVs 2000	Engine Type	Exhaust HC	Exhaust NOx	Exhaust CO	Exhaust $PM_{2.5}$	Exhaust PM_{10}	Exhaust SOx	Exhaust CO_2
Model Default (EPA data):	2-Stroke	346.69	2.44	944.60	7.83	8.51	3.60	6,825.30
	4-Stroke	40.71	19.04	2,545.60	0.41	0.44	3.47	5,647.43
	Total:	387.40	21.48	3490.20	8.24	8.95	7.07	12,472.73
Maine Data (based on survey):	2-Stroke	602.88	4.25	1,642.61	13.61	14.80	6.25	11,869.83
	4-Stroke	44.63	20.85	2,790.47	0.48	0.44	3.81	6,189.27
	Total:	647.51	25.10	4433.08	14.09	15.24	10.06	18,059.10
Difference in Totals:		260.11	3.62	942.88	5.85	6.29	2.99	5,586.37
% Difference:		40%	14%	21%	42%	41%	30%	31%
2010	Engine	HC	NOx	CO	$PM_{2.5}$	PM_{10}	SOx	CO_2
Model Default (EPA data):	2-Stroke	370.97	2.62	1,101.74	8.38	9.11	3.85	7,309.43
	4-Stroke	43.52	20.39	2,721.71	0.43	0.47	3.72	6,048.00
	Total:	414.49	23.01	3,823.45	8.81	9.58	7.57	13,357.43
Maine Data (based on survey):	2-Stroke	645.17	4.55	1,757.84	14.57	15.84	6.70	12,711.77
	4-Stroke	47.71	22.33	2,983.71	0.48	0.52	4.08	6,626.14
	Total:	692.88	26.88	4,741.55	15.05	16.36	10.78	19,337.91
Difference in Totals:		278.39	3.87	918.10	6.24	6.78	3.21	5980.48
% Difference:		40%	14%	19%	41%	41%	30%	31%
2020	Engine	HC	NOx	CO	$PM_{2.5}$	PM_{10}	SOx	CO_2
Model Default (EPA data):	2-Stroke	398.89	2.83	1,086.84	9.01	9.79	4.14	7,862.97
	4-Stroke	46.76	21.93	2,924.87	0.47	0.51	4.00	6,506.02
	Total:	445.65	24.76	4,011.71	9.48	10.30	8.14	14,368.99
Maine Data (based on survey):	2-Stroke	694.03	4.90	1,890.98	15.67	17.04	7.21	13,674.43
	4-Stroke	51.43	24.03	3,209.88	0.51	0.56	4.39	7,127.94
	Total:	745.46	28.93	5,100.86	16.18	17.60	11.60	20,802.37
Difference in Totals:		299.81	4.17	1,089.15	6.70	7.30	3.46	6,433.38
% Difference:		40%	14%	21%	41%	41%	27%	31%

Table 3.3: Emission Modeling Results for Marine SI, 2000

Watercraft 2000	Equipment Description	Engine Type	Exhaust HC	Exhaust NOx	Exhaust CO	Exhaust $PM_{2.5}$	Exhaust PM_{10}	Exhaust SOx	Exhaust CO_2
Model Default:	Outboard	2 Stroke	7,904.94	201.59	18,273.27	445.78	484.54	95.24	118,766.90
	PWC/Jetboat	2 Stroke	4,962.98	27.91	10,229.89	213.73	232.32	42.73	57,808.27
	Inboard/Sterndrive	4 Stroke	587.06	565.58	12,854.42	6.43	6.99	66.73	67,299.63
Total:			13,454.98	795.08	41,357.58	665.94	723.85	204.70	243,874.80
Maine Data:	Outboard	2 Stroke	6,716.05	147.07	15,136.70	382.67	415.94	82.44	102,400.81
	PWC/Jetboat	2 Stroke	330.97	2.03	683.97	14.85	16.15	3.00	3,999.51
	Inboard/Sterndrive	4 Stroke	184.29	147.57	3,678.97	1.83	1.99	19.16	19,375.45
Total:			7,231.31	296.67	19,499.64	399.35	434.08	104.60	125,775.77
Difference in Totals:			6,223.67	498.41	21,857.94	266.59	289.77	242.09	118,099.03
% Difference:			46%	63%	53%	40%	40%	49%	48%

Table 3.4: Emission Modeling Results for Marine SI, 2010

Watercraft 2010	Equipment Description	Engine Type	Exhaust HC	Exhaust NOx	Exhaust CO	Exhaust $PM_{2.5}$	Exhaust PM_{10}	Exhaust SOx	Exhaust CO_2
Model Default:	Outboard	2 Stroke	5,806.46	250.99	18,878.20	459.43	499.38	108.37	124,972.06
	PWC/Jetboat	2 Stroke	1,475.62	142.33	8,755.33	51.63	56.12	35.95	40,014.23
	Inboard/Sterndrive	4 Stroke	624.31	605.69	13,680.97	6.84	7.43	71.47	72,073.26
Total:			7,096.39	998.12	41,314.50	517.90	562.93	215.79	237,059.55
Maine Data:	Outboard	2 Stroke	4,498.95	208.59	15,980.29	379.44	412.44	93.66	106,350.76
	PWC/Jetboat	2 Stroke	112.28	9.39	611.48	4.32	4.7	2.56	2,869.15
	Inboard/Sterndrive	4 Stroke	197.87	159.21	3,951.78	1.97	2.14	20.68	20,903.60
Total:			4,809.10	377.19	20,543.55	385.73	419.28	116.90	130,123.51
Difference in Totals:			2,287.29	621.82	20,770.95	132.17	143.65	98.89	106,936.04
% Difference:			32%	62%	50%	26%	26%	46%	45%

Table 3.5: Emission Modeling Results for Marine SI, 2020

Watercraft 2010	Equipment Description	Engine Type	Exhaust HC	Exhaust NOx	Exhaust CO	Exhaust $PM_{2.5}$	Exhaust PM_{10}	Exhaust SOx	Exhaust CO_2
Model Default:	Outboard	2 Stroke	4,297.00	308.74	19,831.49	474.59	515.86	120.44	132,011.17
	PWC/Jetboat	2 Stroke	687.10	179.56	8,934.96	13.03	14.17	36.25	37,793.60
	Inboard/Sterndrive	4 Stroke	673.42	651.56	14,752.41	7.37	8.01	76.88	77,531.39
Total:			5,657.52	1,139.86	43,518.86	494.99	538.04	233.57	247,336.16
Maine Data:	Outboard	2 Stroke	3,932.36	244.99	17,218.48	388.45	422.23	101.08	111,830.99
	PWC/Jetboat	2 Stroke	49.06	12.20	625.57	1.04	1.13	2.52	2,635.74
	Inboard/Sterndrive	4 Stroke	212.40	170.90	4,241.89	2.11	2.30	22.20	22,438.45
Total:			4,193.82	428.09	22,085.94	391.60	425.66	125.80	136,905.18
Difference in Totals:			1,463.70	711.77	21,432.92	103.39	112.38	107.77	110,430.98
% Difference:			26%	62%	49%	21%	21%	46%	45%

Emission Reductions due to Regulation

The emission reductions due to the new regulations on snowmobiles and ATVs for the years 2010 and 2020 can be seen in Table 3.6. These reduction estimates were obtained using the figures in Table 1.6 for the predicted reductions for four pollutants, along with the modeling results. Using the Maine Data values for snowmobiles and ATVs, the percentage reduction estimates in Table 1.6 were applied to the estimated tonnage of pollution for the four pollutants in 2010 and 2020 to get the tonnage reduction estimates.

The NOx estimates are in parentheses because these figures represent an increase rather than a decrease in NOx emissions due to the regulations. As discussed in the Literature Review section, NOx and VOC are the precursors that form ozone. Ozone is in most cases "NOx-limited", which means that a relatively small amount of NOx can enable the formation of high amounts of ozone when VOC levels are high (EPA, 2002e). Ozone can also be "VOC-limited" in areas where amounts of NOx are very high, and levels of VOC are quite low. This usually happens in areas that are very urban. Because recreational vehicles are more likely to be ridden in areas that are NOx-limited, this raises the question of why the regulation has been put forward as it has.

Because ozone forms more readily in warmer temperatures, the NOx increase is not as serious a problem with snowmobiles. All-terrain vehicles are ridden all year, so this is a problem when considering ATV use. The EPA stated in the support document that NOx levels would be lowered starting in the year 2012 for snowmobiles, but they don't mention anything about decreasing NOx emissions from ATVs. Given this understanding, it is interesting that they do not consider this in the regulation of these vehicles.

Sales Modeling Results

Price Elasticity Estimates

Using sales data for the years 1992 through 2001 (Appendix A), the theoretical model discussed earlier was run using OLS. The output from this regression can be seen below. All of the price variables were significant for a 99% confidence interval. None of the other independent variables were significant, but it was felt that they should still be kept in the model because they are variables that should be in the equation. The overall fit of the model was good, having an R-squared value of 0.7823. The F-value was 16.43, making the overall fit of the variables significant within a 99% confidence interval.

$$\ln(S_y) = -42.53 - 0.27\ln(inc_y) + 5.33\ln(pop_y) + 0.84\ln(int_y) - 2.53\ln(Po_y) - 2.19\ln(Pi_y) - 2.68\ln(Pj_y) - 2.52\ln(Ps_y) + \ln(e)$$

All of the price variables ended up having very similar price elasticities. These values were similar to the EPA's estimates for price elasiticities for these vehicles (EPA, 2002e). The EPA estimated a –2.1 price elasticity for both snowmobiles and ATVs based on a study done on boats which estimated the price elasticity for motorboats to be -2.0.

Table 3.6: Reductions in Emissions Due to Regulation for Snowmobiles and ATVs (tons of pollution)

Snowmobiles		HC		CO		NOx		PM	
		Maine Data	Model Default	Maine Data	Model Default	Maine Data	Model Default	Maine Data	Model Default
2010	% Reduction:	15%	15%	15%	15%	(16%)	(16%)	4%	4%
	Tons Reduced:	1,045.69	804.55	3,290.32	2,220.67	(11.49)	(6.29)	13.09	10.11
2020	% Reduction:	57%	57%	46%	46%	(101%)	(101%)	42%	42%
	Tons Reduced:	4,277.13	3,290.66	9,349.59	7,329.88	(77.74)	(42.76)	147.94	114.34
ATVs		HC		CO		NOx		PM	
		Maine Data	Model Default	Maine Data	Model Default	Maine Data	Model Default	Maine Data	Model Default
2010	% Reduction:	32%	32%	5%	5%	(11%)	(11%)	32%	32%
	Tons Reduced:	221.72	132.64	437.08	191.17	(2.96)	(2.53)	10.05	5.88
2020	% Reduction:	86%	86%	13%	13%	(25%)	(25%)	86%	86%
	Tons Reduced:	641.09	383.26	663.11	521.52	(7.23)	(6.19)	29.05	17.01

Sales Regressions

A logarithmic trendline seemed to be the best fit for each of the sales datasets. Sales were forecasted 15 years into the future using regression analysis. Maine watercraft sales first are slightly declining, and then leveling off. Snowmobile sales are increasing, and then leveling off. This follows the trend in overall U.S. sales (Appendices B, C).

Figure 3.1: Maine Watercraft Sales

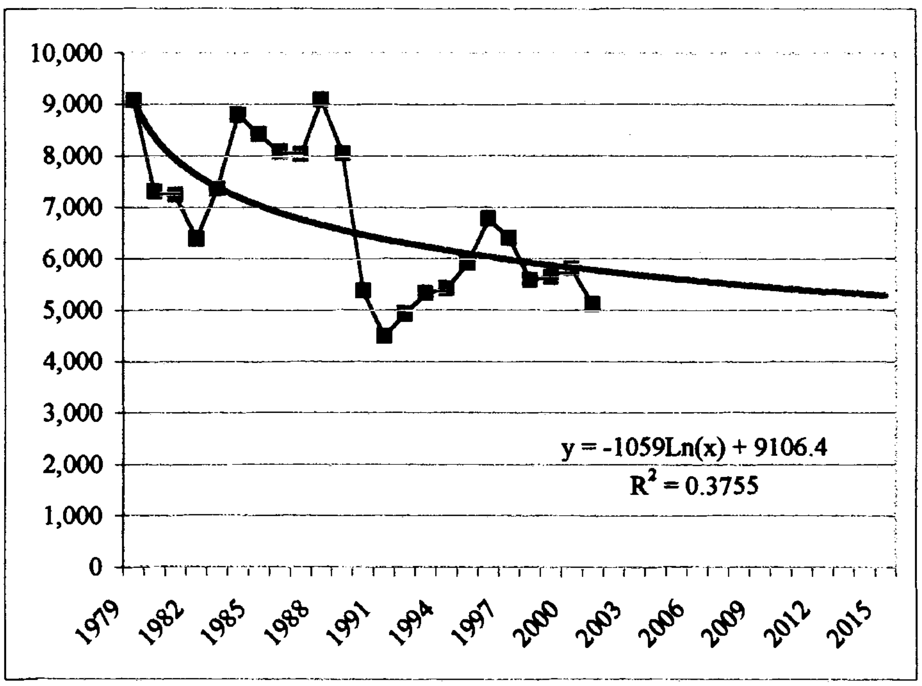
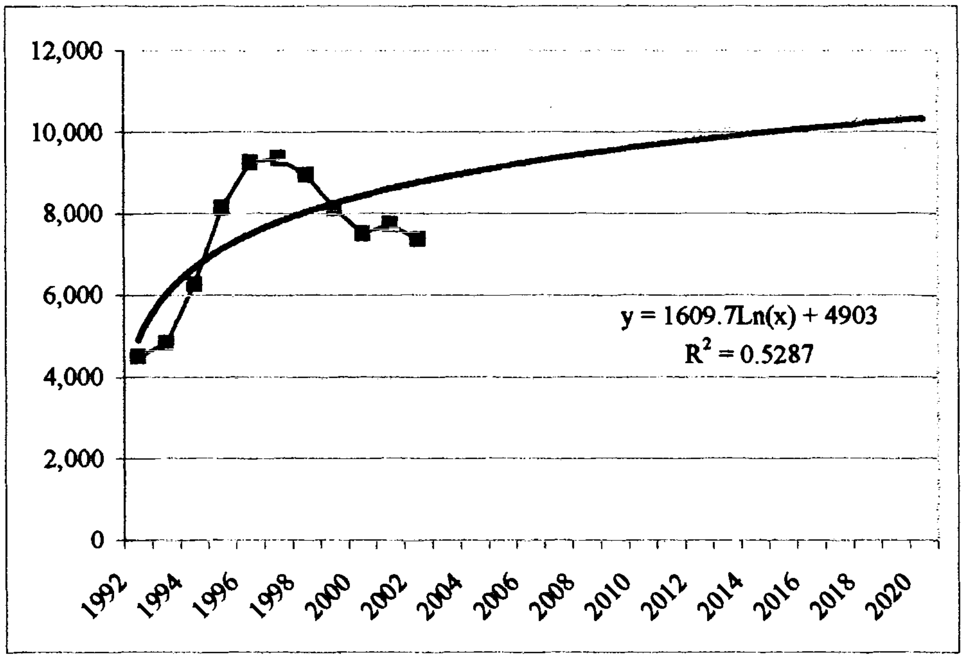


Figure 3.2: Maine Snowmobiles Sales



Effects of Regulations on Sales

Figures 3.3 – 3.5 outline the effects of the regulations for snowmobiles and watercraft on sales of these vehicles in Maine. There are three phase-in periods for the regulations on air emissions from snowmobiles (Table 1.4). Each of these is represented in the figures. Effects of the regulations on sales of snowmobiles are shown for both short and long-term costs. Figure 3.5 shows future watercraft sales decreasing somewhat rapidly and then leveling out well below the trendline for predicted sales. This is due to two things. First, the average price for a vehicle from this category was found to be \$3,899 in 2001 as compared to an average price of \$6,127 for snowmobiles (Appendix E). Price elasticities were shown to be quite elastic for both vehicle categories (around – 2.5). This, coupled with the fact that control costs are relatively high and increasing over the 2002 to 2006 time period, causes the resulting effects on future watercraft sales shown.

Figure 3.3: Effects of Controls on Future Snowmobile Sales in Maine (short-term costs)

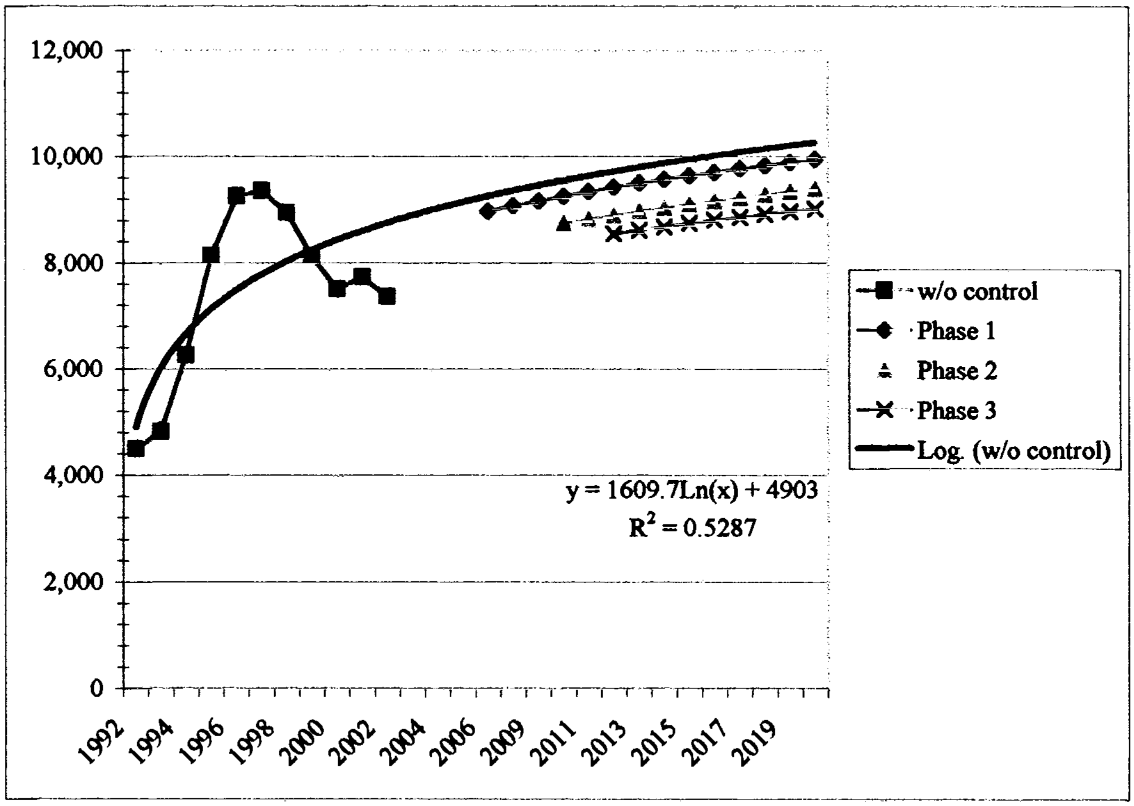


Figure 3.4: Effects of Controls on Future Snowmobile Sales in Maine (long-term costs)

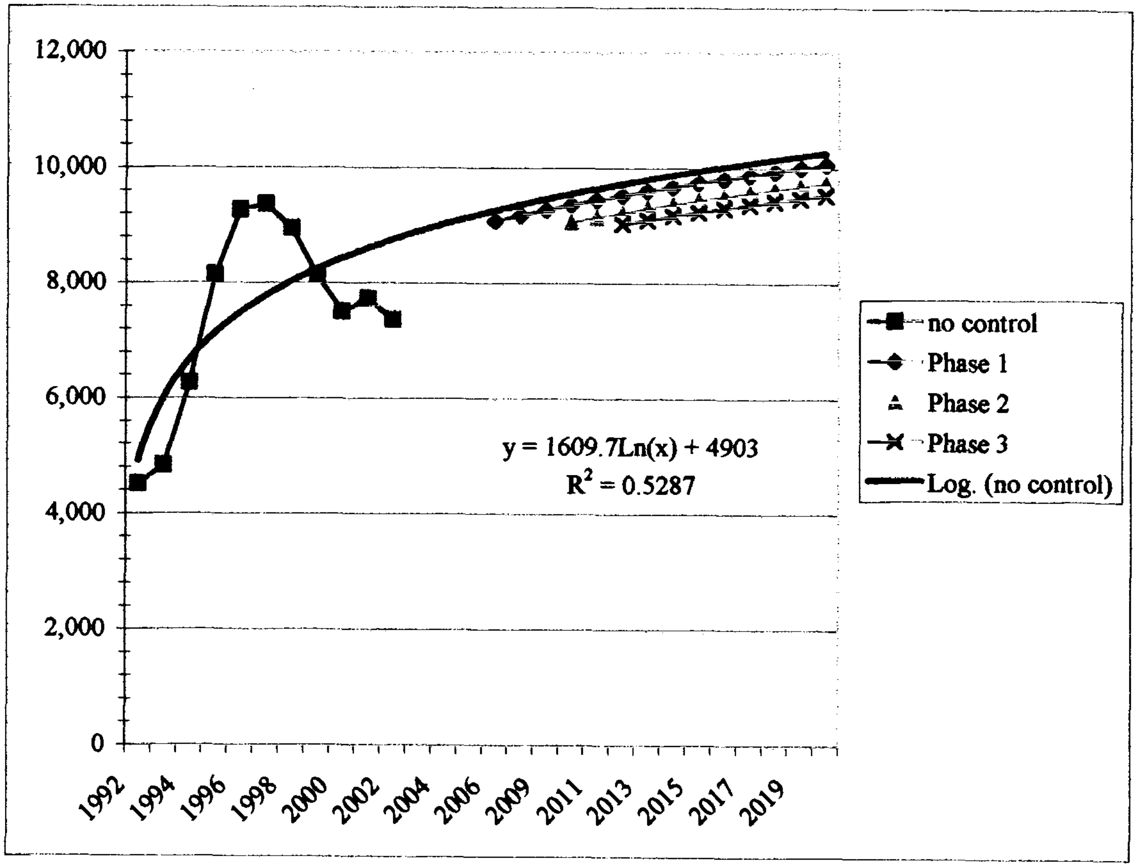
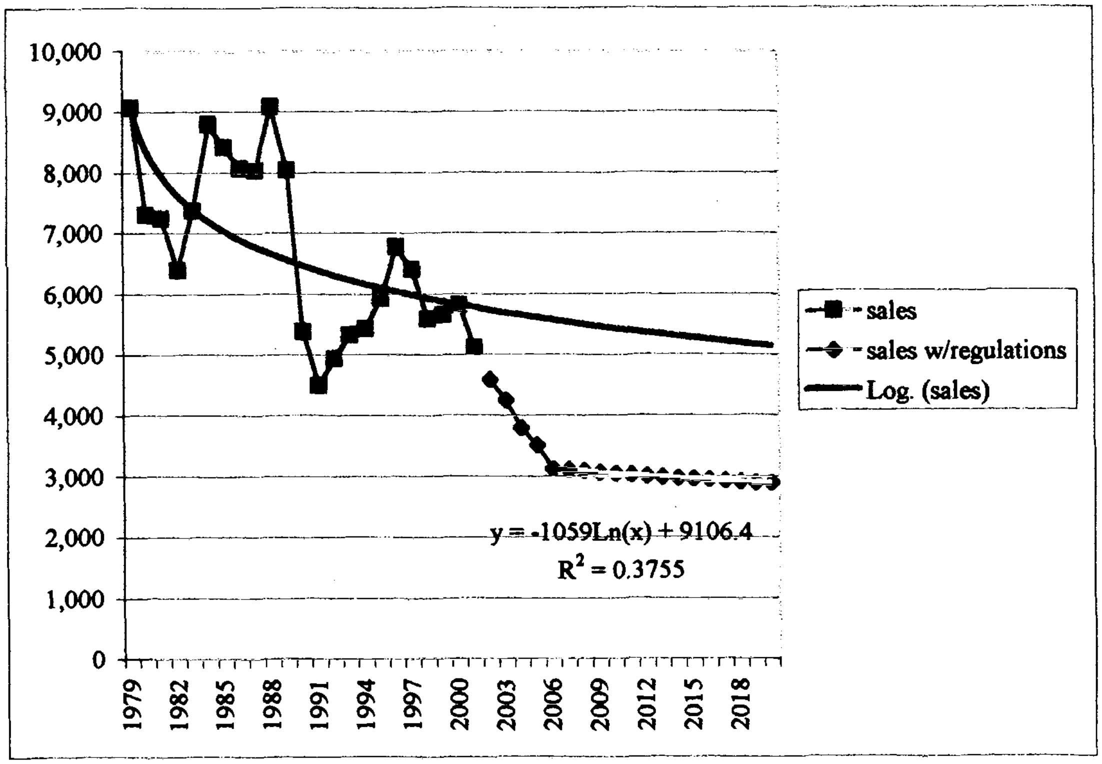


Figure 3.5: Effects of Controls on Future Watercraft Sales in Maine



Basic estimates for the costs of the regulations in terms of lost sales can be seen in Tables 3.7 and 3.8. One of the alternatives considered in the regulatory support document for the regulations on snowmobiles involves withholding further regulations after the first or second phase-in period. Therefore, we decided to estimate the total cost through the year 2020 in terms of lost revenues for each phase-in period separately.

These estimates for the reductions in sales rely on the premise that the entire change in price due to the cost of the regulation is passed on to consumers from the producers. It also is based on the assumption that none of the factors that shift demand are in place (price of substitutes or compliments, changes in income, tastes and preferences). For example, with the increased price of snowmobile, normally snowmobilers may choose to switch to other forms of recreational entertainment, such as riding ATVs or hiking. This is assuming none of those type changes are taking place. This is also assuming no shift in supply is taking place, which would necessarily affect price. Therefore, this presents a very rough estimate as to what the decrease in revenues might actually be under future regulations on these vehicles.

This analysis does not take into consideration the fuel-cost savings that consumers will encounter due to the increased efficiency levels of these engines. In many cases, the fuel-savings benefits over the lifetime of the vehicle outweigh the initial increased costs due to regulation (Table 1.5). Some individuals may value initial costs way above future savings, while others may take these savings into consideration when purchasing one of these vehicles.

Table 3.7: Predicted Reductions in Sales Due to Regulation

Year	Decline in Watercraft Sales	Using Short-term Costs			Using Long-term Costs		
		Decline in Snowmobile Sales (phase 1)	Decline in Snowmobile Sales (phase 2)	Decline in Snowmobile Sales (phase 3)	Decline in Snowmobi le Sales (phase 1)	Decline in Snowmobile Sales (phase 2)	Decline in Snowmobile Sales (phase 3)
2002	1,155 (20%)						
2003	1,445 (25%)						
2004	1,855 (33%)						
2005	2,093 (37%)						
2006	2,445 (44%)	278 (3%)			179 (2%)		
2007	2,429 (44%)	281 (3%)			181 (2%)		
2009	2,413 (44%)	284 (3%)			183 (2%)		
2010	2,398 (44%)	287 (3%)	802 (8%)		185 (2%)	487 (5%)	
2011	2,383 (44%)	290 (3%)	809 (8%)		186 (2%)	492 (5%)	
2012	2,369 (44%)	292 (3%)	816 (8%)	1,172 (12%)	188 (2%)	496 (5%)	688 (7%)
2013	2,355 (44%)	294 (3%)	823 (8%)	1,181 (12%)	190 (2%)	500 (5%)	694 (7%)
2014	2,341 (44%)	297 (3%)	829 (8%)	1,190 (12%)	191 (2%)	504 (5%)	699 (7%)
2015	2,328 (44%)	299 (3%)	835 (8%)	1,199 (12%)	192 (2%)	507 (5%)	704 (7%)
2016	2,316 (44%)	301 (3%)	841 (8%)	1,207 (12%)	194 (2%)	511 (5%)	709 (7%)
2017	2,303 (44%)	303 (3%)	846 (8%)	1,215 (12%)	195 (2%)	514 (5%)	713 (7%)
2018	2,291 (44%)	305 (3%)	851 (8%)	1,223 (12%)	196 (2%)	518 (5%)	718 (7%)
2019	2,279 (44%)	306 (3%)	857 (8%)	1,230 (12%)	197 (2%)	521 (5%)	722 (7%)
2020	2,268 (44%)	308 (3%)	861 (8%)	1,237 (12%)	198 (2%)	524 (5%)	726 (7%)
Total	41,723	4,125	9,169	10,856	2,656	5,573	6,373

Cost-per-ton Reduction Estimates

Cost-per-ton values were calculated for the reduction of emissions from snowmobiles for three types of pollutants. This was done using both the default and Maine data emissions estimates. Due to the differences in the Model Default and Maine Data emissions estimate results, there were significant differences in the cost-per-ton estimates using each of these. This is an interesting and important result, because it shows how sensitive these estimates are to small differences in the source data.

There was a 23% difference in cost-per-ton estimates for HC and PM for both years being examined, with the estimates obtained using the Model Default data results being the higher of the two (Table 3.8). For CO, this difference was 33% in 2010 and 22% in 2020. This is an important result for several reasons. If the Maine Data results are the more accurate of the two, this means that cost-per-ton as calculated in this manner are estimated at a higher value than they should be when using the data provided for use by the Nonroad Model. If Maine were to draft it's own air emission policies for snowmobiles based on results using the default data in the nonroad model, then they would be placing a higher value on each ton of pollution to be reduced than what it should be.

Table 3.8: Cost-per-ton Reduction Estimates for Snowmobiles

Snowmobiles		HC			CO			PM		
		Maine	Default	% difference	Maine	Default	% difference	Maine	Default	% difference
2010	short-term	$1,881.22	$2,445.06	23%	$597.87	$885.85	33%	$150,280.52	$194,576.85	23%
	long-term	$1,143.49	$1,486.21	23%	$363.41	$538.46	33%	$91,346.98	$118,272.21	23%
2020	short-term	$703.33	$914.17	23%	$321.75	$410.41	22%	$20,334.13	$26,309.52	23%
	long-term	$412.87	$536.65	23%	$188.88	$240.92	22%	$11,936.76	$15,444.50	23%

Chapter 4

CONCLUSION

This research has accomplished several goals in examining air emissions from recreational vehicles in Maine. It was found that snowmobiles in Maine produced almost 5000 tons of HC, and that motorized watercraft produced close to 13,500 tons of HC emissions in the year 2000. Given that nonroad sources produced 40% of the volatile organic compounds (a subset of HC) in 1999, it is apparent that regulation on these vehicles is an important step in reducing overall air emissions for the state.

Costs of regulation on recreational vehicles will affect sales. It was found from our sales regressions that the regulations proposed for snowmobiles will cause a 12% decline in sales in 2012. This is a significant result, although the actual reduction in sales will be dependent on how much of the regulation costs are absorbed by consumers and how much of the costs are absorbed by the manufacturers.

Cost-per-ton estimates for the reduction of pollution from snowmobiles were significantly different using the emissions reductions estimates found using the data supplied for use by the Nonroad Model by the EPA, and the data obtained using the gasoline consumption survey for snowmobiles. This is an important result when considering drafting state air emission policies for these vehicles.

In conclusion, this research provides an overview of the impact of recreational vehicle use on air emissions in the State of Maine. This report has provided a comparison between EPA's data and our own for the activity values levels and populations of these vehicles in the state. The two sets of data provided different emission and cost-per-ton estimate results. Even small differences in population and activity had profound effects on the differences in emissions estimates, and therefore the cost-per-ton estimates for the reduction in pollution from these sources. This conclusion outlines the importance of having accurate data, to the extent possible, for purposes of regulation. This research has provided an important step from national to state-level information, and is a good background for further research and policy work on air emissions from these sources.

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APPENDIX A: Populations of Recreational Vehicles in Maine

The *watercraft adj* column is the number of watercraft adjusted by 7% to account for the subtraction of diesel engines. Seven percent is the percentage of diesel watercraft out of the total population according to the 2001 survey data.

APPENDIX A: Populations of Recreational Vehicles in Maine

year	snowmobiles	atvs	watercraft	watercraft adj
1970				
1971	42,933			
1972	53,879			
1973	65,960			
1974	60,623			
1975	73,737			
1976	71,222		118,381	110,094
1977	71,502		110,790	103,035
1978	67,421		114,403	106,395
1979	63,646		117,167	108,965
1980	40,869		113,714	105,754
1981	51,511		115,090	107,034
1982	57,178		117,212	109,007
1983	42,177		116,419	108,270
1984	47,862		117,842	109,593
1985	48,881	19,993	119,038	110,705
1986	51,347	26,003	115,440	107,359
1987	56,582	21,029	114,182	106,189
1988	58,148	19,276	123,723	115,062
1989	56,615	19,577	132,039	122,796
1990	64,848	19,832	112,559	104,680
1991	61,641	21,310	111,308	103,516
1992	63,471	20,671	112,981	105,072
1993	64,985	21,447	113,590	105,639
1994	70,043	22,390	115,123	107,064
1995	71,306	23,857	115,895	107,782
1996	76,821	24,324	127,905	118,952
1997	77,752	27,270	133,529	124,182
1998	84,205	28,834	126,665	117,798
1999	81,935	23,414	129,226	120,180
2000	80,467	27,153	126,478	117,625
2001	75,350	31,567		

Source: IFW, 2001

APPENDIX B: Sales Estimations for Snowmobiles

Maine made up around 5.5% of total U.S. sales according to ISMA data in 2001. We make an assumption here that this is the percentage of total U.S. sales for the total time period for which we have data.

APPENDIX B: Sales Estimations for Snowmobiles

year	snowmobile sales (U.S.)	snowmobile sales (ME)
1971		
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991		
1992	81,946	4,507
1993	87,809	4,829
1994	114,057	6,273
1995	148,207	8,151
1996	168,509	9,268
1997	170,325	9,368
1998	162,826	8,955
1999	147,867	8,133
2000	136,601	7,513
2001	140,629	7,735
2002	134,082	7,375

Source: ISMA, 2002

APPENDIX C: Sales Estimations for Watercraft

The *Maine Reg %* column refers to the percentage of Maine registrations out of the total U.S. registrations for the years given. This number multiplied by the total U.S. sales was used to obtain the values in the column *est sales (ME)*. Using industry data, the percentages of total U.S. sales that each of the three watercraft types made up were obtained. These numbers were then multiplied by the *est sales (ME)* that were adjusted for deisel engines to get the Maine sales in each year for the three types of watercraft.

APPENDIX C: Sales Estimations for Watercraft

year	ME reg %	sales (US)	est sales (ME)	est sales (ME) (adj for deisel)	%			#		
					outboard	inboard	jetboat	outboard	inboard	jetboat
1979	0.014	798,600	11,180	10,397	0.873	0.127		9,077	1,320	
1980	0.013	669,200	8,700	8,091	0.903	0.096		7,306	777	
1981	0.013	658,400	8,559	7,960	0.910	0.090		7,243	716	
1982	0.013	592,325	7,700	7,161	0.893	0.107		6,395	766	
1983	0.013	700,385	9,105	8,468	0.871	0.129		7,375	1,092	
1984	0.013	851,280	11,067	10,292	0.855	0.145		8,800	1,492	
1985	0.013	828,700	10,773	10,019	0.841	0.159		8,426	1,593	
1986	0.012	862,000	10,344	9,620	0.840	0.160		8,081	1,539	
1987	0.011	949,700	10,447	9,716	0.828	0.172		8,045	1,671	
1988	0.012	983,900	11,807	10,981	0.828	0.172		9,092	1,889	
1989	0.012	875,400	10,505	9,770	0.824	0.176		8,050	1,719	
1990	0.010	691,000	6,910	6,426	0.838	0.162		5,385	1,041	
1991	0.010	634,800	6,348	5,904	0.762	0.131		4,499	773	
1992	0.010	627,950	6,280	5,840	0.739	0.135	0.107	4,316	788	625
1993	0.010	680,175	6,802	6,326	0.717	0.126	0.126	4,536	797	797
1994	0.009	771,400	6,943	6,457	0.684	0.132	0.157	4,417	852	1,014
1995	0.009	868,660	7,818	7,271	0.631	0.122	0.184	4,588	887	1,338
1996	0.010	833,950	8,340	7,756	0.627	0.127	0.247	4,863	985	1,916
1997	0.010	794,100	7,941	7,385	0.632	0.132	0.236	4,667	975	1,743
1998	0.009	763,100	6,868	6,387	0.692	0.124	0.184	4,420	792	1,175
1999	0.009	774,600	6,971	6,483	0.726	0.127	0.147	4,707	823	953
2000	0.009	788,900	7,100	6,603	0.757	0.118	0.125	4,998	779	825
2001	0.009	708,300	6,375	5,929	0.738	0.136	0.126	4,375	806	747

Source: NMMA, 2001

APPENDIX D: Data Used in OLS Regression Analysis

This table presents the data used to obtain price elasticity estimates using OLS regression analysis. The *#sold* column was obtained as described in the previous appendices that described obtaining sales estimates. *Population* refers to Maine's population, *int (real)* is the real interest rate, and *Po, Pi, Pj,* and *Ps* represent the prices for outboard watercraft, inboard watercraft, jetboats, and snowmobiles in 2001 dollars, respectively.

APPENDIX D: Data Used in OLS Regression Analysis

year	type	#sold	income	pop	int (real)	Po	Pi	Pj	Ps
1992	out board	4,316	23,111	1,235,748	3.3	5,733	0	0	0
	inboard	5,052	23,111	1,235,748	3.3	0	29,371	0	0
	jetboat	736	23,111	1,235,748	3.3	0	0	6,397	0
	snowmobile	4,507	23,111	1,235,748	3.3	0	0	0	5,484
1993	out board	4,536	22,979	1,238,256	3.1	5,721	0	0	0
	inboard	5,248	22,979	1,238,256	3.1	0	29,237	0	0
	jetboat	712	22,979	1,238,256	3.1	0	0	7,080	0
	snowmobile	4,829	22,979	1,238,256	3.1	0	0	0	5,760
1994	out board	4,417	23,246	1,237,687	4.6	6,110	0	0	0
	inboard	5,605	23,246	1,237,687	4.6	0	31,846	0	0
	jetboat	1,189	23,246	1,237,687	4.6	0	0	6,770	0
	snowmobile	6,273	23,246	1,237,687	4.6	0	0	0	5,856
1995	out board	4,588	23,406	1,237,438	6.1	6,827	0	0	0
	inboard	6,384	23,406	1,237,438	6.1	0	22,547	0	0
	jetboat	1,796	23,406	1,237,438	6.1	0	0	6,962	0
	snowmobile	8,151	23,406	1,237,438	6.1	0	0	0	6,204
1996	out board	4,863	23,888	1,241,436	5.4	7,002	0	0	0
	inboard	6,771	23,888	1,241,436	5.4	0	37,688	0	0
	jetboat	1,908	23,888	1,241,436	5.4	0	0	7,441	0
	snowmobile	9,268	23,888	1,241,436	5.4	0	0	0	6,063
1997	out board	4,668	24,423	1,245,215	6.2	7,534	0	0	0
	inboard	975	24,423	1,245,215	6.2	0	40,946	0	0
	jetboat	1,743	24,423	1,245,215	6.2	0	0	7,526	0
	snowmobile	9,368	24,423	1,245,215	6.2	0	0	0	6,516
1998	out board	4,420	25,429	1,247,554	6.8	7,421	0	0	0
	inboard	5,596	25,429	1,247,554	6.8	0	41,042	0	0
	jetboat	1,176	25,429	1,247,554	6.8	0	0	7,916	0
	snowmobile	8,955	25,429	1,247,554	6.8	0	0	0	6,506
1999	out board	4,707	25,798	1,253,040	5.8	8,479	0	0	0
	inboard	823	25,798	1,253,040	5.8	0	44,495	0	0
	jetboat	953	25,798	1,253,040	5.8	0	0	8,328	0
	snowmobile	8,133	25,798	1,253,040	5.8	0	0	0	6,346
2000	out board	4,999	26,102	1,274,923	6.0	8,988	0	0	0
	inboard	765	26,102	1,274,923	6.0	0	51,097	0	0
	jetboat	839	26,102	1,274,923	6.0	0	0	8,760	0
	snowmobile	7,513	26,102	1,274,923	6.0	0	0	0	6,171
2001	out board	4,376	26,385	1,286,670	4.2	9,259	0	0	0
	inboard	806	26,385	1,286,670	4.2	0	57,033	0	0
	jetboat	747	26,385	1,286,670	4.2	0	0	8,635	0
	snowmobile	7,735	26,385	1,286,670	4.2	0	0	0	6,360

APPENDIX E: Snowmobile Sales Reductions Due to Regulations

price elasticity: -2.52
average price: $6,127

	year	short-term	long-term
control cost phase 1:	2006	$73	$47
control cost phase 2:	2010	$204	$124
control cost phase 3:	2012	$293	$172

year	est sales	short-term				long-term			
		percentage decrease	sales w/control			percentage decrease	sales w/control		
			phase 1	phase 2	phase 3		phase 1	phase 2	phase 3
2006	9,262	phase 1: -0.03	8,984			phase 1: -0.02	9,083		
2007	9,366		9,085				9,185		
2009	9,464		9,179				9,281		
2010	9,556	phase 2: -0.08	9,269	8,754		phase 2: -0.05	9,371	9,068	
2011	9,643		9,353	8,834			9,456	9,151	
2012	9,725	phase 3: -0.12	9,433	8,909	8,553	phase 3: -0.07	9,537	9,229	9,037
2013	9,804		9,509	8,981	8,622		9,614	9,304	9,110
2014	9,879		9,582	9,050	8,688		9,688	9,375	9,180
2015	9,950		9,651	9,115	8,751		9,758	9,443	9,246
2016	10,019		9,718	9,178	8,811		9,825	9,508	9,310
2017	10,084		9,782	9,238	8,869		9,889	9,570	9,371
2018	10,148		9,843	9,296	8,925		9,951	9,630	9,430
2019	10,208		9,902	9,352	8,978		10,011	9,688	9,486
2020	10,267		9,959	9,405	9,030		10,068	9,743	9,541

Sales reductions were obtained using the equation found on page 21 in the text. The average prices used in these estimations was the average price of the vehicle in question over the range of years for which we had data in 2001 dollars.

APPENDIX F: Watercraft Sales Reductions Due to Regulations

price elasticity: -2.46
average price: $3,899

year	control cost	est sales	percentage decrease	sales w/ controls
2002	$319	5741	-0.20	4586
2003	$402	5698	-0.25	4253
2004	$520	5656	-0.33	3801
2005	$591	5616	-0.37	3523
2006	$695	5578	-0.44	3133
2007	$695	5540	-0.44	3112
2008	$695	5505	-0.44	3092
2009	$695	5470	-0.44	3072
2010	$695	5436	-0.44	3053
2011	$695	5404	-0.44	3035
2012	$695	5372	-0.44	3017
2013	$695	5341	-0.44	3000
2014	$695	5311	-0.44	2983
2015	$695	5282	-0.44	2967
2016	$695	5254	-0.44	2951
2017	$695	5227	-0.44	2936
2018	$695	5200	-0.44	2920
2019	$695	5174	-0.44	2906
2020	$695	5148	-0.44	2891

Sales reductions were obtained using the equation found on page 21 in the text. The average prices used in these estimations was the average price of the vehicle in question over the range of years for which we had data in 2001 dollars.

BIOGRAPHY OF THE AUTHOR

Erin Bock was born in Gainesville, Florida on November 22, 1975. She was raised in Sylva, North Carolina, and graduated from Smoky Mountain High School in 1994. She then attended Western Carolina University and received her Bachelor's degree in Biology in 1998. Erin is a candidate for the Master of Science degree in Resource Economics and Policy in May, 2003.