Nine Ports in the 49th State:
Commercial Marine Inventory for Alaska

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ABSTRACT

In Alaska, marine travel is an essential part of the interstate transportation system, and marine vessels are responsible for the movement of many goods into the State. In addition, marine tourism is an important contributor to the state's economy. Under contract to the Alaska Department of Environmental Conservation (ADEC), E.H. Pechan & Associates, Inc. (Pechan) prepared 2002 base year and forecast year commercial marine emissions inventories for several key ports. The ports included Anchorage, Dutch Harbor, Homer, Juneau, Ketchikan, Kivalina, Kodiak, Nikiski, and Valdez. Emission estimates were developed for the following pollutants: sulfur dioxide (SO_2), oxides of nitrogen (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), ammonia (NH_3), and volatile organic compounds (VOCs). These inventories will support analyses to characterize the emission reductions that will be needed to achieve and maintain compliance with regional haze standards.

This paper describes the data sources and procedures used to characterize activity for the vessel fleet calling on the ports of interest, including passenger ships, tankers, cargo ships, and fishing vessels. The emissions inventory accounts for cruise-related activity 25 miles out from the breakwater, reduced speed zone (RSZ) and maneuvering activity, and time spent in port (hotelling). Emissions estimates by port are also presented. An emissions inventory for these ports had not been developed prior to this effort. As such, this project was valuable in establishing data availability and inventory data needs with various Alaska State agencies, including the Marine Exchange of Alaska, the Alaska Marine Highway System, and the Commercial Fisheries Entry Commission. Recommendations for future research to improve the inventory are also presented.

INTRODUCTION

The Alaska Department of Environmental Conservation (ADEC) is currently working to develop a statewide emissions inventory for all sources for criteria and regional haze pollutants. To date, Alaska has not prepared a specific emission inventory of marine sources, and as such is now focusing on preparing an inventory for this sector. Much of Alaska is not connected by an integrated system of roads. Therefore, marine travel is an important part of the transportation system. Marine tourism is an important part of the economy and marine transportation is necessary for the movement of goods into the State. E.H. Pechan & Associates, Inc. (Pechan) provided support to ADEC in preparing an emissions inventory for this important sector.

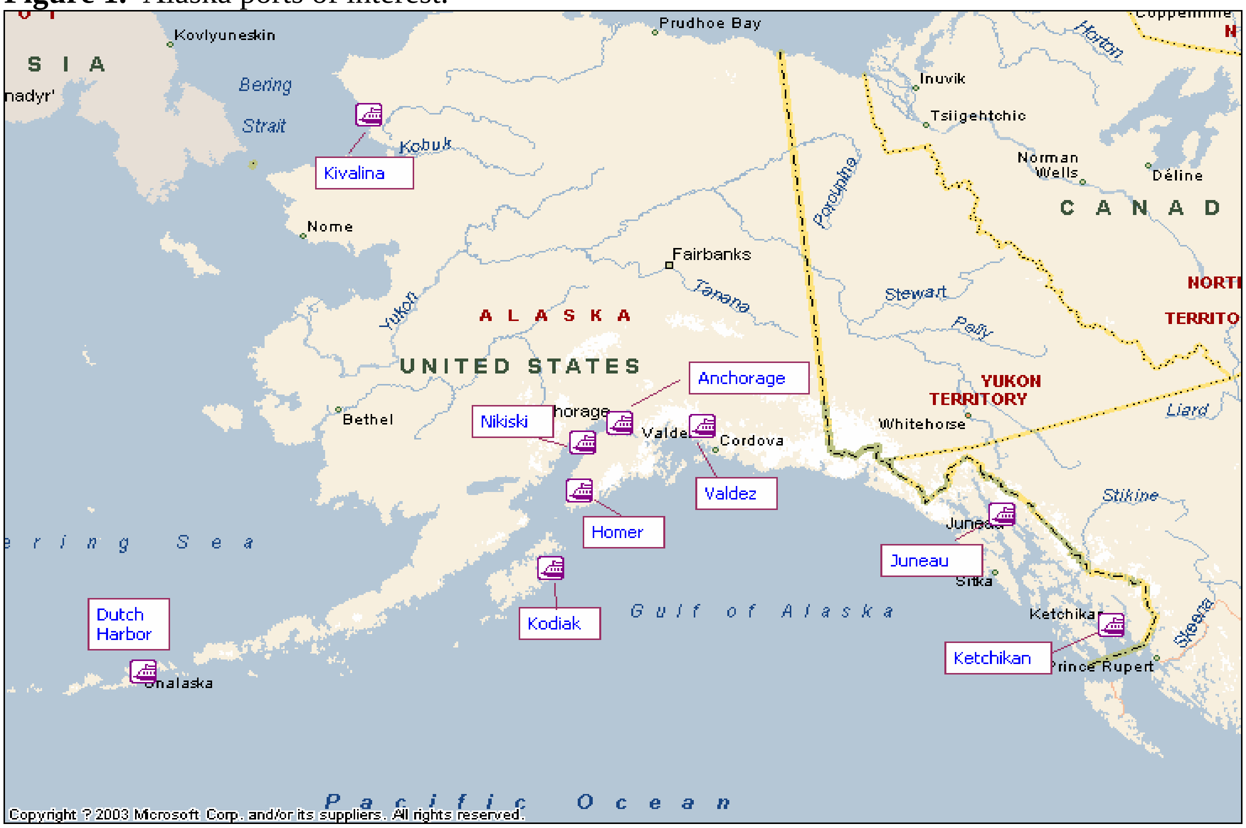
The objective of this project was to develop annual and seasonal (summer/winter) emission estimates from commercial marine vessels for ten Alaskan ports, including:

- Anchorage (major cargo center);
- Dutch Harbor (major seafood processing);
- Homer (ferry/fishing/cargo);
- Juneau (major cruise destination/ferry/fishing);
- Ketchikan (major cruise destination/ferry/fishing);

- Kivalina (port for large mine);
- Kodiak (ferry/fishing/cargo);
- Nikiski (industrial cargo);
- Prudhoe Bay (industrial cargo); and
- Valdez (oil tankers/fishing).

Figure 1 provides a State map that indicates the location of the ports of interest. The emissions inventory accounts for cruise related activity 25 miles out from the breakwater, reduced speed zone (RSZ) and maneuvering activity, and time spent in port (hotelling). For this effort, the summer season is defined as April 1 through September 30, and winter season is defined as October 1 through March 31. Pollutants included in the inventory include: sulfur dioxide (SO_2), oxides of nitrogen (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), ammonia (NH_3), and volatile organic compounds (VOCs). Emissions estimates were developed for 2002, with projections provided for 2005 and 2018. These inventories will support analyses to characterize the emission reductions that will be needed to achieve and maintain compliance with regional haze standards.

Figure 1. Alaska ports of interest.



INVENTORY DEVELOPMENT

Description

This portion of the paper summarizes the steps taken for development of the marine emission inventory. First, a description is provided of the source category and the types of vessels each port supports. This is followed by a description of the data collected to estimate activity for each vessel category, including vessel calls, engine size (horsepower) time-in-mode and load factors. Finally, a discussion is included of the available emission factors, forecast assumptions and results.

The commercial marine vessel (CMV) sector includes many types of vessels, such as ocean-going vessels (OGVs), commercial fishing vessels, ferries, barge towboats, and harbor or short-haul tugs. Note that some tugs and towboats also operate as ocean-going or long-haul tugs. OGVs can be further divided into subcategories depending on the cargo they carry. These subcategories include container ships, general cargo ships, dry bulk ships, liquid bulk ships (i.e., tankers), and cruise ships.

The ports of interest engage in freight cargo, fishing, and passenger operation activities. Table 1 lists the vessel categories that are included in the inventory for each of the nine ports.

Note that for Prudhoe Bay, no “out of port” calls were recorded by the Marine Exchange of Alaska (MXAK) in 2004. Since there was not a “Sea Lift” operation in 2002, only minimal tug and workboat activity took place in 2002 for this port, and the Marine Exchange could not provide information on these schedules. In addition, due to the limited time period of operation during the late summer, activity and emissions were not estimated for Prudhoe Bay. For ports that recorded calls for vessels classified as “miscellaneous,” the number of calls was relatively small, and the characteristics of these vessels are unknown. As such, emissions for miscellaneous vessels were not developed.

Table 1. Vessel categories by Alaskan port.

Port	**Ammonia Tanker**	**Bulk Carrier**	**Car Carrier**	**Container**	**General Cargo**	**LNG Tanker**	**Miscellaneous**	**Oil Tanker**	**Passenger**	**Roll On Roll Off**	**Reefer**	**Tug**	**Ferry**	**Fishing**
Anchorage		√		√	√			√	√	√		√		√
Dutch Harbor			√	√	√		√	√	√		√	√		√
Homer	√	√		√		√		√	√			√	√	√
Juneau		√			√		√		√			√	√	√
Ketchikan		√			√		√		√			√	√	√
Kivalina		√										√		
Kodiak		√		√	√		√		√			√	√	√
Nikiski	√	√				√		√				√		√
Valdez		√			√			√	√			√	√	√

* Miscellaneous includes: Canadian Coast Guard, Greenpeace, Oceanographic Survey and Research, and Yacht

Activity Data

Activity for each CMV category was calculated using the following equation:

$$Activity_{mode} = Power \times LoadFactor \times Time_{mode} \times Calls$$

where:

$Activity_{mode}$	=	activity by mode (kilowatt [kW]-hours)
Power	=	rated engine power by vessel and engine type (kWs)
Load Factor	=	load factor of the engine by vessel type and mode
$Time_{mode}$	=	time in mode per call by vessel type (hours)
Calls	=	number of port calls by vessel and engine type

This calculation was performed for both propulsion and auxiliary engines and for each activity mode. Four activity modes are typically used to characterize CMV operations; cruise, reduced speed zone (RSZ), maneuver, and hotel. Underway emissions may be defined as the combined activity of cruise and RSZ modes. Port emissions typically reflect the combined activity of maneuvering and hotelling modes. Hotelling is defined as the time the vessel is at dock. Both propulsion engines and auxiliary engines are operating during cruise, RSZ, and maneuvering modes. Only auxiliary engines operate during hotelling. Pechan disaggregated the fleet according to engine type (i.e., 2-stroke, 4-stroke, or steam) and horsepower (hp) range to assign appropriate emission factors that are based on these characteristics.

Oceangoing vessels

Vessel Calls

For ocean-going freight vessels, passenger vessels (i.e., cruise ships), towboats, and assist tugs, vessel calls were based on data from the MXAK. In 2002, the MXAK started to track vessel calls for those ships with a gross ton weight of at least 300 tons (Page, 2005). As such, these data will not include activity for small fishing or other harbor vessels.

Because the 2002 data compiled by the MXAK were determined to be incomplete, data representing 2004 calendar year received from the MXAK was back-casted to estimate 2002 activity (MXAK, 2005a). A summary of annual 2004 vessel calls by port and vessel type is provided in Table 2. The calls were based on recorded arrivals of vessels, categorized by vessel type, to each port area. Knowing the trends in vessel activity from 2002 to 2004, the MXAK also recommended adjustments to apply to the 2004 vessel calls (MXAK, 2005b).

Tugboat calls were provided by the MXAK, as well as non-self propelled barge calls. However, the MXAK did not recommend that the recorded tugboat calls be used as an indicator of activity. As such, Pechan estimated tugboat assists to be 1 call per ocean-going vessel call, for all vessel types except tankers. Two tugboats were assumed to assist in the docking of oil tankers. In addition, tugboats were assumed to operate primarily within the breakwater and no cruise mode emissions were estimated for these vessels. This is likely the case for most ocean-going vessel assists, though activity and emissions for long-haul tugs towing barges may be underestimated using this assumption.

In addition to the number of vessel calls, information to characterize the majority of the vessels calling on each port was provided by the MXAK. These data included:

- Vessel Name;
- International Marine Organization (IMO) No.;
- Lloyd's Registry No.;
- Vessel Type;
- Gross Weight (tons);
- Dead Weight Tonnage (tons);
- Engine Type (i.e., diesel, steam, gas turbine);
- Propulsion Engine No.;
- Propulsion Engine Size (kw);
- Generator or Auxiliary Engine No.; and
- Auxiliary Engine Size (kw).

Characterizing the vessel-specific fleets by engine type, engine configuration, and engine size is necessary to assign the appropriate loading factors and emission factors. The specific engine configuration was not specified in the data set. For example, diesel engines were not identified as either 2-stroke (i.e., slow speed), or 4-stroke (i.e., medium speed). As such, Pechan assigned each diesel propulsion engine to 2-stroke or 4-stroke based on further discussions with the MXAK (Bodron, 2005). In general, large passenger ships, tankers and Roll-on/Roll-offs (ROROs) are diesel-electric, medium speed engines. Bulk carriers, general cargo ships, containerships, and small cruise ships were all assumed to be 2-stroke slow speed engines.

Table 2. 2004 Vessel calls by port and vessel category.

Port	Vessel Type[2,3]	Vessel Type Name	Number of Calls
Anchorage	BAR	Barge	58
	BBU	Bulk Carrier	7
	FSH	Fishing	2
	GGC	General Cargo	5
	MPR	Passenger	6
	RORO	Roll On Roll Off	106
	TTA	Tanker Oil	12
	UCC	Container	119
	XTG	Tug	319
Dutch Harbor	BAR	Barge	65
	FSH	Fishing	411
	GGC[1]	General Cargo	158
	MISC	Miscellaneous	5
	MPR	Passenger	9
	TTA	Tanker Oil	2
	UCC	Container	143
	XTG	Tug	370
Homer	BAR	Barge	11
	BBU	Bulk Carrier	21
	FSH	Fishing	4
	LNG	Liquid Natural Gas	1
	MPR	Passenger	2
	NH3	Ammonia Tanker	11
	TTA	Tanker Oil	14
	UCC	Container	1
	XTG	Tug	73
Juneau	BAR	Barge	94
	BBU	Bulk Carrier	1
	FER	Ferry	292
	GGC	General Cargo	1
	MISC	Miscellaneous	5
	MPR	Passenger	471
	XTG	Tug	96
Ketchikan	BAR	Barge	163
	BBU	Bulk Carrier	1
	FER	Ferry	266
	FSH	Fishing	5
	GGC	General Cargo	1
	MISC	Miscellaneous	9
	MPR	Passenger	458
	XTG	Tug	165
Kivalina	BAR	Barge	4
	BBU	Bulk Carrier	20
	XTG	Tug	24
	BAR	Barge	33
	BBU	Bulk Carrier	1
	FSH	Fishing	8
	GGC	General Cargo	57
	MISC	Miscellaneous	3
	MPR	Passenger	9
	UCC	Container	100
	XTG	Kodiak	191

Port	Vessel Type[2,3]	Vessel Type Name	Number of Calls
Nikiski	BAR	Barge	14
	BBU	Bulk Carrier	20
	LNG	Liquid Natural Gas	32
	NH3	Ammonia Tanker	14
	TTA	Tanker Oil	63
	XTG	Tug	206
Valdez	BAR	Barge	34
	BBU	Bulk Carrier	1
	FER	Ferry	24
	FSH	Fishing	2
	GGC	General Cargo	3
	MPR	Passenger	1
	TTA	Tanker Oil	393
	XTG	Tug	824

[1]Per MXAK, 75% of GGC ships calling on Dutch Harbor classified as Reefer vessels for estimating emissions
[2] Miscellaneous includes: Canadian Coast Guard, Greenpeace, Oceanographic Survey and Research, and Yacht
[3]Tug (XTG) calls listed estimated based on vessel calls for ocean-going vessels, including barges, but excluding cruise ships, ferry, fishing and miscellaneous.

Further analysis and interpretation of the hp data provided by Lloyd's was also required for some vessels. For certain diesel propulsion engines, the number of propulsion engines provided was multiplied by the listed power in kilowatts to develop total propulsion power. However, for a diesel-electric cruise ship or RORO equipped with more than 4 main engines, using this methodology would overestimate total ship power. For these identified vessels, the reported propulsion engine size was used as the total propulsion power, without multiplication by the number of engines, per guidance from MXAK.

Table 3 provides a summary of average propulsion and auxiliary power by port and vessel type. These average values were developed by weighting the reported engine size by the number of calls for those engines characterized (which for some vessel types were a subset of the total calls). Table 3 also provides average speeds used for estimating time in cruise mode, which are discussed in more detail below, along with other time-in-mode estimates.

Time-in-Mode

Four activity modes are accounted for including cruise, RSZ, maneuver, and hotel. Mode-specific emission factors have been developed for larger vessels, though these data are not available for smaller Category 1 and 2 vessels such as ferries or fishing vessels. Most engines operate at different load factors depending on the mode, which is important to reflect in the overall activity estimate.

Cruise - Emissions for ocean-going vessels in cruise mode were estimated for each port from 25 miles outside of the harbor area, or breakwater, consistent with the U.S. Environmental Protection Agency's (EPA's) methodology for deep sea port inventories (EPA, 1999a). Cruise time-in-mode was estimated based on this 25-mile distance and average ship speeds, using the equation below:

*Cruise = 25 / [Vessel Speed)] * 2*

Vessel speeds for most ocean-going vessel types were estimated from available data compiled by EPA for select "Typical Ports" (EPA, 1999a). An EPA emissions inventory study matched ports in Alaska to one of two Typical Ports, including Ports of the Puget Sound and Port of Coos Bay, Oregon (EPA, 2002). For all ports except for Kivalina, data on vessel speeds for vessels operating in the Puget Sound port area were used. For Kivalina, data reported for Coos Bay was used. Speeds were assigned by matching available speeds by vessel type, dead weight tonnage (DWT), and engine size. Table 3 lists the speeds assumed by port and vessel type.

Table 3. Summary of listed vessel and engine data by port.

Vessel Type	Vessel Type Name	Engine Type	Engine Configuration	Total Calls	Weighted Propulsion Engine, kW	Weighted Auxiliary Engine, kW	Service Speed, knots
ANCHORAGE							
BBU	Bulk Carrier	DSL	2-stroke	7	6,105	3,400	14
GGC	General Cargo	DSL	2-stroke	2	4,039	3,705	12
MPR	Passenger	DSL	2-stroke	6	8,135	3,068	14.5
RORO	Roll-On/Roll-Off	STM	Steam	106	22,414	4,029	25
TTA	Tanker Oil	DSL	2-stroke	12	9,080	4,250	15
UCC	Container	DSL	2-stroke	119	16,784	6,181	19
DUTCH HARBOR							
car carrier		DSL	2-stroke	1	12,085	3,090	18
GGC	General Cargo	DSL	2-stroke	103	4,353	2,869	12
MPR	Passenger	DSL	2-stroke	7	7,953	4,731	21
TTA	Tanker Oil	DSL	2-stroke	2	4,410	7,500	15
UCC	Container	DSL	2-stroke	139	28,902	7,062	22
HOMER							
BBU	Bulk Carrier	DSL	2-stroke	21	5,728	4,254	14
LNG	Liquid Natural Gas	STM	Steam	1	15,660	6,000	16
MPR	Passenger	DSL	2-stroke	2	18,196	8,831	21
NH3	Ammonia Tanker	DSL	2-stroke	11	9,614	1,618	15
TTA	Tanker Oil	DSL	2-stroke	14	8,443	2,899	15
UCC	Container	DSL	2-stroke	1	17,940	6,210	20
JUNEAU							
BBU	Bulk Carrier	DSL	2-stroke	1	5,392	0	16
FER[1]	Ferry	DSL	2-stroke	290	7,502	1,514	-
MPR	Passenger	DSL	2-stroke	16	18,327	10,021	16
MPR	Passenger	DSL	4-stroke	367	29,125	14,500	16
MPR	Passenger	GT	Gas Turbine	84	21,041	0	16
KETCHIKAN							
BBU	Bulk Carrier	DSL	2-stroke	1	5,442	3,480	14
FER[1]	Ferry	DSL	2-stroke	265	7,599	1,529	-
MPR	Passenger	DSL	2-stroke	4	27,728	23,558	21
MPR	Passenger	DSL	4-stroke	361	28,930	14,960	21
MPR	Passenger	GT	Gas Turbine	83	21,294	0	21
KIVALINA							
BBU	Bulk Carrier	DSL	2-stroke	20	9,073	3,616	14
KODIAK							
GGC	General Cargo	DSL	2-stroke	57	800	79	12
MPR	Passenger	DSL	2-stroke	6	8,413	4,144	21
MPR	Passenger	DSL	4-stroke	1	37,800	11,925	21
MPR	Passenger	GT	Gas Turbine	1	17,000	0	23
UCC	Container	DSL	2-stroke	100	16,815	6,400	19
NIKISKI							
BBU	Bulk Carrier	DSL	2-stroke	17	5,731	3,706	14
LNG	Liquid Natural Gas	STM	Steam	32	15,660	6,000	16
NH3	Ammonia Tanker	DSL	2-stroke	14	9,595	2,006	15
TTA	Tanker Oil	DSL	2-stroke	59	8,557	2,366	15
VALDEZ							
BBU	Bulk Carrier	DSL	2-stroke	1	7,355	10,600	15
FER[1]	Ferry	DSL	2-stroke	24	9,086	1,338	-
GGC	General Cargo	DSL	2-stroke	1	5,760	1,348	12
MPR	Passenger	DSL	2-stroke	1	31,200	9,410	21
TTA	Tanker Oil	DSL	2-stroke	90	14,497	3,208	14
TTA	Tanker Oil	DSL	4-stroke	55	11,228	7,767	14
TTA	Tanker Oil	STM	Steam	231	19,511	2,259	16

[1]Ferry engine size and average speed based on data provided by AMHS.

Reduced Speed Zone (RSZ) and Maneuvering - Table 4 provides a summary of the vessel time-in-mode calculated based on data provided by the pilots for the Ports of Juneau, Ketchikan, and Dutch Harbor. For Ketchikan, times for both southbound and northbound calls were averaged, since the MXAK call data were not characterized as northbound or southbound. In addition, for Juneau, cruising speeds for all vessels was 16 knots per the pilots association.

A request was made for these data from the Southwest Alaska Pilots Association for the ports of Anchorage, Homer, Kodiak, Nikiski, and Valdez. Due to the time of the data request (i.e., mid-June during peak season), a pilot was not available to provide the information.

Table 4. Reduced speed zone and maneuvering times per call for select ports.

Port	RSZ Time, hrs	Maneuvering Time, hrs
Ketchikan		
Southbound	2.06	0.67
Northbound	2.63	0.67
Average	2.35	0.67
Juneau		
	2.00	1.00
Dutch Harbor		
	0.79	1.00

For tug boats, RSZ time was assumed equivalent to the RSZ for each vessel type that the tugs assisted, weighted by the number of calls for each vessel type. Maneuvering time for tugs was assumed to be 20 percent times higher than the average port-specific maneuvering time.

Shifting is the practice of a vessel entering a port area, and docking at anchor or PWD for a time, and then proceeding to another anchor or PWD within the same port area, which would impact maneuvering time. For Ketchikan and Juneau, the pilots association indicated that minimal shifting occurs.

For those ports where port-specific data were not obtained, times for these modes were estimated according to EPA procedures (EPA, 1999a). Using average speeds by ship type, a minimum RSZ time per call was calculated by dividing 10 miles, the estimated round-trip distance for deceleration and acceleration, by 65 percent of the average speed. Maneuvering time-in-mode was assumed to be 1 hour for each port call.

Hotelling - Hotelling represents the time the ship spends at port. This time was based on data obtained by port and vessel type from the MXAK (MXAK, 2005a; MXAK, 2005b). Average hotelling times provided by the MXAK and listed in Table 5 were used where there was little variation in the hotelling times according to the 2004 arrival and departure data from the MXAK. Port-specific times for certain vessel types were calculated based on 2004 arrival and departure times from the MXAK data, and are shown in Table 6.

Load Factors

Pechan used average load factors developed by other studies for each vessel type and mode of operation. Table 7 presents the load factors that EPA recommends for propulsion engine loads for various vessel types in cruise, RSZ, and maneuvering mode (EPA, 2000). Auxiliary load assumptions for container, tanker, cruise, reefer, and bulk ships were based on data available from the Port of Los Angeles (POLA, 2004). Like the propulsion load factors, these values represent load factors that vary by time in mode, which is expected for auxiliary engines as well. See Table 8 for auxiliary load factors by vessel type.

Table 5. Average hotelling times per vessel type.

Vessel Type	Vessel Type Name	Hotelling time, hrs
BBU	Bulk Carrier	60
MPR	Passenger	10
RORO	Roll On Roll Off	19
UCC	Container	19
Car Carrier	Car Carrier	60
FER	Ferry	2

Table 6. Port-specific hotelling times per vessel type from 2004 MXAK call data.

Vessel Type	Vessel Type Name	Port	Hotelling time, hrs
FSH	Fishing	Dutch Harbor	103
GGC	General Cargo	Anchorage	22
		Dutch Harbor	362
		Juneau	7
		Ketchikan	3
		Kodiak	14
		Valdez	878
LNG	Liquid Natural Gas	Homer	86
		Nikiski	50
NH3	Ammonia Tanker	Homer	72
		Nikiski	51
TTA	Tanker Oil	Anchorage	68
		Dutch Harbor	15
		Homer	106
		Nikiski	52
		Valdez	38
UCC	Container	Dutch Harbor	30

Table 7. Propulsion and auxiliary engine load factors for ocean-going vessels.

		Propulsion Engine Load Factors by Mode		
Codes	Vessel Type	Cruise	RSZ	Maneuver
BU	Bulk	0.80	0.40	0.20
CC	Container	0.80	0.30	0.15
GC	General Cargo	0.80	0.35	0.20
CH	Chemical Carrier	0.80	0.40	0.20
RR	RORO	0.80	0.30	0.15
RF	Reefer	0.80	0.30	0.15
TA	Tanker	0.80	0.40	0.20
VE	Car Carrier	0.80	0.30	0.15
PA	Passenger	0.80	0.20	0.10
MS	Miscellaneous	0.80	0.30	0.15

Table 8. Auxiliary engine load factors by mode.

Vessel Type	Cruise	RSZ	Maneuver	Hotelling
Auto Carrier	0.13	0.30	0.67	0.24
Bulk Carrier	0.17	0.27	0.45	0.22
Container	0.13	0.25	0.50	0.17
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous*	0.17	0.27	0.45	0.22
Passenger	0.80	0.80	0.80	0.64
Reefer	0.20	0.34	0.67	0.34
RORO	0.15	0.30	0.45	0.20
Tanker	0.13	0.27	0.45	0.67

*Use for Tugs and Ferries

Ferries

The AMHS is the principal ferry system that services multiple ports along the Inside Passage, Southcentral, and Southeastern Alaska. Summer and fall/winter/spring operating schedules for 2002 were obtained from AMHS (AMHS, 2005). Pechan compiled the number of ferry calls for each vessel/route that services each port. Table 9 shows the number of calls by vessel and by port, as well as information on the engine size and service speed for each motorized vessel in the fleet (O'Loane, 2005). The average hp to be used in port-specific calculations was derived by weighting the hp of each vessel servicing a port by the number of trips it contributes.

Table 9. 2002 Annual ferry calls by port and vessel horsepower and speed.

Port	Vessel Name	Calls	Propulsion hp*	Service Speed
Ketchikan	Matanuska	92	7400	16.5
	Kennicott	118	13380	16.8
	Taku	173	8122	16.5
	Columbia	30	12350	17.3
	LeConte	118	4300	14.5
	Aurora	245	4300	14.5
	Prince of Wales**	518	3000	14.5
	Total Calls	**1,293**		
Juneau	Matanuska	55	7400	16.5
	Kennicott	119	13380	16.8
	Taku	177	8122	16.5
	Columbia	31	12350	17.3
	LeConte	154	4300	14.5
	Aurora	15	8000	16.5
	Malaspina	97	4300	14.5
	Total Calls	**648**		
Valdez	Bartlett	136	5,100	13.3
	Tustumena	42	13,380	16.8
	Kennicott	5	3470	13.0
	Total Calls	**183**		
Kodiak	Tustumena	137	5,100	13.3
	Kennicott	4	13,380	16.8
	Total Calls	**141**		
Homer	Tustumena	151	5,100	13.3
	Kennicott	4	13,380	16.8
	Total Calls	**155**		

NOTES: * Auxiliary engine power for all ships will be based on average hp and number of engines in AMHS fleet (583 hp x 2 engines = total auxiliary hp of 1,166).
**This ferry services the Interisland Ferry route between Ketchikan and Hollis.

The Interisland Ferry Authority provides additional service between Ketchikan and Hollis twice daily from the end of May to mid-September, and once a day for the remainder of the year. The running length of this trip is 3 hours, with a service speed of 13.5. Interisland Ferry trips were added to the AMHS ferry trips for the port of Ketchikan.

Service speed information was used to estimate emissions in cruise mode. Maneuvering and RSZ times were estimated using EPA default assumptions. Hotelling times were estimated to be 2 hours per call per the MXAK (MXAK, 2005a).

Fishing Vessels

Commercial fish landings are recorded at eight of the ten ports, excluding Kivalina and Prudhoe Bay. Fishing vessel counts were based on data from the Alaska Department of Fish and Game, who maintain the Commercial Fisheries Entry Commission (CFEC). The CFEC tracks receipts for fish landings, or "fish tickets," for each landing made by a licensed commercial fishing vessel at a specific port. Due to confidentiality issues, these data are not publicly available by fishing vessel. At Pechan's request, the CFEC compiled statistics which included the total number of boats making fish landings, the pounds of fish landed, and the associated earnings by port for calendar 2002 (CFEC, 2005a). These data are shown in Table 10. The CFEC also provided vessel attribute data for all vessels that contributed to the total volume of the fish landing at each port of interest. By matching on vessel license number, these data were linked to CFEC's vessel attribute database to estimate characteristics of fishing fleets actually operating and making landings at each port, including number of vessels by fuel type, as well as average length, gross tons, and hp. Where vessels were not reported as either gasoline or diesel-fueled, these assignments were made based on the distribution of identified gasoline and diesel vessels by port. Also, average hp values did not include zero records, so that averages would not be skewed by non-reporting. Since the fishing vessel identification data for Nikiski could not be released due to confidentiality, vessel attributes from the nearby port of Homer were used with the Nikiski vessel counts.

Table 10. 2002 Fishing vessel counts, pounds landed, and estimated gross earnings by port.

Port	Number of Vessels	Pounds Landed	Estimated Gross Earnings
Anchorage	11	22,026	$36,717
Dutch Harbor	297	909,583,248	$166,189,235
Homer	274	10,764,649	$7,944,977
Juneau	184	2,933,470	$4,403,520
Kodiak	485	244,189,370	$46,767,910
Ketchikan	495	69,048,996	$12,166,613
Nikiski	78	*	*
Valdez	492	20,038,664	$5,945,649

NOTE: *Confidential data.

For completeness, Pechan also compiled vessel counts by port for charter fishing vessels. Charter vessel counts by port are available on CFEC's web site (CFEC, 2005b). These data represent the actual port where the charter boat is registered for operation, so these counts were used directly to estimate activity at a specific port.

Forty eight (48) vessels were included in both the commercial fishing vessel database and the sport vessel (charter) database. These boats are assumed to engage in each of these two separate activities at different times of the year, and as such were included in the base activity estimates for both types of fishing operations.

Per CFEC, the commercial vessel data do not include all vessels involved in set gill net fishing activities, which occur near shore using small open skiffs equipped with outboard motors. At this time, reliable data are not available to estimate vessel counts and activity for these smaller fishing operations. The CFEC believes the best method to estimate this activity would be a survey of set gill net fishermen (Iverson, 2005).

Many fisheries operate in Alaska (defined as a species/area/gear combination; for example, salmon/Kodiak/gillnet), at various seasons and various distances from shore. Local information on estimated hours of operation per year (i.e., how many hours are engines in operation) was not identified or determined to be readily available. This value will depend in part on the fishery season, and how long it may take a vessel to catch its quota, if one exists. A survey of harbor vessels for the State of California's Air Resources Board's (ARB) *Statewide Commercial Harbor Craft Survey* show that on average, 62 percent of the total commercial fishing and charter fishing occur within 25 miles of shore (ARB, 2004). In addition, the survey also determined that commercial fishing vessels operated their propulsion engines on average 1,250 hours per year, and commercial passenger fishing vessels operated their main engines 1,875 hours per year. However, fishery operation profiles in California may not be representative of activity in Alaska, and as such these data were not used.

Pechan based the hours of operation on a study of fishing vessels in the Midwest Regional Planning Organization region (ENVIRON, 2004). For this study, fishing vessels were estimated to operate 475 hours per year, which is higher than the NONROAD model activity estimate for recreational marine diesel vessels of 200 hours per year, but is believed to be more representative than the ARB estimates that are over 1,000 hours per year. In addition, based on discussions with the Southeast Marine Pilots Association, charter fishing vessel activity is likely to occur near shore, but much of the commercial fishing activity corresponding to landings in Ketchikan and Juneau is likely occurring outside of the 25-mile limit. Therefore, Pechan estimated that all charter fishing activity occurred within the port area, but only 20 percent of the commercial fishing activity occurred within this area. These estimates were used for other ports in Southwest Alaska as well, since information specific to ports in this region was not identified or provided by fishery officials or pilots that were contacted.

The above methodology was used for all ports with fishing activity except for Dutch Harbor. In Dutch Harbor, the ships are much larger than fishing vessels at the other ports and travel hundreds of miles into the Bering Sea. As such, the vast majority of the fishing occurs beyond the 25-mile limit, and there are also restrictions on fishing within this limit of Dutch Harbor port (Anthony, 2005). For this port, the vessel counts were equated with vessel calls, so that only the time associated with a fishing vessel at service speed within 25 miles of the breakwater, and time spent at RSZ, maneuvering, and hotelling were accounted for in the emission calculations (similar to all other ocean-going freight vessels). Hotelling time for some of the commercial fishing vessels making landings can be significant. The MXAK data indicated hotelling times averaging 103 hours for Dutch Harbor vessels.

Emission Factors

In its 1999 final rule for commercial marine diesel engines, EPA defined three categories of marine diesel engines based on engine displacement, power and revolutions per minute (EPA, 1999b). Table 11 presents the definitions for each category. EPA developed a baseline emissions inventory for each category. In 2003, a separate rule was finalized for Category 3 engines. EPA prepared a more detailed emissions inventory for Category 3 engines in the regulatory support document for that rulemaking (EPA, 2003a).

Table 11. U.S. EPA marine engine category definitions.

Category	Displacement per Cylinder	Power Range (kW)	Revolutions per Minute Range
1	disp. < 5 liters and power ≥ 37 kW	37 - 2,300	1,800 - 3,000
2	5 ≤ disp. < 30 liters	1,500 - 8,000	750 - 1,500
3	disp ≥ 30 liters	2,500 - 80,000	60 - 900

Using EPA methodologies, Pechan assigned each propulsion and auxiliary engine to an EPA Marine Engine Category based on the vessel type (EPA 2002; EPA, 2003a). Table 12 presents Pechan's assignments for each vessel and engine type.

Pechan obtained Category 3 engine emission factors for NO_x, hydrocarbons (assumed equivalent to VOC), CO, PM, and SO_2 from EPA (EPA, 2002). Category 1 and Category 2 engine emission factors for NO_x, hydrocarbons, CO, and PM were obtained from (EPA, 1999b) and emission factors for SO_2 were obtained from a CMV emission inventory prepared for the European Commission (ENTEC, 2002). Emission factors for gas turbine cruise ships were obtained from EPA's *Analysis of Commercial Marine Vessel Emissions and Fuel Consumption Data (EPA,* 2000). Tables 13 and 14 present the emission factor values for each mode of operation, where available. Fine particulate matter (less than or equal to 2.5 microns [$PM_{2.5}$]) emissions are assumed to be 97 percent of the PM_{10} (less than or equal to 10 microns) emissions. This ratio is based on an updated analysis of particle size distribution data analysis performed for nonroad diesel engines in EPA's NONROAD2004 model (EPA, 2004a).

Table 12. EPA marine engine category by vessel type.

Vessel Type	Propulsion	Auxiliary
Bulk	Cat 3	Cat 2
Container	Cat 3	Cat 2
General Cargo	Cat 3	Cat 2
RORO	Cat 3	Cat 2
Reefer	Cat 3	Cat 3
Tanker	Cat 3	Cat 2
Car Carrier	Cat 3	Cat 2
Passenger	Cat 3	Cat 3
Miscellaneous	Cat 3	Cat 2
Towboat	Cat 2	Cat 1
Tug Assist	Cat 2	Cat 1
Ferry	Cat 2	Cat 1
Fishing	Cat 1	Cat 1

Table 13. Criteria pollutant emission factors for Category 3 engines.

Mode	Engine	VOC Grams per kW-hour	NO_x Grams per kW-hour	CO Grams per kW-hour	PM_{10}-PRI Grams per kW-hour	SO_2 Grams per kW-hour
Cruise	2-stroke	0.530	23.60	1.10	1.73	12.82
	4-stroke	0.530	16.60	0.70	1.76	12.99
	Steam	0.067	2.80	0.30	2.49	20.06
RSZ	2-stroke	0.530	23.60	1.10	1.73	12.82
	4-stroke	0.530	16.60	0.70	1.76	12.99
	Steam	0.067	2.80	0.30	2.49	20.06
Maneuver	2-stroke	2.803	32.06	8.14	2.91	19.81
	4-stroke	2.910	22.64	5.94	2.98	20.30
	Steam	0.067	2.80	0.30	2.49	20.06
Hotel	2-stroke	0.134	13.36	2.48	0.32	1.43
	4-stroke	0.134	13.36	2.48	0.32	1.43
	Steam	0.067	2.80	0.30	2.49	20.12
All Modes	Gas Turbine	0.25	4.45	1.15	0.29	0.45

Table 14. Criteria pollutant emission factors for Category 1 and 2 engines

Engine Category	Power (kW)	CO (Grams per kW-hour)	NO_x (Grams per kW-hour)	VOC (Grams per kW-hour)	PM_{10}-PRI (Grams per kW-hour)	SO_2 (Grams per kW-hour)
Category 2	all	2.48	13.36	0.134	0.32	3.92
Category 1	75-130	1.7	10	0.27	0.4	2.27
	130-225	1.5	10	0.27	0.4	2.27
	225-450	1.5	10	0.27	0.3	2.27
	450-560	1.5	10	0.27	0.3	2.27
	560-1000	1.5	10	0.27	0.3	2.27
	1000+	2.5	13	0.27	0.3	2.27

Diesel fishing vessel emissions were based on the Category 1 emission factors in Table 14. For gasoline-fueled fishing vessels, Pechan used EPA NONROAD model emission factors for recreational 4-stroke gasoline inboard engines. NONROAD emission factors vary by technology type; emission factors were weighted by that fraction of the fleet assumed to be meeting each technology type. Emission factor values for both engine types were assigned based on the average hp of the vessels for a given port.

NH_3 from the combustion of residual and distillate diesel was based on EPA emission factors developed on a fuel consumption basis for heavy-duty highway diesel engines (EPA, 2003b). The ammonia emission factor is estimated to be 83.3 milligrams per gallon diesel fuel. Since emission factors are based on fuel consumption, Pechan converted the activity data in kW-hour to gallons using brake-specific fuel consumption (BSFC) rates for each engine type. The BSFC values for Category 1 and 2 engines are available from a South Coast Air Quality Management District study of marine vessels (AQMD, 2004). The Category 3 BSFC values were obtained from an International Maritime Organization report on emissions from CMV (IMO, 2000).

Forecasts

<u>Activity Factors</u>

Pechan compiled surrogate data to be used for projecting emissions. In cases where category-specific projections pertinent to Alaska or a specific port were available, these data were used. For example, the Port of Ketchikan has developed projections of cruise ship activity up to the year 2015. These forecasts account for historic growth trends, passenger forecasts based on Ketchikan's market capture level, and an expected future deployment of 35 additional cruise ships (KPFF, 2002). The results of the report are representative of other major cruise ports in the Alaska region, as well as Ketchikan. As such, these forecasts were used to project the increase in cruise ship travel to all of the call ports of interest in Alaska. Ketchikan's cruise ship projections included projections for large cruise ships and small cruise ships. Projections for small cruise ships were assigned to Anchorage since their port is currently restricted to receive only small cruise ships. The projections for large cruise ships were assigned to the other ports of harbor for cruise ships. No growth in gas turbine cruise ships was assumed based on discussions with the Southeast Alaska Marine Pilots Association indicating that some cruise lines currently operating gas turbine ships were not planning to purchase new gas turbine ships (at least in the near future) because of the high cost of the fuel to run the turbine.

For ocean-going vessels including tugs, Pechan compiled historic data on freight traffic (in thousand short tons) available from the U.S. Army Corps of Engineers annual report, *Waterborne Commerce of the United States* (USACE, 2005). These data are available for the time series 1964-2003, and represent national freight data. Linear extrapolations of the time series data resulted in a strong correlation (i.e., an R^2 of 0.90) and showed a modest growth of 23 percent from 2002 to 2018.

Pechan also investigated the use of port-specific time series freight data available from the USACE to project emissions. Juneau and Ketchikan make up more than 87 percent of the freight commerce shown for Alaska ports in the USACE data. Both ports show a decline in tonnage and when grown linearly to 2018, actually produced negative values. When grown exponentially, the combined 2018 growth factor for the two ports is 0.353. Since Anchorage and Ketchikan will both be expanding their ports in the near future, a decline this dramatic in freight tonnage does not seem plausible (APET, 2005; KPFF, 2002). As such, Pechan relied on the national freight tonnage for all ports, with the exception of Anchorage. Anchorage provided tonnage for 1995-2003 by commodity (Anchorage, 2005). These data were extrapolated to develop the 2005 and 2018 projections.

Projections of ferry activity were based on updated Alaska state population forecasts (DOLWD, 2005). The Alaska Labor and Workforce Department indicated their updated county level projections would be released no earlier than late summer 2005. Since Alaska's most recent population projections start with 2003 as the base year, an adjustment was developed to back-cast 2002 year populations.

For fishing vessels, Pechan developed growth factors using linear extrapolations of historic State total fish landings, available from the National Oceanic and Atmospheric Administration for 1980-2003, for all ports (NOAA, 2005).

Table 15 provides the growth factors applied to 2002 emissions to reflect growth to 2005 and 2018.

Table15. Growth factors by vessel type, port, and year

Vessel Category	SCC(s)	SCC Description	Port	2005 Growth Factor	2018 Growth Factor
Passenger	2280002050	Marine Vessels, Commercial, Diesel, Cruise Ships	Anchorage	1.138	1.746
		Marine Vessels, Commercial, Diesel, Cruise Ships	All Other Ports	1.208	2.369
	2280004050	Marine Vessels, Commercial, Gas Turbine, Cruise Ships	All Ports	1	1
Fishing	2280004030	Marine Vessels, Commercial, Gasoline, Fishing Vessels	All Ports	1.311	1.888
Ferry	2280002022	Marine Vessels, Commercial, Diesel, Ferries	All Ports	1.033	1.173
Ocean-going vessels	2280002100	Marine Vessels, Commercial, Diesel, Port emissions	Anchorage	1.165	1.734
	2280003100	Marine Vessels, Commercial, Residual, Port emissions			
	2280002100	Marine Vessels, Commercial, Diesel, Port emissions	All Other Ports	1.077	1.233
	2280003100	Marine Vessels, Commercial, Residual, Port emissions			
Tug	2280002021	Marine Vessels, Commercial, Diesel, Tugs	Anchorage	1.165	1.734
			All Other Ports	1.077	1.233

Control Factors

EPA has promulgated two sets of CMV regulations: a regulation setting Category 1 and 2 marine diesel engine standards and a regulation setting Category 3 marine diesel engine standards. In addition to the EPA standards, beginning in 2000, marine diesel engines greater than or equal to 130 kW are subject to an international NO_x emissions treaty (MARPOL) developed by the International Maritime Organization. Overall emission reductions were estimated for each projection year of interest using base year and future year control case emission estimates from the regulatory support documents prepared for these rulemakings (EPA, 1999c; EPA, 2003c).

Table 16 provides the percent reductions applied to estimate 2005 and 2018 emissions. In 2005, only Category 1 engines are subject to EPA standards. Reductions expected from MARPOL in 2005 are minimal. For 2018 forecasts, SO_2, PM_{10} and $PM_{2.5}$ emission reductions associated with decreases in the diesel fuel sulfur content were also included based on emission inventories in EPA's Regulatory Impact Analysis for the Clean Air Diesel Rule (EPA, 2004b). Due to the low diesel sulfur limits required in the future, significant SO_2 reductions are expected. Where exhaust PM standards already apply to certain categories of vessels (i.e., Category 1), a combined emission reduction was calculated for each future year that accounted for both the exhaust standards and reductions in PM sulfate due to the fuel sulfur limits.

Table 16. Expected CMV emission reductions by year, engine category and pollutant.

Forecast Year	Engine Category	Percent Reduction				
		VOC	NO_x	PM10-PRI	PM25-PRI	SO_2
2005	Category 1	3.0	5.0	4.0	4.0	0.0
2018	Category 1	21.6	28.0	38.9	38.9	97.6
2018	Category 2	0.0	20.5	12.1	12.1	97.6
2018	Category 3	0.0	14.9	12.1	12.1	97.6

Results

Annual 2002 emissions were calculated by vessel type, engine type and mode of operation using the port-specific activity data in kW-hours. Emissions were calculated by multiplying the activity in kW-hours by the emissions factor in grams per kW-hour and a conversion factor from grams to tons.

All CMV emissions were calculated as annual 2002 emissions. Summer and winter season emissions were also calculated. Seasonal fractions were based on the average number of summer and winter MXAK 2004 vessel calls for each port and vessel type. For ferries, the 2002 AMHS ferry schedule reported calls by month, so that the number of calls in each season relative to the annual total was calculated. Fishing activity was assumed to occur evenly throughout the year (i.e., 50 percent in summer and 50 percent in winter) for all ports. These summer and winter fractions were applied to the annual emissions to estimate summer and winter season emissions. For inventory reporting purposes, SCCs were then assigned to each vessel category, and port-specific emissions were also assigned to boroughs. The 2002 results were then projected to 2005 and 2018 using the growth and control factors discussed in the prior section.

Table 17 presents 2002, 2005, and 2018 summaries by borough. Note that Ketchikan port includes emissions reported under two boroughs, and Homer and Nikiski are reported under the same borough. The vessel types contributing to the majority of emissions for the ports of Anchorage, Dutch Harbor, and Kodiak are container and reefer ships, while tankers are the largest emission source for Homer, Nikiski, and Valdez. Cruise ships are the overwhelming contributor to emissions in the Juneau and Ketchikan port areas. For Kivalina, oceangoing bulk carriers for transporting ore concentrate from the mine, as well as tugboats, are the only significant emission sources.

For complete pollutant emission inventories by port and by vessel type, the reader is referred to the final report for the project (Pechan, 2005). This report also contains maps that depict the area 25 miles out from each port for which emission estimates were developed.

Table 17. 2002, 2005, and 2018 annual CMV emissions by borough (tons/year).

2002

FIPs Code	Borough Name	Port	VOC	NOX	CO	SO2	PM10-PRI	PM25-PRI	NH3
02020	Anchorage	Anchorage	7.4	277.1	67.9	202.5	24.6	23.8	0.1
02016	Aleutians West	Dutch Harbor	19.3	1,185.4	187.1	307.5	44.0	42.7	0.4
02122	Kenai Peninsula	Homer & Nikiski	19.7	533.8	254.5	200.7	21.8	21.2	0.4
02110	Juneau	Juneau	53.5	1,631.3	254.1	839.8	117.6	114.0	0.7
02130	Ketchikan Gateway	Ketchikan	24.5	885.5	135.9	342.5	50.7	49.2	0.4
02201	Prince of Wales - Outer Ketchikan	Ketchikan	33.8	725.7	325.0	412.3	53.6	52.0	0.5
02188	Northwest Arctic	Kivalina	0.5	27.2	3.4	11.5	1.4	1.3	0.0
02150	Kodiak Island	Kodiak	12.1	280.0	113.6	102.9	12.9	12.5	0.2
02261	Valdez-Cordova	Valdez	23.4	859.5	299.7	584.6	66.5	64.5	0.6

2005

FIPs Code	Borough Name	Port	VOC	NOx	CO	SO2	PM10	PM25	NH3
02020	Anchorage	Anchorage	8.9	323.2	84.2	28.6	27.8	235.9	0.2
02016	Aleutians West	Dutch Harbor	21.2	1,284.9	203.7	47.7	46.3	333.9	0.5
02122	Kenai Peninsula	Homer & Nikiski	24.3	593.5	317.8	24.0	23.3	221.2	0.4
02110	Juneau	Juneau	64.5	1,936.3	306.3	141.0	136.8	1,005.9	0.8
02130	Ketchikan Gateway	Ketchikan	29.3	1,054.2	161.1	60.9	59.0	409.5	0.4
02201	Prince of Wales - Outer Ketchikan	Ketchikan	42.0	845.7	413.3	64.0	62.0	489.8	0.6
02188	Northwest Arctic	Kivalina	0.6	29.3	3.7	1.5	1.4	12.4	0.0
02150	Kodiak Island	Kodiak	14.8	318.2	143.9	14.5	14.1	115.9	0.2
02261	Valdez-Cordova	Valdez	27.8	936.9	363.3	71.9	69.8	632.2	0.7

2018

FIPs Code	Borough Name	Port	VOC	NOx	CO	SO2	PM10	PM25	NH3
02020	Anchorage	Anchorage	13.2	420.5	123.1	40.0	38.8	176.8	0.3
02016	Aleutians West	Dutch Harbor	24.6	1,267.1	238.0	48.4	47.0	9.5	0.6
02122	Kenai Peninsula	Homer & Nikiski	31.8	621.7	436.8	25.1	24.4	81.3	0.6
02110	Juneau	Juneau	119.4	3,035.9	522.2	237.2	230.1	48.6	1.5
02130	Ketchikan Gateway	Ketchikan	56.3	1,689.7	300.5	103.0	99.9	19.3	0.8
02201	Prince of Wales - Outer Ketchikan	Ketchikan	67.4	1,199.4	594.3	104.1	100.9	24.1	1.0
02188	Northwest Arctic	Kivalina	0.7	28.5	4.2	1.5	1.4	0.3	0.0
02150	Kodiak Island	Kodiak	19.0	333.9	201.7	14.9	14.5	3.8	0.3
02261	Valdez-Cordova	Valdez	35.6	976.2	483.7	78.9	76.5	464.0	0.8

CONCLUSIONS

In developing a 2002 inventory for the ports of interest, data representative of 2002 vessel fleets and operations were obtained where feasible and available. Assumptions made for this Alaska port emissions inventory and recommendations for future research are discussed below.

Though time-in-mode data were obtained for some ports (e.g., Juneau, Alaska, and Dutch Harbor) from pilot associations, time spent maneuvering and in reduced-speed zone for most ports were estimated using EPA default methods. In addition, the location of a pilot station or breakwater could not be confirmed for all ports, which will impact the distance and time in reduced-speed zone. Cruising vessel speeds for many vessel types were estimated using data for similar vessels in the Port of Puget Sound. Refinements to time-in-mode and cruising speeds may be obtained from Lloyd's Registry or from the Alaska ship pilots.

Ocean-going vessel activity was not available from the MXAK for 2002. As such, data for 2004 was used and adjusted accordingly to 2002. In addition, the classification of each vessel by engine type configuration (e.g., diesel 2-stroke versus 4 stroke) was not provided, though guidelines for assigning these classifications to vessels was provided by the MXAK. In addition, horsepower information for some vessels from the Lloyd's data base was uncertain (i.e., in terms of number of engines and available power), and some discretion was used in making these final assignments. Future efforts should focus on the use of actual data for the base year of interest (if available from the MXAK), coupled with the verification of all engine characteristics.

Alaska fisheries are numerous, and fishing seasons and the areas surrounding ports where fishing vessels operate will depend on the fishery. Fishing vessel hours of operation were assumed based on estimates from another study. In attempting to obtain data on annual hours of fishing vessel use, many fisheries experts believed a survey of fisherman is needed. In addition, the vessel fish landing data from the CFEC that forms the basis of the fishing activity does not include set gill net fishing boats, which may have significant near shore operations. Assumptions were also made for many ports concerning the area where fishing vessels operated. A survey to refine the areas of operation as well as the hours of operation for various fishing vessels may assist in determining the relative significance of fishing vessels compared with other ocean-going vessels.

Starting in 2003, some of the Princess cruise ships calling on Juneau have been relying on surplus hydroelectric power supplied by the local power company and as such have been turning off their ship auxiliary engines and boilers when they dock. This trend was not accounted for in the emissions estimated for 2005 and 2018, but would result in decreased hotelling emissions for a portion of the fleet. If use of shore power continues to increase, future inventories should make adjustments to this component of the inventory for those ports that host a large number of cruise ships relying on shore power.

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