Category 1 / Category 2 Vessel Port Underway Split for 2011 National Emission Inventory
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Richard Billings, Heather Perez, Roger Chang, and Jennifer Sellers
Eastern Research Group, Inc.
1600 Perimeter Park Drive, Suite 200, Morrisville, NC 27560
Richard.Billings@erg.com

Laurel Driver
U.S. Environmental Protection Agency
Research Triangle Park, NC
Driver.Laurel@EPA.gov

ABSTRACT

Recently, the U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards (OAQPS) used the National Emission Inventory (NEI) data for commercial marine vessels[1] to model local air quality, and found that smaller vessels equipped with Category 1 and 2 marine engines had a disproportionate amount of emissions in port areas. It was determined that these elevated levels of emissions were due to older State Implementation Plan (SIP) guidance that assumed that 75 percent of marine distillate fuel was combusted in port areas, and 25 percent of the fuel was combusted while underway[2].

The EPA decided to use data from the 2007 Category 1 and Category 2 Census report[3] to reallocate the EPA's Office of Air Quality and Transportation (OTAQ) criteria pollutant emission estimates for these marine vessel sources to get a more accurate estimate of port and underway emissions. The approach developed for the Category 1 and 2 Census showed that the amount of fuel and emissions released in the port varies by vessel type, but in aggregate, activity and emissions associated with ports is roughly 12% of total activity; conversely, underway activities accounted for 88% of fuel usage from these Category 1 and 2 vessels.

This paper discusses how the Category 1 and 2 Census data were developed, and how these data were used to reallocate the 2011 NEI emission estimates for port and underway distillate fueled vessels.

INTRODUCTION

Historically speaking, attention to marine vessel emissions has focused on larger ships equipped with Category 3 engines (engines with a cylinder displacement greater than 30 liters). This is appropriate, as these vessels are associated with significant emissions of criteria pollutants, greenhouse gases (GHGs), and hazardous air pollutants (HAPs). There also tends to be a reasonable amount of quality data to characterize the Category 3 fleet and quantify their vessel traffic patterns.

Initially, the fuel-based approach recommended for the 1990 Clean Air Act SIP inventories provided very rough estimates of emissions. Over time, the recommended approach to estimate emissions from these vessels has evolved to incorporate vessel-specific power, engine speed, and vessel data from sources such as Global/IHS Register of Ships, and Very High Frequency (VHF) and satellite tracking data compiled for the Automatic Identification System (AIS) which can now be mapped and analyzed in geographic information systems (GIS).

For smaller vessels equipped with Category 1 and 2 engines (engines with a cylinder displacement between 2.5 and 30 liters), there are considerably less vessel characteristics and activity data available. For many years the primary emission inventory guidance for these vessels was from the 1989 SIP methodology which was based on port fuel sales.[2] This approach included an assumption about what fraction of fuel was consumed by these vessels in port and underway. As these smaller vessels tend to use distillate fuels, the guidance assumed that 75% of fuel was combusted in port and 25% while underway.[3] Discussions with OTAQ staff over the years about the port fraction of emissions associated with these smaller vessels indicated that this was clearly an assumption that would need to be evaluated in the future. The future came when EPA's air quality modelers noted elevated estimates of HAP exposure in ports associated with vessels equipped with Category 1 and 2 engines. At this point, the EPA looked to see whether there were existing studies available to help improve the spatial allocation of emissions from these smaller vessels. In 2005, the EPA commissioned Eastern Research Group, Inc. (ERG) and a consortium of scientists and engineers to develop a census of vessels equipped with Category 1 and Category 2 engines and estimate time spent in port and underway (*Category 2 Vessel Census, Activity and Spatial Allocation Assessment and Category 1 and 2 In-Port / At- Sea Splits)*.[3] Data from this report were used to revise the spatial allocation of the small vessel emissions in the EPA's 2008 air quality modeling dataset and the 2011 NEI.

APPROACH

This paper provides a general overview of how the Category 1 and 2 vessel Census was developed and how the results for the Census were applied to the 2011 NEI data to enhance the spatial distribution of emissions. Because both the Category 1 and 2 Census[3] and the NEI[1] studies are comprehensive and often complex, it is recommended that the original reports be reviewed to obtain details concerning the assumption made or data sources used. It should also be noted that the Category 1 and 2 Census report[3] was completed in 2007 therefore the vintage of the data used in the report varies relative to the agency that was provided the information; ranging from 2000 to 2007.

Development of Category 1 and 2 Census Data

To understand the changes made to the 2011 NEI Category 1 and 2 emission allocations, it is necessary to first understand the study used to improve the spatial element of the NEI. Development of data to better quantify small vessel activities was a real challenge given the diversity of the vessel fleet and lack of any consolidated central data sources of vessel characteristics or activity. In the Category 1 and 2 Census[3], these smaller vessels were split into the following vessel types:

- Tugs and tow boats
- Commercial fishing vessels
- Coast Guard vessels
- Ferries
- Small deep water cargo ships
- Offshore support vessels
- Small cargo ships that operate on the Great Lakes
- Research vessels

A team of researchers was assigned to each vessel group to investigate and identify appropriate data sources that could be used to account for:

- The number of vessels in operation
- Vessel characteristics (vessel size, engine size, speed, engine category)
- Annual activity data (hours of operation, fuel usage, utilization rates)

- Time these vessels spend in port or while underway, and
- Areas where these vessels operate.

This assessment led to the identification of a range of useful data sources as noted in Table 1.

After the vessel count and activity data were compiled, team members shared their preliminary results with staff from other vessel groups to ensure the level of detail and assumptions made in compiling the data were consistent. In a couple of cases, innovative methods developed to differentiate between Category 1 and Category 2 vessels were found to be useful to other vessel groups.

Even with the coordination between the teams, the compiled data were often significantly different. Efforts were required to standardize the data to populate the project's database. The first step in this process was to determine how many vessels were currently in operation for each vessel type, and differentiate between what portion of the fleet was Category 1 and Category 2. In most cases, vessel horsepower data were used to roughly approximate the Category 1 and 2 split. For other cases, where power ratings were missing, vessel size attributes such as draft or gross registered tonnage were correlated to vessel power and engine category to help identify Category 1 and 2 vessels.

Ultimately, the final output for the Category 1 and 2 data compilation task was activity, in terms of horsepower hours for each vessel type. Figure 1 provides an overview of how the data elements connect to get activity in horsepower hours.

This approach required development of a typical or each vessel type that included the following vessel data elements:

- Typical number and power rating of the vessels engines, number of propulsion engines per typical vessels engines, or
- Total vessel propulsion power
- Operating parameters such as:
  - Average number of days these vessels typically worked per year, and
  - Typical hours of operation per work day and port/underway split, including:
    - Time spent in port maneuvering or dockside
    - For some offshore vessels time is spent idling at sea, and
    - Typical engine load factors for each vessel type and mode of operation (i.e., cruising, reduced speed, maneuvering, and dockside).

In populating the project database, priority was given to using actual data where available. Next, surrogate data for each vessel group were developed based on observed correlations such as vessel size to vessel power. Lastly, engineering judgments were used derived from the researchers' extensive experience with the vessel types.

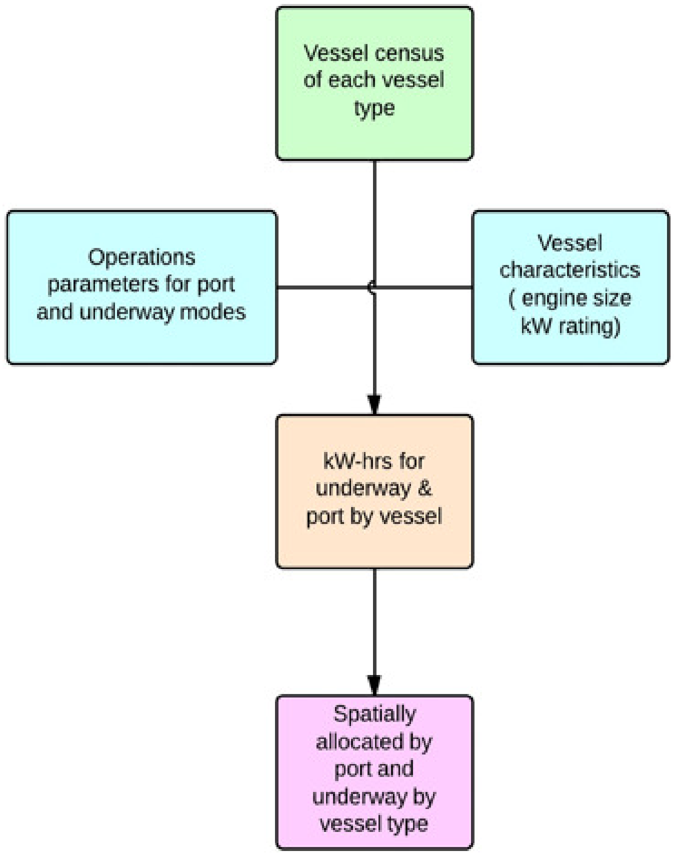
Table 1. Identified Data Sources for Category 1/Category 2 Vessel Characteristics Activity and Traffic.

Vessel Type	Vessel Characteristics	Activity	Spatial Elements
Tugboats	American Waterways Operators U.S. Coast Guard Merchant Vessels of the U.S. U.S. ACE Waterborne Transportation Lines of the U.S. Inland River Record IHS Registry of Ships American Bureau of Shipping	American Waterways Operators U.S. Army Corp of Engineers (ACE) Waterborne Commerce U.S. Coast Guard Vessel Movement Database	Bureau of Transportation Statistics (BTS) - Transportation Atlas U.S. ACE Waterborne Commerce U.S. ACE Waterborne Transportation Lines of the U.S. U.S. ACE Waterway Link Commodity Data
Commercial Fishing	U.S. Coast Guard Merchant Vessels of the U.S. California Commercial Fishing Data Alaska CFEC permits Washington Department of Fish and Wildlife	National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service	NOAA, National Marine Fisheries Service
Coast Guard	U.S. Coast Guard Website		U.S. Coast Guard Website
Ferries	Inland River Record American Bureau of Shipping State Department of Transportation	American Public Transportation Association, Public Transportation Fact Book State Department of Transportation	BTS National Ferry Database State Department of Transportation
Small Deepwater Cargo Vessels	IHS Register of Ships American Bureau of Shipping	U.S. ACE Vessel Clearance and Entrance Data U.S. Coast Guard Vessel Movement Database	BTS Transportation Atlas U.S. ACE Waterway Link Commodity Data

Table 1. Identified Data Sources for Category 1/Category 2 Vessel Characteristics Activity and Traffic.

Vessel Type	Vessel Characteristics	Activity	Spatial Elements
Offshore Support Vessels	Offshore Marine Service Association Rig Zone U.S. Coast Guard Merchant Vessels of the U.S. Offshore Support Vessels of the World	Bureau of Ocean Energy Management (BOEM) Gulf of Mexico emission inventory Workboat (publication)	BOEM Gulf of Mexico emission inventory EPA 2011 NEI data file
Great Lake Vessels	IHS Register of Ships American Bureau of Shipping	U.S. ACE Vessel Clearance and Entrance Data U.S. Coast Guard Vessel Movement Database	BTS Transportation Atlas U.S. ACE Waterway Link Commodity Data
Research Vessels	IHS Register of Ships American Bureau of Shipping	University of Delaware database of research vessels University- National Laboratory System Ocean Physics Laboratory	University of Delaware Database of research Vessels University- National Laboratory System

Figure 1. Overview of approach to get port/underway horsepower hours by vessel type.



Once all the data fields were populated and checked, annual total U.S. horsepower hours were calculated using the following equation, providing results for port and underway activity by vessel type:

$$Thp{=}hr_{ij} = VP_i \times UR_i \times EN_i \times HP_{ij} \times DO_{ij} \times 24 \times LF_{ij}$$

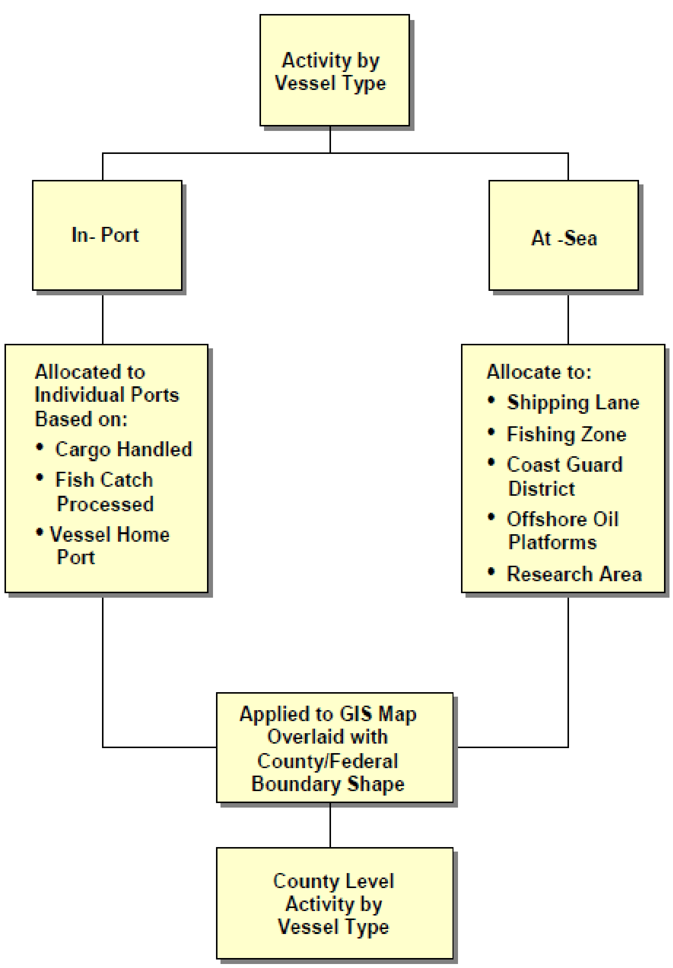
Where:

$Thp\text{-}hr_{ij}$	=	Total annual horsepower hours for vessel type i in mode j
VP_i	=	Population of vessel type i
UR_i	=	Utilization rate for vessel fleet i
EN_i	=	Average number of engines on vessel type i
HP_{ij}	=	Horsepower of vessel type i
DO_{ij}	=	Days of operation of vessel type i in mode j
24	=	Hours per day
LF_{ij}	=	Load factor of vessel type i propulsion engines i mode j
i	=	Vessel type (i.e., deep water, tow, ferries commercial fishing, Great Lakes, Coast Guard, offshore support, and research)
J	=	Mode of operation (i.e., underway cruise, underway idle)

Results from these calculations were carefully assessed for consistency between the vessel groups. Given the varying data quality of each of the compiled data fields, a Monte Carlo analysis was implemented for each vessel type to quantify the inherent uncertainty in the data set. This analysis took into consideration minimum, maximum, and average values by vessel power, annual hours of operation, and engine operating load. Results from the Monte Carlo analysis by vessel type are provided in Appendix A. Review of the statistical analysis of the data and results from the Monty Carlo analysis was helpful in identifying possible anomalies in the data set. Any data that were identified as being questionable were flagged for further study. Because the data were reviewed and checked throughout the process, very few anomalies were identified.

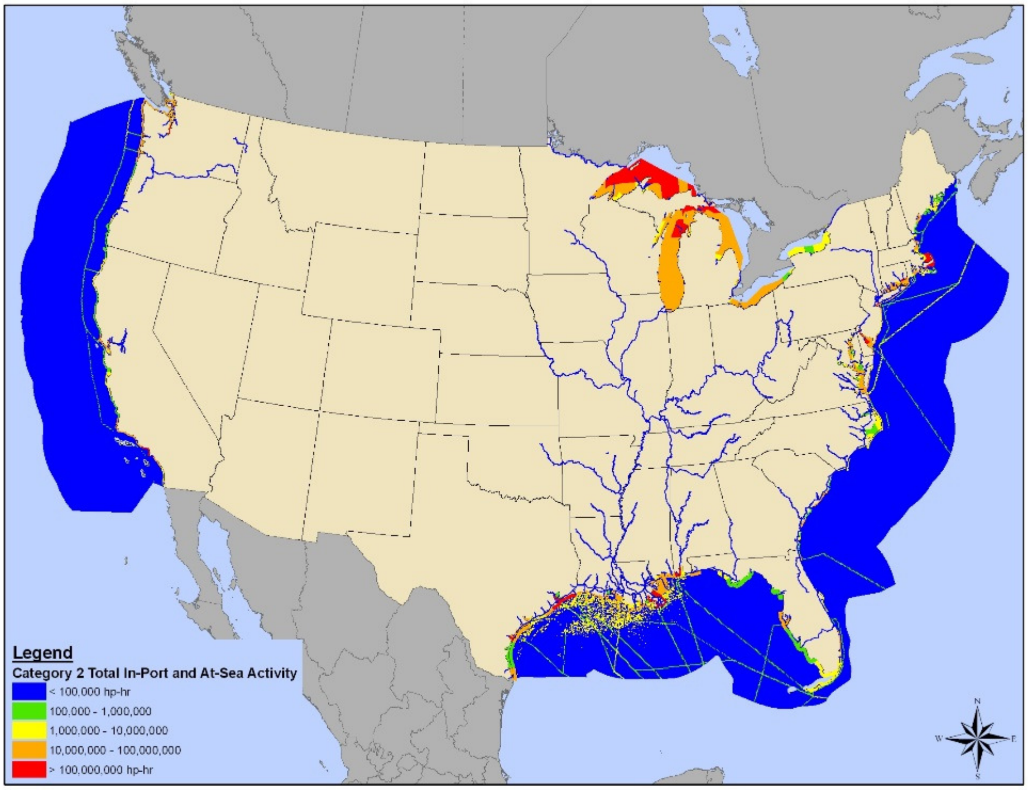
Once the annual national horsepower hours were estimated and checked, they were then apportioned spatially (see Figure 2 for an overview of the approach used). This required review of a wide range of available information to help identify locations where these vessels operate. The location data varied relative to the vessel category. For example, ferry terminals were included in the 2000 online National Census of Ferry[4]Operators (NCFO) from the Bureau of Transportation Statistics. The ports where these terminals were located were considered the port component of the ferry activity. There were no available data defining ferry routes, so it was assumed that county waters around each port terminal represented the underway portion of the trip. Another example included review of state fishing permits to quantify underway fishing vessel activity in state waters, along with data from the 2004 National Marine Fisheries Service.[5] Fishing vessel port activities were assigned to fishing ports, also using data from the National Marine Service. 2006 U.S. Coast Guard online district maps were used to bound the domain for total annual underway activities by U.S. Coast Guard district. The designated home port of each U.S. Coast Guard vessel was used as a surrogate to assign their port activities.

Figure 2. Overview of spatial allocation approach.



The Census Report[3] provides a detail discussion about the data used to spatially allocate the annual horsepower hours for other vessel categories into GIS shapefiles from the Bureau of Transportation Statistics Atlas[6]. Once the horsepower hours were allocated into shapefiles, the data were further split into county boundaries and assigned the appropriate Federal Information Processing Standard (FIPS) code. For activities occurring in Federal waters extending out 200 nautical miles from the coast, the Bureau of Ocean Energy Management (BOEM) lease blocks[7] were used instead of county FIPS codes. Appendix B contains the port and underway activity distributions by vessel type. Figure 3 shows the spatial allocation for port and underway and vessel types combined.

Figure 3. Spatial Allocation for Port and Underway and Vessel Types Combined.



Once the port and underway activity had been spatially allocated, the disaggregated data are compiled into the project database by vessel type; Figure 4 provides a snapshot of the database showing how the vessel type port and underway data were split.

Figure 4. Example of category 1/2 horsepower hours database.

Type	SCC	ShapeID	SumOfActivity(kwhr)
Deepwater	2280002100	10041	2925179.59141152
Deepwater	2280002100	10051	2064903.63424784
Deepwater	2280002100	10105	1290775.62828289
Deepwater	2280002100	10138	1924867.92297332
Deepwater	2280002200	4965	436835759.501891
Deepwater	2280002200	5053	65085898630.45
Ferries	2280002100	10041	2101476770.93242
Ferries	2280002100	10051	1483446361.49052
Ferries	2280002100	10138	1382843377.93067
Fishing	2280002100	10041	22206440.7856701
Fishing	2280002100	10051	15675673.5267366
Fishing	2280002100	10105	4455435.82958092
Fishing	2280002100	10138	14612595.3008981
Fishing	2280002200	4965	27768337.6165895
Fishing	2280002200	5030	6540055.70337239
Fishing	2280002200	5053	26045673278.4031
Government	2280002100	10041	730366185.351693
Government	2280002100	10051	515570324.260571
Government	2280002100	10105	80571024.9844011
Government	2280002100	10138	480605856.247437
Government	2280002200	4965	73137754.6817315
Government	2280002200	5030	17249864.3920389
Government	2280002200	5053	10817121190.8346
GreatLake	2280002200	4965	4869033382.1572
GreatLake	2280002200	5030	1148383156.25106
Support (Offshore & Research)	2280002100	10041	1395296249.89417
Support (Offshore & Research)	2280002100	10051	984948857.744687
Support (Offshore & Research)	2280002100	10105	461770210.336601
Support (Offshore & Research)	2280002100	10138	918152513.559096
Support (Offshore & Research)	2280002200	5053	1.03878837332132E+12
Tugs	2280002100	10041	1602551905.52016
Tugs	2280002100	10051	1131251996.7988
Tugs	2280002100	10105	413993884.570497
Tugs	2280002100	10138	1054533802.60562
Tugs	2280002200	2887	1058543582.98769
Tugs	2280002200	4965	2513526.0430875
Tugs	2280002200	5053	261373.554128676

Application of the Category 1 and 2 Census Data to 2011 NEI

For the NEI, OTAQ provides OAQPS with national port and underway emission estimates for all vessel categories that are consistent with the data developed in support of the EPA's marine vessel rules. ERG supports the EPA in spatially allocating the emissions appropriately and speciating the particulate matter (PM) and volatile organic chemical (VOC) estimates into the HAP components. To ensure consistency with OTAQ's 2011 data, the port and underway emissions were combined and reallocated spatially using the Category 1 and 2 Census data.

The reallocation was implemented by summing all port and underway horsepower hours developed in the Category 1 and 2 Census study. The estimated horsepower-hour values for each vessel type and FIPS code (or BOEM lease block) were divided by the total horsepower-hours to get the fraction of national activity that occurred at each county waterway segment, ocean shipping lane, and port, using the following equation:

$$SA_{iJ} = A_{iJ}/\sum A_{iJ}$$

Where:

SA_{iJ} = Spatial activity factor for vessel type i operating in FIPS/BOEM block J
A_{iJ} = Census Report activity for vessel type i in FIPS/BOEM block J

i = Vessel type (e.g., tug, ferry, fishing) and operation (i.e., port, underway)
J = Specific spatial block (FIPS county shape file or BOEM lease block)

The spatial activity factor for each geographic block was applied to the total national Category 1 and 2 emission estimates to get the emissions for that spatial block for port and underway activities. This approach had two aims: first, to disaggregate OTAQ's national Category 1 and 2 activity and emissions by vessel type and mode and second, to preserve the vessel type-specific spatial allocations developed in the Census report. Table 2 summarizes the 2011 Category 1 and 2 nitrogen oxides (NO_x) emissions by vessel type.

Table 2. 2011 C1/C2 NO_x emission estimates by vessel type (tons/year)

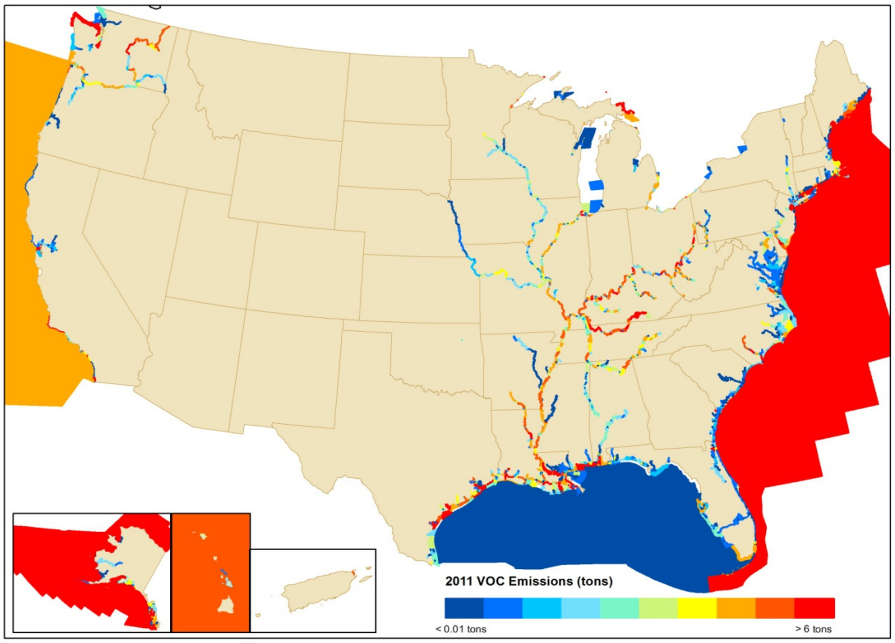
Vessel Type	2280002100 Port	2280002200 Underway
Small Deepwater Cargo Ships	575	56,819
Ferries	20,489	11,032
Commercial Fishing Vessels	3,677	69,793
Coast Guard Vessels	18,274	12,722
Cargo ships that operate on the Great Lakes	300	29,692
Offshore Support & Research Vessels	12,892	318,571
Tugs and Tow Boats	29,007	141,513
Total	**85,214**	**640,143**

Analysis

Figure 5 shows the allocated 2011 volatile organic compound (VOC) Category 1 and 2 emissions. Note the BOEM lease block emissions were aggregated into larger zones (i.e., Atlantic, Gulf of Mexico, Pacific, Alaska, Hawaii, and Puerto Rico). For the most part, the figure shows locations where high levels of activity are occurring such as the lower Mississippi and Ohio River basin, and large Federal areas.

Conversely it is interesting to note that the upstream component of navigable waterways generally show lower levels of activity as expected. It should be noted that activity is proportional to the length of the shape file – regardless of the location of the segment, longer waterway segments may show higher activity levels than short adjacent segments.

Figure 5. 2011 Distribution of Category 1 and 2 VOC emissions for the NEI.



Results from this approach provide a significantly different port and underway split than used in the earlier SIP guidance; instead of port activity accounting for 75 percent of emissions[2], this approach suggests that a value closer to 12 percent may be more accurate. Table 3 shows the port and underway fractions in terms of total percentages for each vessel type included in the Category 1 and 2 Census Report [3]. As the table indicates, some vessels, such as ferries and government vessels (e.g. Coast Guard), do contribute to local port air quality, while other vessels areas such as deep water cargo ships, fishing vessels, offshore support vessels, and tugs are more active outside port.

Table 3. Percentage of horsepower hours allocated to port and underway activities by vessel type.

Vessel Type	% of Port Activity	% of Underway Activity
Deepwater	0.0791	7.8333
Ferries	2.8246	1.5210
Fishing	0.5064	9.6219
Government	2.5239	1.7539
Great Lake	0.0413	4.0934
Support (Offshore & Research)	1.7766	43.9192
Tugs	3.9959	19.5094
Total	**11.7479%**	**88.2521%**

Improvements

It should be noted that this is the first time this type approach was used to quantify smaller vessel activities at the county level. Results from this approach represents a starting point for which improvements can certainly be made. In fact, after developing the preliminary 2011 allocated emissions for the NEI, some issues with the data were discovered.

First, elevated levels of port activity occurred in Louisiana. For large ports in the state that extend over multiple parishes, the emissions were inappropriately assigned to a single parish due to limited spatial information in 2007. This was addressed in the 2011 NEI by reallocating emissions from three shapes for three parishes to eight shapes that cover seven parishes, which more accurately represents the port areas in Baton Rouge, Port of Southern Louisiana, and New Orleans, as noted in Table 4.

Table 4. In-port activity allocation revisions for the Port of Baton Rouge and the Port of South Louisiana for 2011.

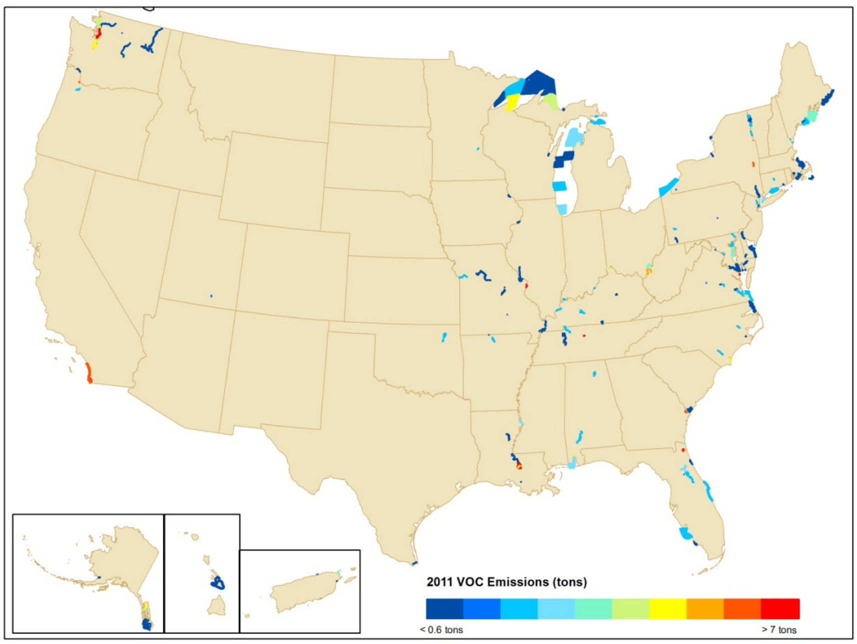
Original Louisiana Port Activity Allocation			
Shape ID	Activity (kw-hr)	Type	FIPS
10007	4,583	Deepwater	22033
10007	5,627,934	Tugs	22033
10130	41,246	Deepwater	22093
10131	22,103,150	Tugs	22095
Total	**27,776,913**		
Revised Louisiana Port Activity Allocation			
Shape ID	Activity (kw-hr)	Type	FIPS
10006	869	Deepwater	22005
10006	1,067,681	Tugs	22005
10128	21	Deepwater	22005
10128	11,338	Tugs	22005
10007	1,019	Deepwater	22033
10007	1,250,766	Tugs	22033
10008	998	Deepwater	22047
10008	1,225,196	Tugs	22047
10129	12,117	Deepwater	22089
10129	6,493,185	Tugs	22089
10130	19,017	Deepwater	22093
10130	10,191,299	Tugs	22093
10131	10,090	Deepwater	22095
10131	5,407,328	Tugs	22095
10009	1,697	Deepwater	22121
10009	2,084,292	Tugs	22121
Total	**27,776,913**		

Second, elevated levels of ferry-related port activity occurred in Connecticut and Massachusetts. This was a similar problem to that noted in Louisiana, where all ferry activities were assigned to one county in each state. Further review of available data suggested that activity should have been allocated to three ports in two counties in Connecticut and seven ports in ten counties in Massachusetts, as noted in Tables 5 and 6. The revised distribution is shown in Figure 6.

Table 5. 2011 ferry trip count in Connecticut ports by terminal from the national Census of ferry operators.

Port Match	Bridgeport	New London	Stamford
Bridgeport – Port Jefferson (NY)	3,432		
New London; Ferry Street – Orient Point; Long Island (NY)		5,460	
New London; State Street – Fishers Island (NY)		1,456	
New London; Ferry Street – Block Island; New Harbor (RI)		378	
Arch Street – Little Capitan Island			1,274
Arch Street – Great Capitan Island			416
Total Trips Per Year	**3,432**	**7,294**	**1,690**

Figure 6. Revised ferry VOC emission distribution.



The last issue found in the data relates to tug-related underway activities. The original Category 1 and 2 Census[3] allocation mapped to 1,864 waterway shapes. These were remapped to a more comprehensive data set of 13,867 shapes that accounted for improvements made by BTS. This update also addressed a complicating issue that for our purposes shipping lanes are not simple single line segments. The fact that waterways or bodies of water can be the county boundary, requires that the water segment shape file be split to allow it to be assigned to the appropriate county on either side of the country boundary.

The revised preliminary data with the above changes made were used in the 2011 NEI Version 2 release.

As local governments and state agencies review the marine vessel component of the NEI[1], they may have useful insight about local vessel traffic patterns that can be used in future emission inventories to further enhance the accuracy of this approach.

Table 6. 2011 Ferry Trip Count in Massachusetts Ports by Terminal from the National Census of Ferry Operators.

Ferry Terminal	Barnstable	Boston	Dukes	Nantucket	New Bedford	Norfolk	Plymouth
Woods Hole – Vineyard Haven; Martha's Vineyard	7,280						
Falmouth Harbor; Falmouth; Clinton Avenue – Oak Bluffs	2,184						
Hyannis – Nantucket	2,184						
Woods Hole – Oak Bluffs; Martha's Vineyard	1,029						
Falmouth; Falmouth Harbor; Falmouth Heights Road – Edgartown	588						
Hyannis – Oak Bluffs; Martha's Vineyard	546						
Provincetown – Plymouth	91						
Long Wharf; Boston – Charlestown Navy Yard; Charlestown		28,392					
Long Wharf; Boston – Provincetown		2,184					
Pemberton Point; Hull – Long Wharf; Boston		2,080					
Rowes Wharf; Boston – Hingham; Hingham Shipyard		780					
Edgartown; Memorial Wharf – Chappaquiddick			16,380				
Vineyard Haven; Martha's Vineyard – Woods Hole			7,280				
Oak Bluffs; Martha's Vineyard – Woods Hole			1,029				
Edgartown; Memorial Wharf – Falmouth; Falmouth Harbor; Falmouth			588				
Oak Bluffs; Martha's Vineyard – Nantucket			91				
Nantucket – Hyannis				2,184			
Harwich Port; Saquatucket Harbor – Nantucket				1,092			
Nantucket – Oak Bluffs; Martha's Vineyard				364			
New Bedford – Martha's Vineyard					1,820		
Fore River; Quincy – Long Wharf; Boston						4,200	
Hull – Boston							1,040
Hingham; Hingham Shipyard – Rowes Wharf; Boston							780
Plymouth – Provincetown							91
Total Trips Per Year	**13,902**	**33,436**	**25,368**	**3,640**	**1,820**	**4,200**	**1,911**

CONCLUSIONS

Use of the Category 1 and Category 2 Census[3] to reallocate EPA/OTAQ's 2011 criteria pollutant emission estimates for this marine vessel source provided data to allow for a better approximation of port and underway activities than the approach recommended in earlier SIP guidance documents. The SIP methodology assumed that 75 percent of distillate fuel typically used by smaller vessels, such as those equipped with Category 1 and 2 engines, is combusted within the port area[2]. Based on the approach developed for the Category 1 and 2 Census, the amount of fuel used and emissions released in the port varies by vessel type, but in aggregate, activity and emission associated with ports is roughly 12% of total activity. Conversely, SIP guidance suggested that 25 percent of distillate fuel usage was used in underway activities[2], while the Category 1 and 2 Census estimated underway activities accounted for 88% of fuel usage.

Another important improvement that using the Category 1 and 2 Census data provided was the ability to estimate fuel usage and emissions not only for in-port and underway activities, but also by vessel type. This will, hopefully, help local governments and state agencies in their review of the marine vessel component of the NEI and allow for inclusion of better local data. For instance, now a reviewing agency can see what vessel types contribute to local air quality issues; and if the inventory provides estimates for a vessel type that does not operate in a port or county, they can suggest a better match to local information. If the inventory appears reasonable, the data can also help local agencies to better prioritize control options targeting the vessel types that have the most significant impact on local air quality.

EPA and ERG are updating the Category 1 and Category 2 Census[3] data for the 2014 NEI and will be converting the horsepower hours to kilowatt-hours in order to match current EPA emission factors. Updated data sources will also be used to refine the spatial allocation data to represent changes in activity in the 2014 NEI.

REFERENCES

1. U.S. Environmental Protection Agency, *2011 National Emission Inventory (NEI),* March 2015. http://www.epa.gov/ttnchie1/trends/

2. U.S. Environmental Protection Agency, *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources,* July 1989.

3. U.S. Environmental Protection Agency, *Category 2 Vessel Census, Activity and Spatial Allocation Assessment and Category 1 and 2 In-Port / At- Sea Splits*, February 16, 2007.

4. Bureau of Transportation Statistics ~~2000~~, National Ferry Database, 2000. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/ncfo/index.html

5. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Annual Commercial Landings by Group, downloaded June 2006. http://www.st.nmfs.gov/st1/commercial/landings/gc_runc.html

6. U.S. Department of Transportation, Bureau of Transportation Statistics, 2014 National Transportation Atlas Database. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_database/2014/index.html

7. Bureau of Ocean Energy Management GIS data/ Shapefiles, 2007. http://www.boem.gov/Maps-and-GIS-Data/

KEY WORDS

Marine vessels
Category 1 marine engines
Category 2 marine engines
Port activity
Underway activity
National Emission Inventory

Appendix A. Results from the Monte Carlo Analysis by Vessel Type

Figure A-1 - Deep Water Vessel

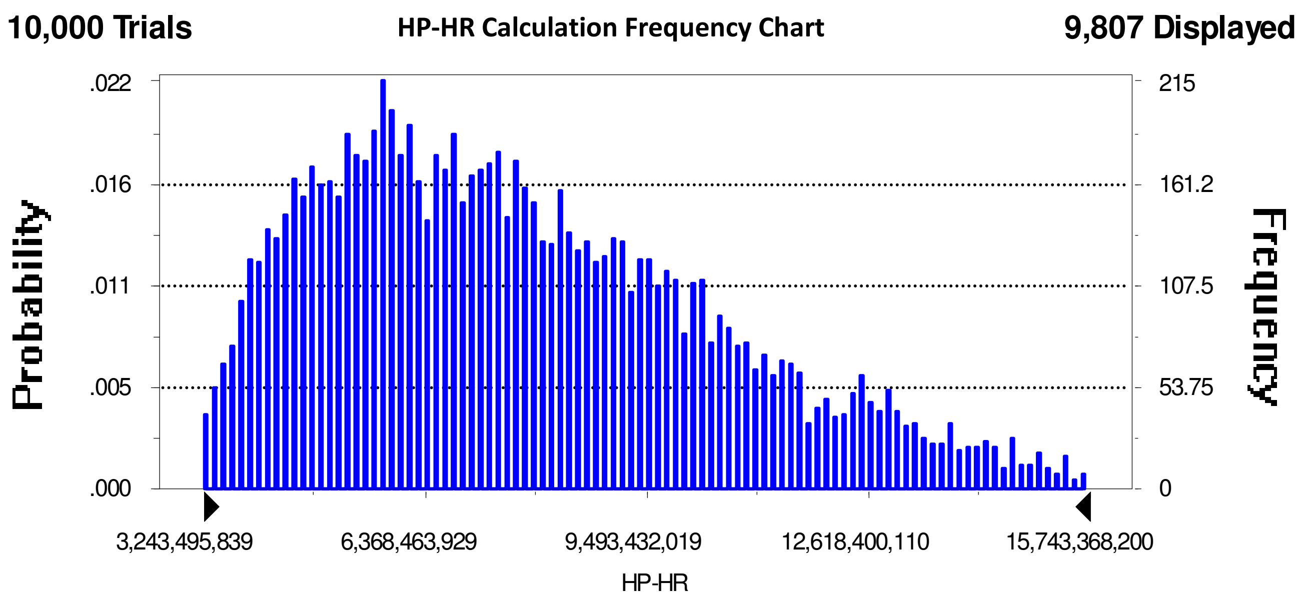


Figure A-2 - Tow Vessel

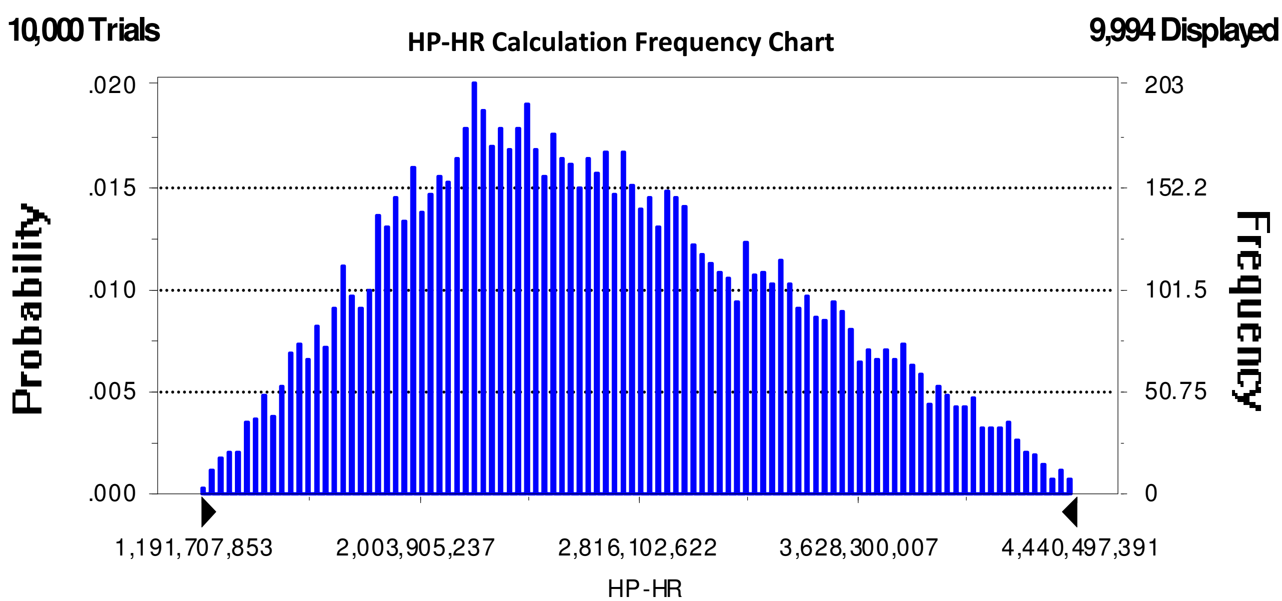


Figure A-3 - Ferry Vessel

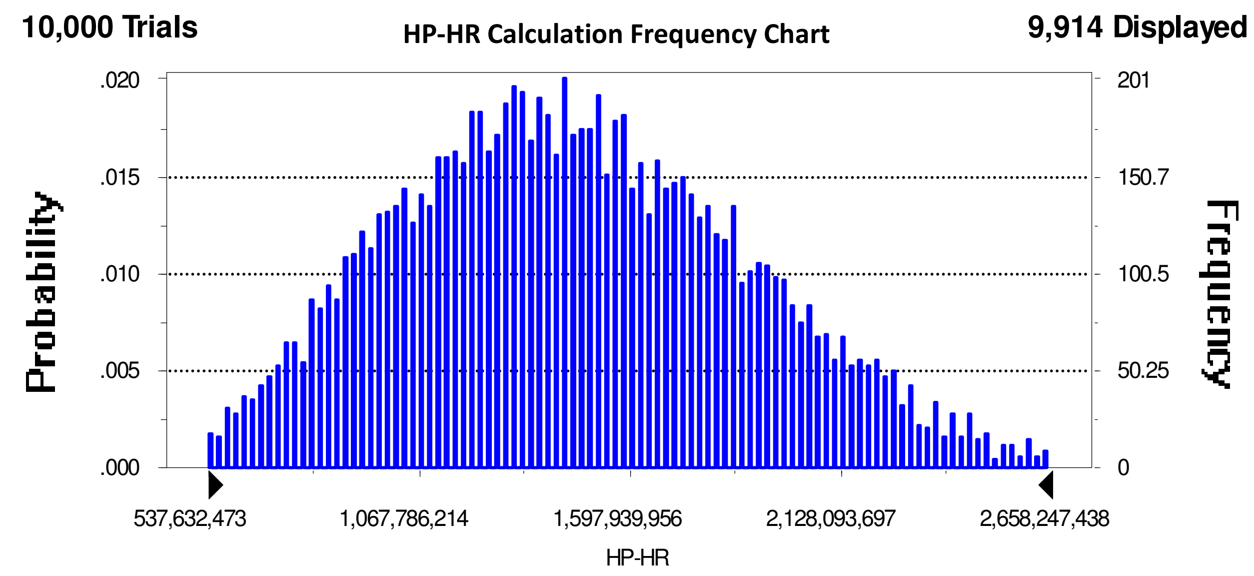


Figure A-4 - Commercial Fishing Vessel

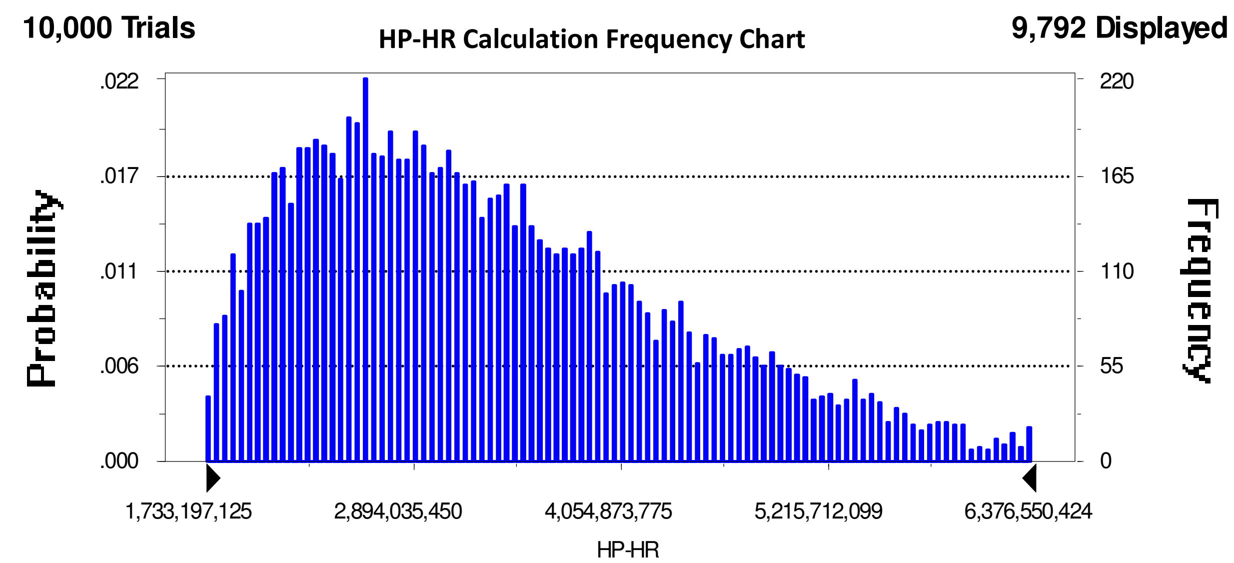


Figure A-5 - Great Lakes Vessel HP-HR Calculation Frequency Chart

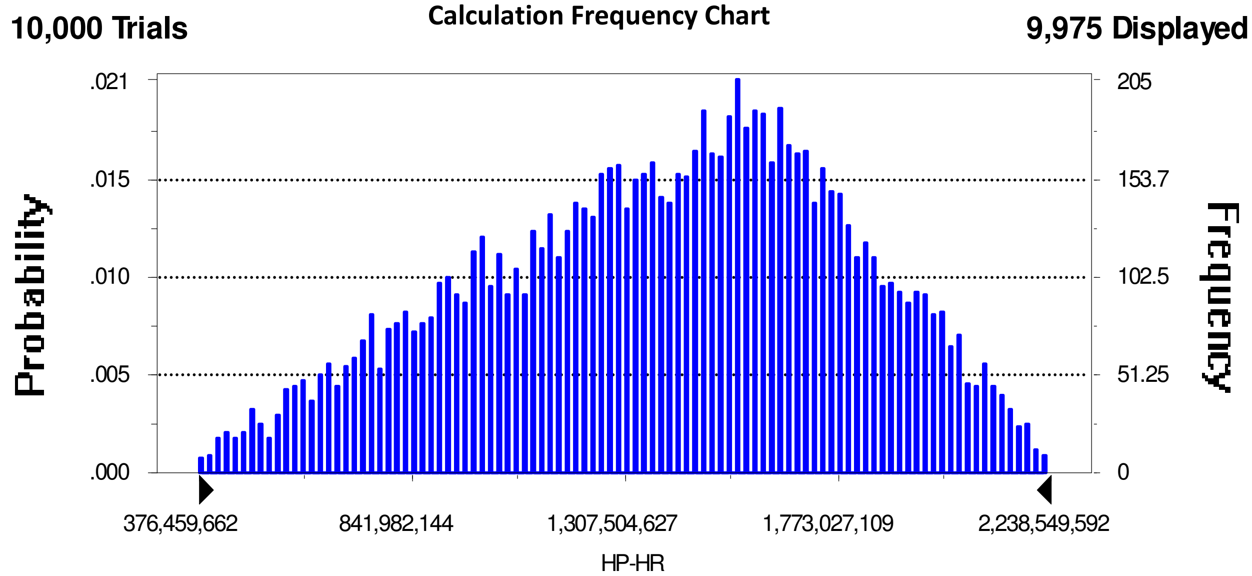


Figure A-6 - Coast Guard Vessel HP-HR Calculation Frequency Chart

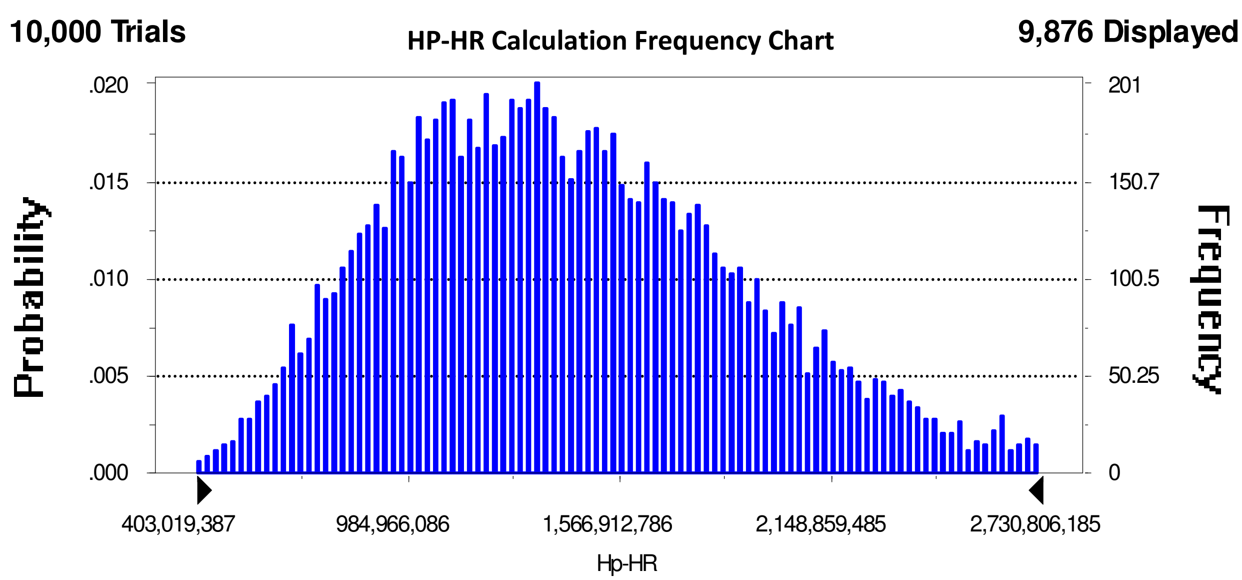


Figure A-7 - Offshore Vessel

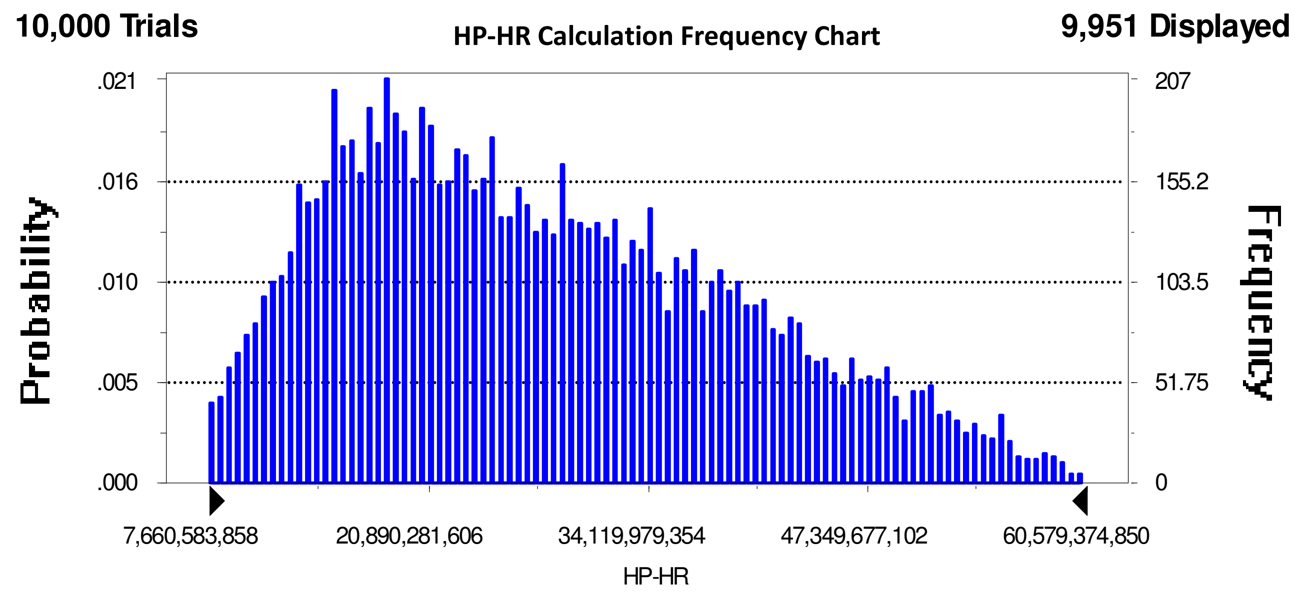
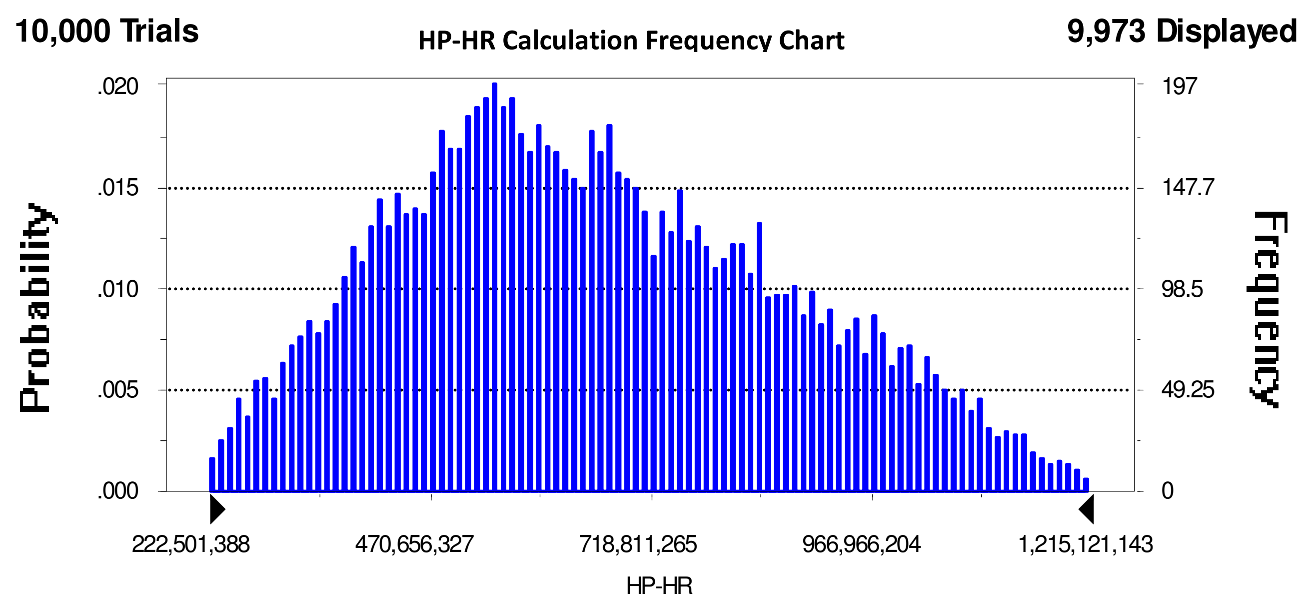


Figure A-8 - Research Vessel



Appendix B. Spatial Distribution of Activity by Vessel Type

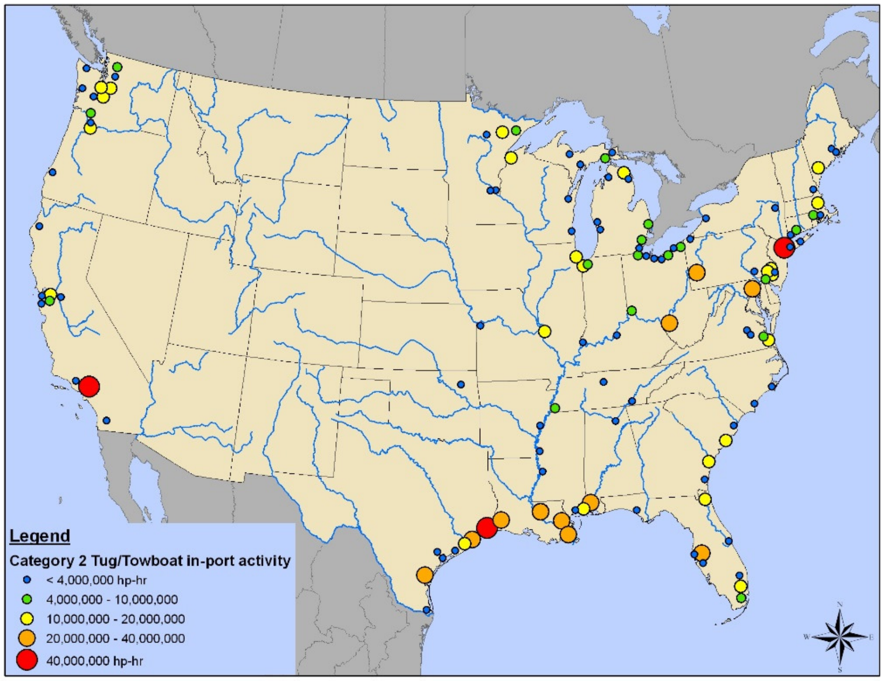


Figure B-1. Tug/Towboat In-Port Activity

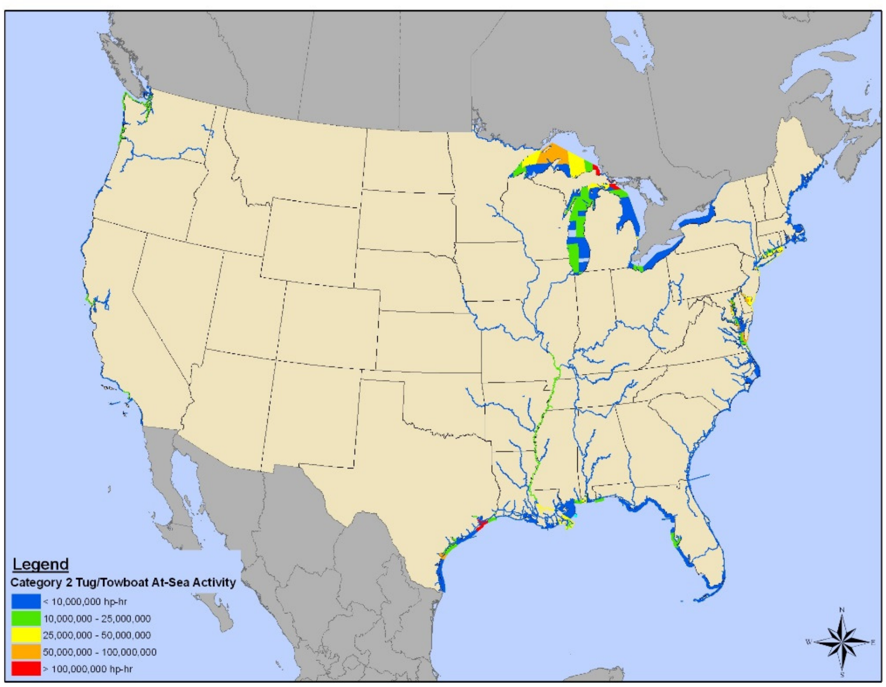


Figure B-2. Tug/Towboat At-Sea Activity

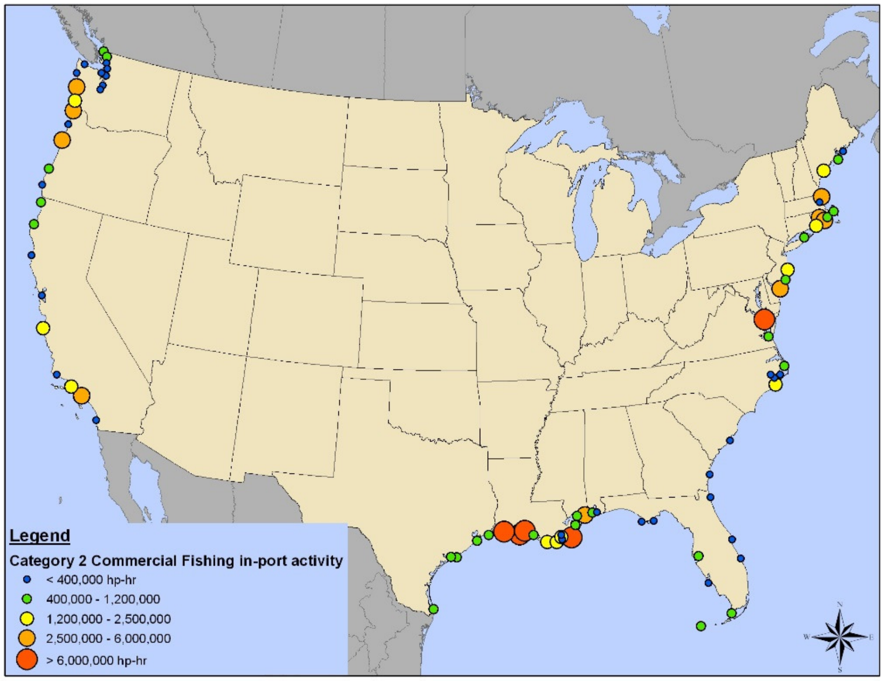


Figure B-3. Commercial Fishing In-Port Activity

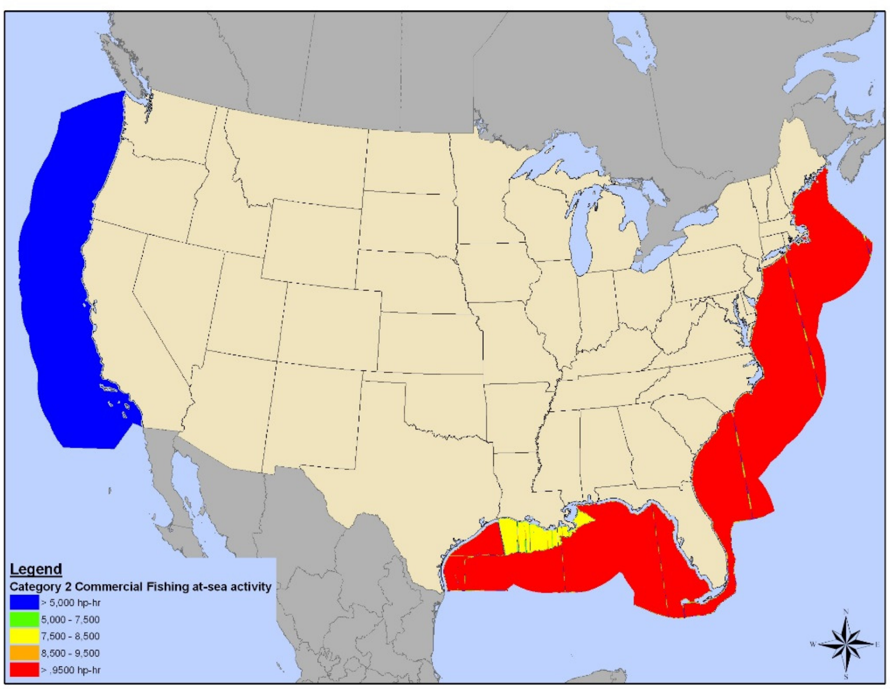


Figure B-4. Commercial Fishing At-Sea Activity

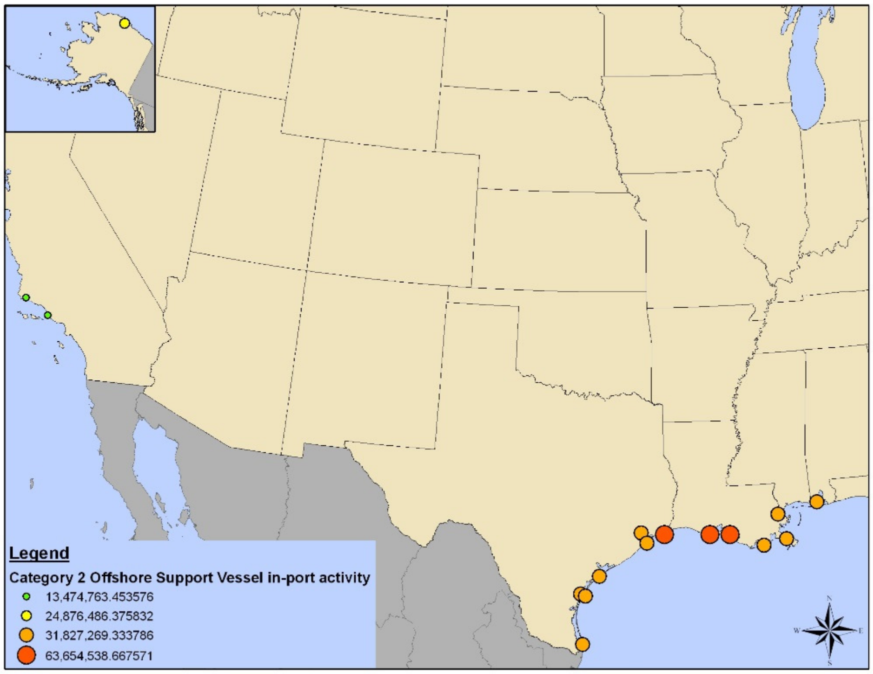


Figure B-5. Offshore Support Vessel In-Port Activity

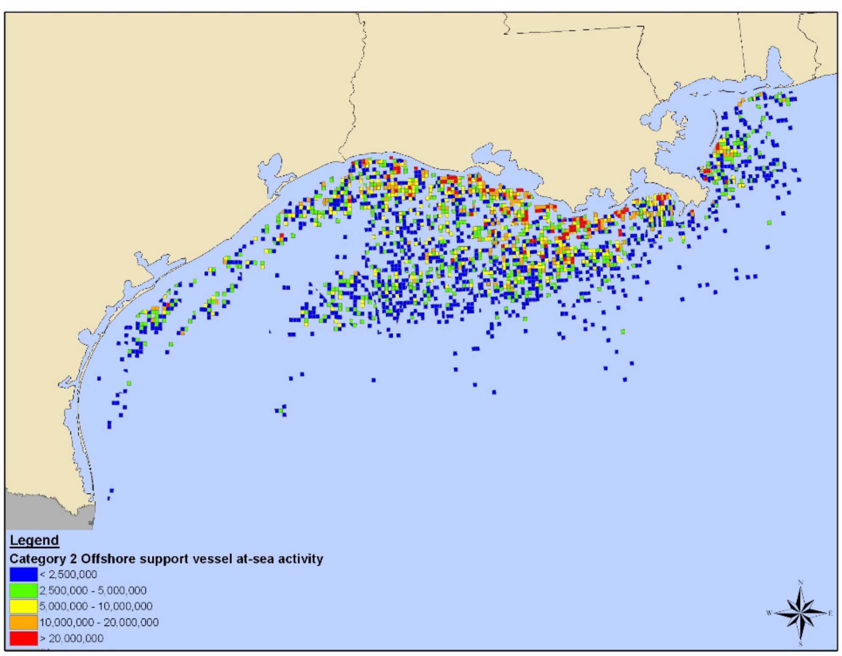


Figure B-6. Offshore Support Vessel At-Sea Activity

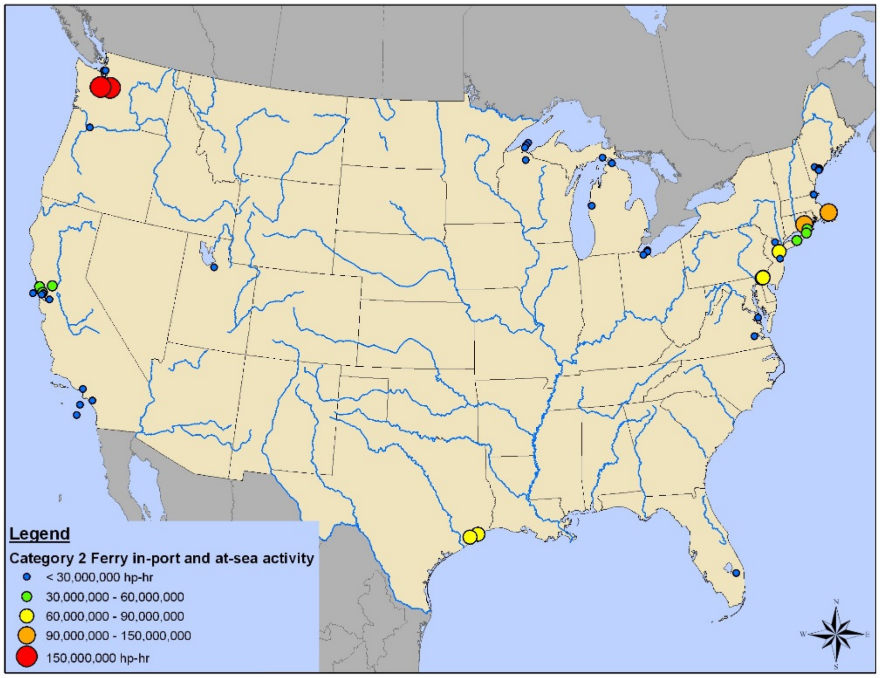


Figure B-7. Ferry In-Port and At-Sea Activity

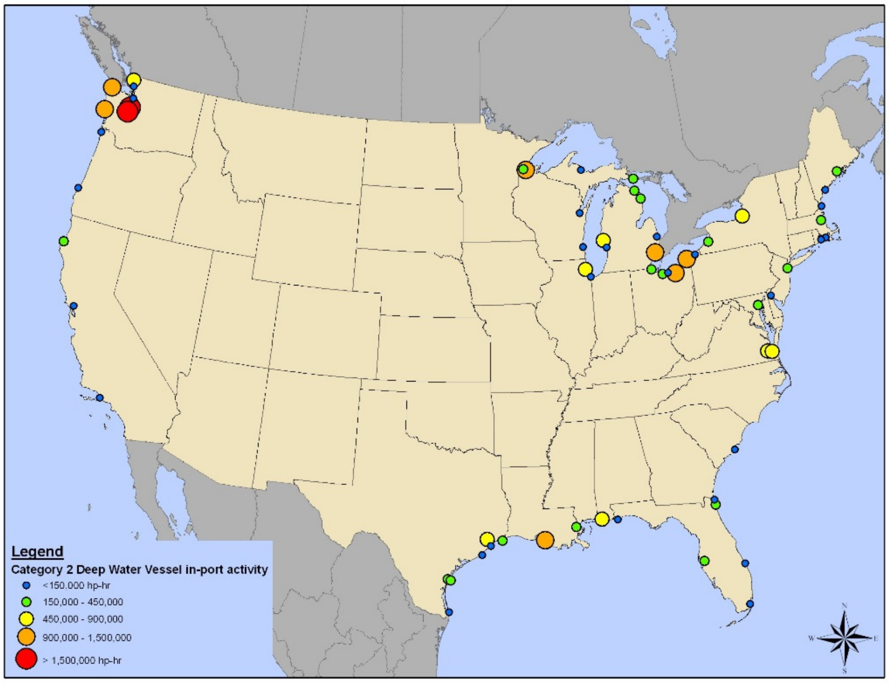


Figure B-8. Deep Water Vessel In-Port Activity

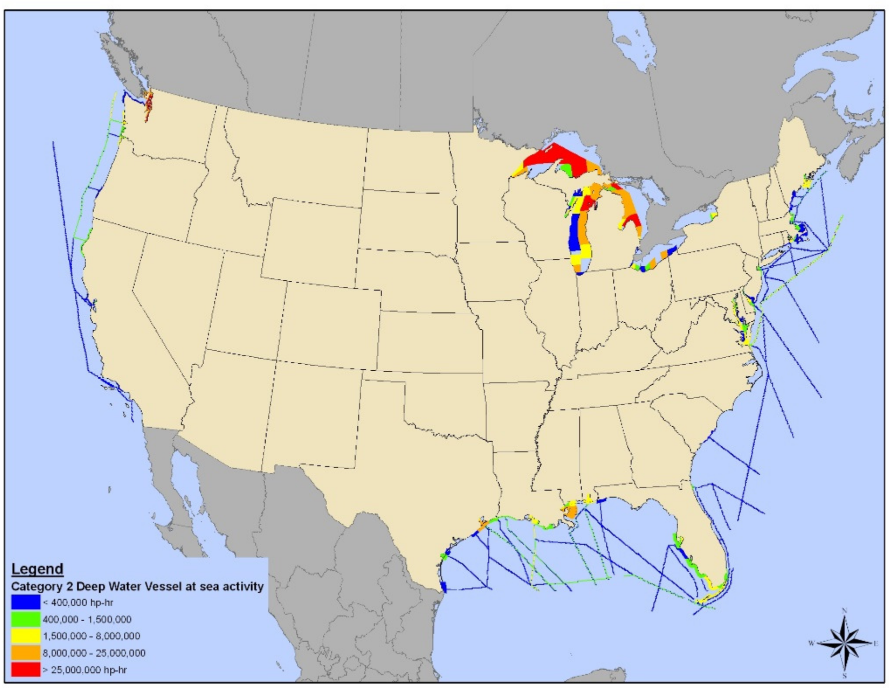


Figure B-9. Deep Water Vessel At-Sea Activity

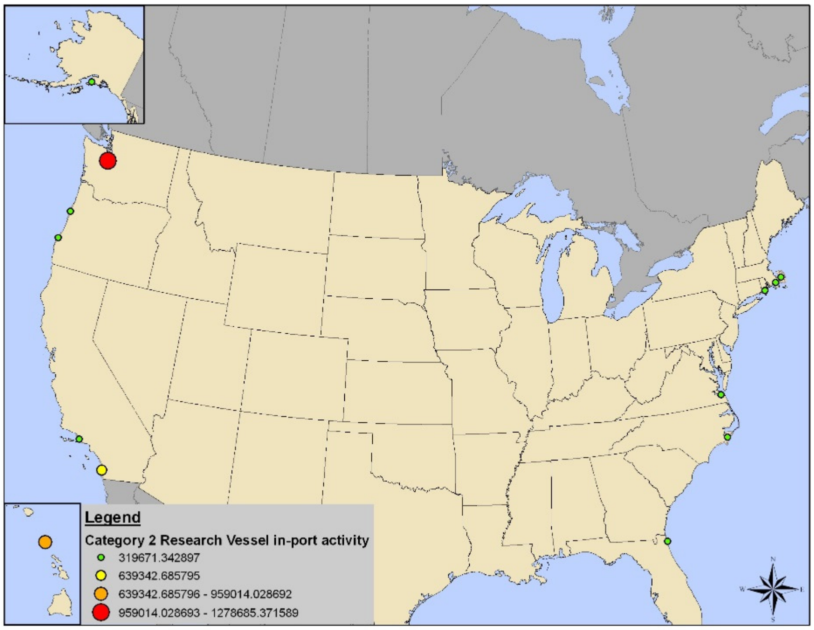


Figure B-10. Research Vessel In-Port Activity

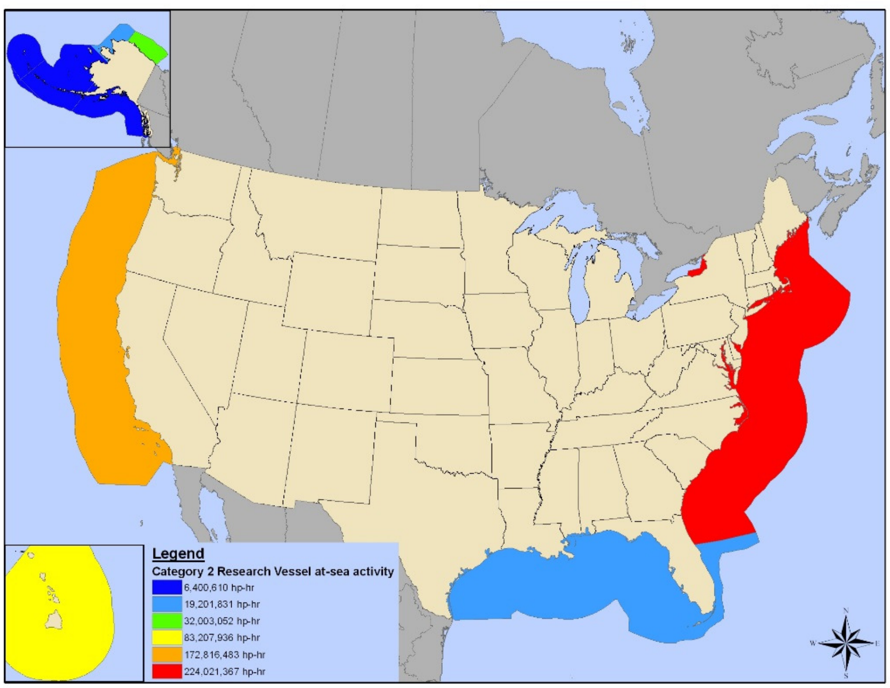


Figure B-11. Research Vessel At-Sea Activity

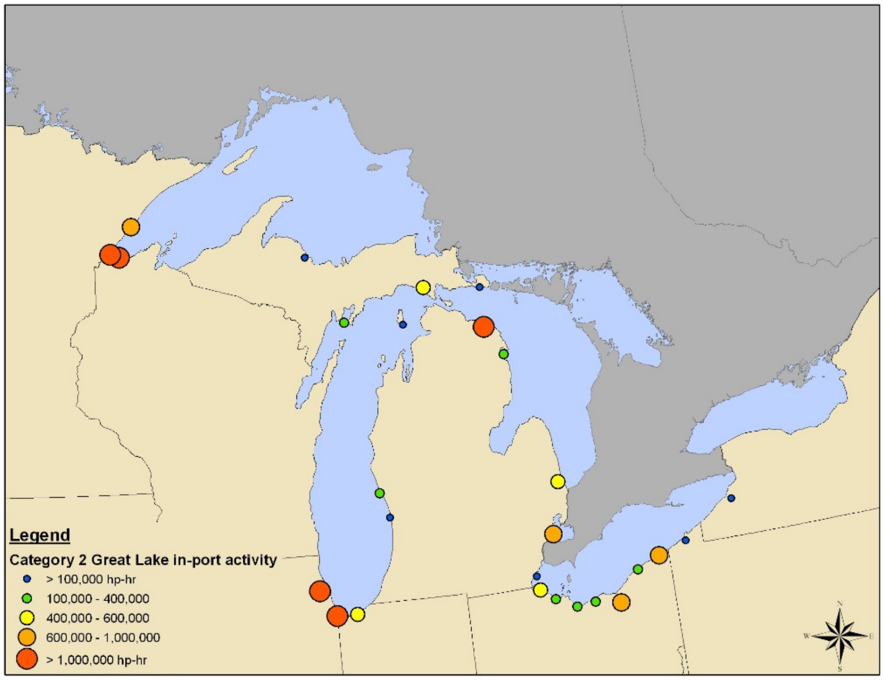


Figure B-12. Great Lake and Other Vessel In-Port Activity

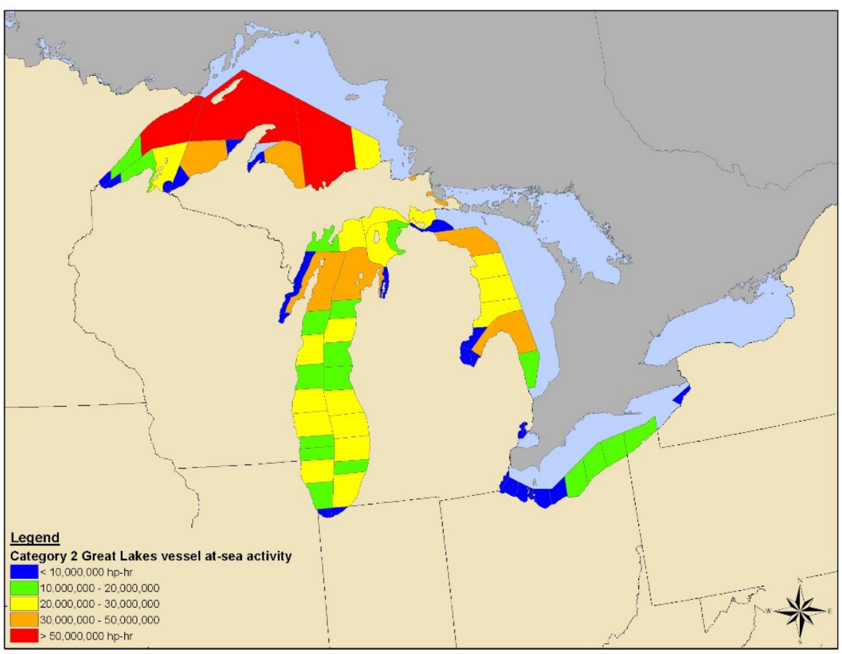


Figure B-13. Great Lakes and Other Vessel At-Sea Activity

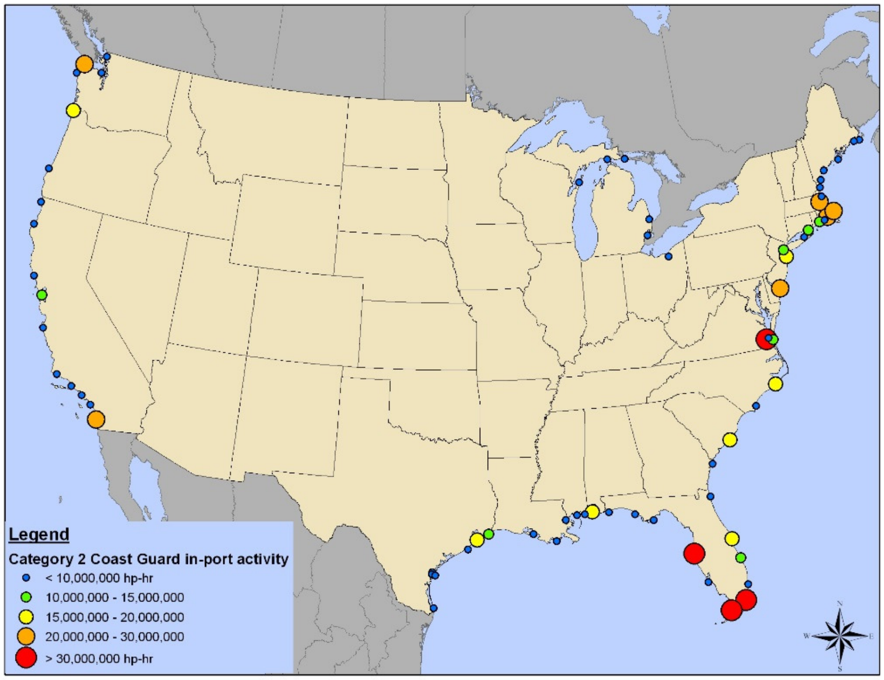


Figure B-14. Coast Guard In-Port Activity

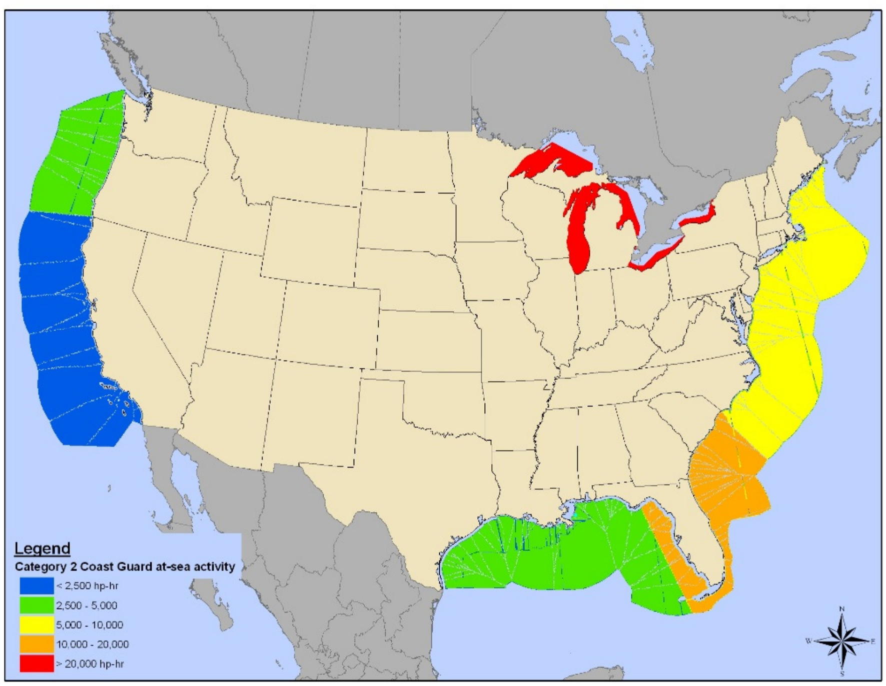


Figure B-15. Coast Guard At-Sea Activity