PORT OF SEATTLE
UNDERWATER NOISE MITIGATION AND MANAGEMENT PLAN

AMBIENT NOISE ASSESSMENT REPORT

PREPARED FOR:

PORT OF SEATTLE

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INTRODUCTION

The Port of Seattle (Port) outlines its environmental goals in its Century Agenda. In order to track progress and maintain momentum toward achieving its goals, the Port is pursuing an increased certification level in Green Marine for the Underwater Noise criteria. Green Marine is a voluntary environmental certification program that encourages its members to take measurable steps to reduce their environmental impact and invest in operational improvements to improve environmental outcomes. As part of their Green Marine certification, the Port developed an Underwater Noise Mitigation and Management Plan (UNMMP) that will help chart a course for setting and achieving noise reduction targets. To quantify success of noise reduction efforts, the Port collected ambient underwater noise data in Elliott Bay to use as a baseline. The Port deployed a hydrophone at Pier 69 along the Seattle Waterfront during four (4) 72-hour periods in 2022 following methods described below (Figure 1).

Figure 1. Vicinity map showing the hydrophone deployment location at Pier 69.

BACKGROUND

There is a paucity of data on underwater noise within Puget Sound and the Salish Sea. Various hydrophone networks, managed by many different organizations, are installed throughout the area and collect a variety of data. Still, gaps exist, both geographically and in the subject of the recordings (i.e., tracking orca/marine mammal communications versus tracking anthropogenic sources of underwater noise). While sporadic data exist on ambient underwater noise levels in the Port operations area, comprehensive data do not; thus, these noise levels are not well-understood. Further, the data lack synthesis—there is currently not a single database through which to share and compare data. In response to this, Quiet Sound, a collaborative group tackling the issues surrounding underwater noise in Puget Sound, is working to close the gaps and synthesize data.

Through Quiet Sound, the Port is supporting a gap analysis being conducted by University of Washington (UW) and the National Oceanic and Atmospheric Administration (NOAA) to identify where more hydrophones are needed. This may culminate in the purchase and deployment of hydrophone equipment in some of the identified areas. In a project funded by Alaska Airlines through the Bonneville Environmental Foundation's Promise the Pod Initiative, a Quiet Sound partner, Oceans Initiative, is also working to analyze existing sound levels in Washington waters.

The Port's Ambient Noise Assessment Program will be implemented in conjunction with all other ongoing and planned hydroacoustic studies in Puget Sound and the Salish Sea. The goal will be to assess background underwater noise levels in the Port operations area, and to compare vessel traffic data with underwater noise levels.

METHODS

Noise data collection occurred during four (4) 72-hour periods with varying levels of vessel activity between April and November 2022—three during times of elevated vessel noise and one during an expected "quiet" period. The elevated vessel noise deployments occurred during periods of varying use by vessel type: when cruise ships were calling, during a holiday weekend when increased pleasure boating was anticipated, and when cargo ships were calling. The quieter period occurred over the Thanksgiving break during two days when no cargo or cruise ships were scheduled and Elliott Bay was expected to be relatively quiet. The deployments also coincided with seasonal periods of increased historical use by Endangered Species Act (ESA)-listed marine mammals.

The hydrophone was deployed from the west end of Pier 69 along the Seattle Waterfront in an orientation that ensured acoustic "line of sight" between the hydrophone and Elliott Bay. The Port provided access to a gated portion of the pier for deployment and recovery. This secure location allowed for collection of ambient underwater noise data as large ships (cruise, cargo, etc.), ferries, tour boats, and pleasure boats traveled through Elliott Bay and berthed at various terminals/marinas around the bay.

The hydrophone was suspended from the pier at mid-water depth. Water depth at the deployment location ranged from approximately 46 feet to 62 feet, depending on tide. The hydrophone cable was attached to a weighted nylon cord to reduce horizontal drift of the hydrophone. Table 2 details the equipment that was used to monitor underwater sound pressure levels.

Table 1. Equipment for underwater noise data collection.

Item	Specifications	Minimum Quantity	Usage
CR-1 Hydrophone with 200 feet of cable	Receiving Sensitivity-198dB ±3dB re 1V/μPa	1	Capture underwater sound pressures and convert to voltages that can be recorded/analyzed by other equipment.
SpectraDAQ-200 Data Acquisition Sound Card (2-channel)	Sampling Rate- 24K Hz to 192 kHz	1	Analyzes and transfers digital data to laptop hard drive via USB 3.0.
Laptop computer	Compatible with digital analyzer	1	Record digital data on hard drive and signal analysis.
Real Time and Post-analysis software (SpectraPLUS)	-	1	Monitor real-time signal and post-analysis of sound signals.

Data collection equipment was set to record 10 hertz (Hz) to 50 kilohertz (kHz) with a sampling rate of 96 kHz. To facilitate further analysis, the underwater signal was recorded as both text files (.txt) and wave files (.wav). Recorded data were not altered, such as by data compression algorithms or technologies (e.g. MP3, compressed.wav, etc.).

The hydrophone was deployed midday and programmed to record for approximately 72 hours per deployment starting in afternoon or evening. Data were typically collected over three nights and three days to allow for comparison between acoustically different conditions (e.g., night versus day, weekday versus weekend, etc.). Environmental data were noted at time of deployment, and weather was noted based on online weather data for the 72-hour period. Vessel presence, type, size, speed, and direction data were acquired from VesselFinder. Data were provided for all vessels within acoustic line-of-sight of Elliott Bay. One line of data was provided for each vessel—this data point was taken at the vessels' max speed.

Vessel data were merged with the acoustic data by matching the date and time stamp; this resulted in one data point for each vessel that corresponded with the underwater noise level during that $1/10^{th}$ of a second. To more accurately reflect the period during which underwater noise levels may have been influenced by vessel presence (e.g., ten minutes before and after the max speed recording), data for each vessel were copied to any adjacent lines of data that were elevated above what the background had been prior to the vessel presence.

Hydroacoustic data from each deployment were analyzed (average, maximum, and minimum volume recorded) for each type of vessel identified by VesselFinder. Data were further analyzed by average vessel length and by average vessel speed for each type of vessel. Average noise levels for daytime and nighttime periods (06:00-17:59 and 18:00-05:59, respectively) and for each date of deployment were also calculated.

Because decibels (dB) are logarithmic and thus differences are exponential not linear, the axis for average volume in the figures in this report is presented from 120 dB to 138 dB to better depict the differences in underwater noise levels; the axes do not start at 0.

Limitations

Because this study was a "pilot" study, there was limited time and budget for collecting all data and conducting all analyses desired. Limitations to data collection included timing constraints and equipment constraints. We conducted four deployments, but in ideal conditions, a hydrophone would be deployed continuously. Also, the positioning of the hydrophone along the Seattle waterfront may have resulted in added noise that would not have been recorded if the hydrophone had been secured mid-Bay in 190 feet of water, as described in the Compendium of Background Sound Levels for Ferry Terminals in Puget Sound (Washington State Ferries [WSF] 2020). Placing the hydrophone in deeper water would reduce the amount of airplane, traffic, weather, etc. surface noise detected. The seawall along the waterfront may also result in an echo effect that could skew data. Last, use of a hydrophone array for recording would allow us to triangulate on noise sources to have a more accurate representation of what vessel (or other source) was contributing to the recorded levels.

More complete vessel tracker data, including vessel positions in relation to the hydrophone would allow for corrections for distance. For this study, analyses were conducted on raw data with no correction for distance to the hydrophone. This may result in skewed results; however, all vessels were treated the same with regards to this limitation. Military vessels may have been moored at the deployment site and harbor cruise vessels pass right past the hydrophone; most other vessels called at terminals at the southeast, south, or north ends of Elliott Bay.

Last, we were unable to expand analyses into the statistical realm, so all results are descriptive based on tables and visual observations of figures.

RESULTS

Deployment 1 – Cruise Ships

The first hydrophone deployment occurred from 18:00 on Saturday, April 23 through 21:00 on Tuesday, April 26, 2022. This deployment aimed to isolate cruise ship noise data by timing the data collection on a weekend before the recreational boating season had begun and when minimal cargo trips were scheduled. During this period, three cargo ship and three cruise ship sailings were scheduled (all from Pier 66).

The air temperature during the deployment ranged from a low of 42 to a high of 67 degrees Fahrenheit (°F). There was no measurable precipitation, and max wind speeds ranged from 9 to 17 (Tuesday afternoon) miles per hour (MPH). Visibility was 10 miles (mi) throughout the deployment.

Twelve types of vessels were identified by VesselFinder as being present in Elliott Bay during this deployment (Table 1). In descending order by volume (dB), the loudest vessel types were: tugs, ferries (both WSF and high-speed passenger ferries), one pleasure craft, container ships/bulk carriers, and cruise ships (Table 1). When comparing by size, container ships and cruise ships were relatively quieter for how long they are (Figure 2). When comparing by speed, high speed passenger ferries and the law enforcement boat were relatively quiet for max travel speed within Elliott Bay (Figure 3).

During this deployment, the average daytime underwater noise level when vessels were not known to be present was 128.7 dB and when vessels were known to be present was 134.0 dB. The average nighttime noise level when vessels were not known to be present was 126.7 dB and when vessels were known to be present was 133.1 dB (Figure 4). Average hourly volumes when known vessels were present were generally higher than when no known vessels were present, with notable exceptions at 09:00, 13:00, 15:00, and 19:00 (Figure 5).

Table 2. Sample size and average volume recorded (dB; descending order) during times when each type of vessel was present.

Vessel Category	Vessel Type	n	Average Volume (dB)
Cargo	Bulk Carrier	4	132.9
	Container Ship	5	133.2
	Total Cargo	**9**	**133.1**
Cruise	Cruise	4	133.6
Ferries	Ferry	1	134.2
	High Speed Craft - Fast Ferry	4	133.7
	Total Ferries	**5**	**133.9**
Small High-Speed Craft	Pilot	1	128.4
	Law Enforcement	1	129.1
	Pleasure Craft	1	134.3
	Diving Operations	1	129.9
	Total High-Speed Craft	**4**	**134.2**
Tug	Tug	19	133.4
	Tug >200	1	136.1
	Other - Crane Dredge	1	129.7
	Total Tug	**21**	**133.9**
No Known Vessels	No Known Vessels		127.6
Grand Total		**43**	**127.9**

Figure 2. Average length and underwater noise volume for each type of vessel present during this deployment.

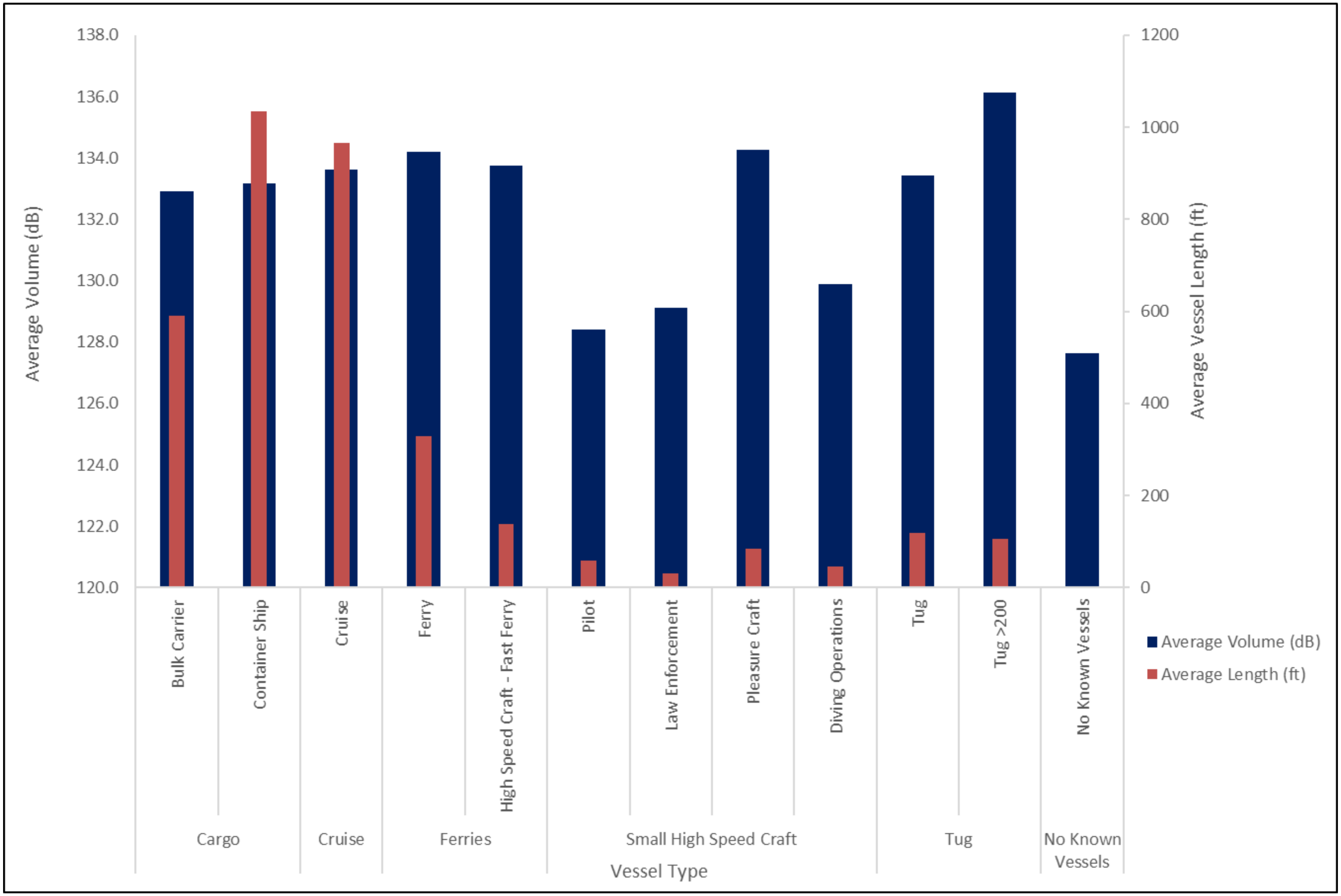


Figure 3. Average speed and underwater noise volume for each type of vessel present during this deployment.

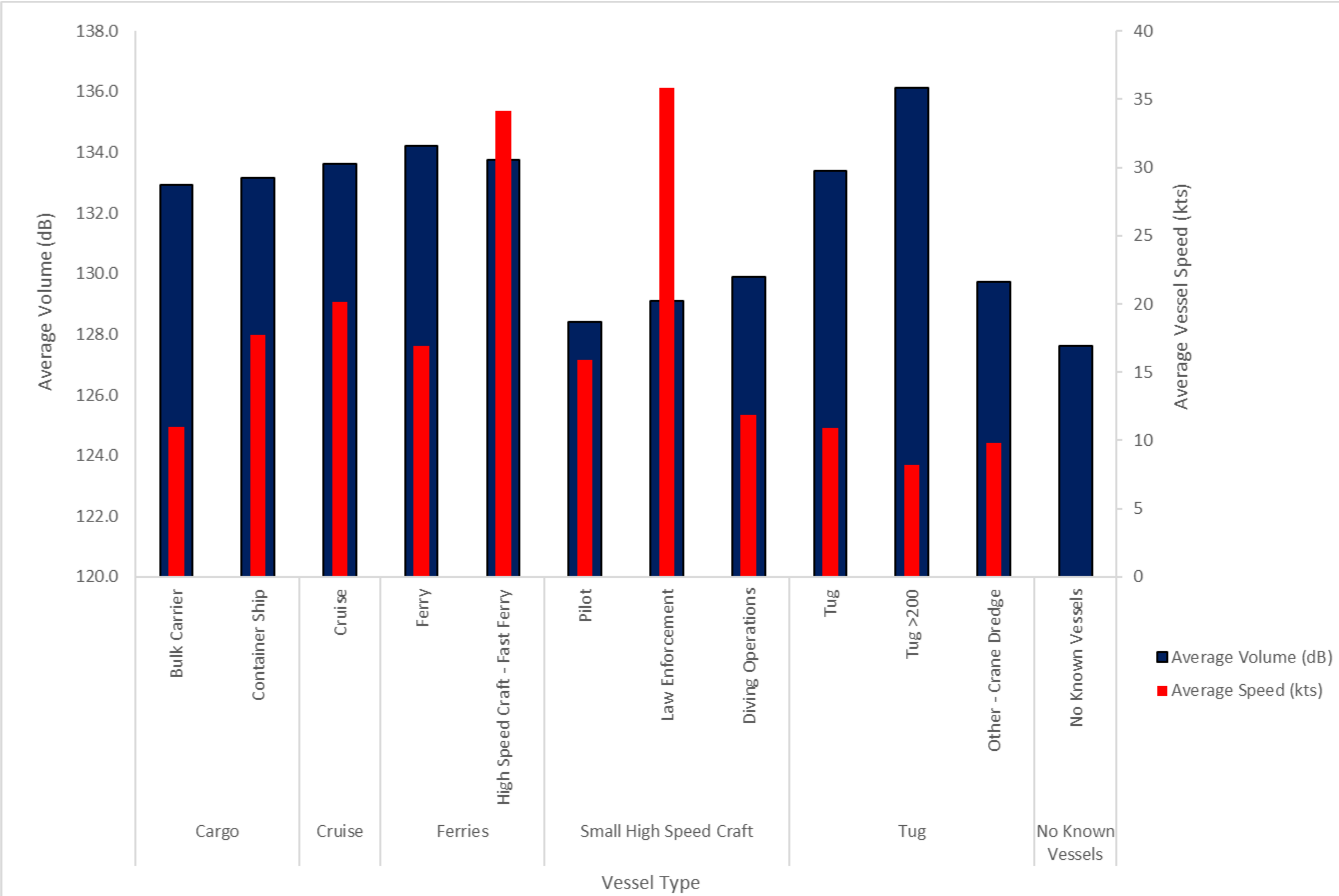


Figure 4. Average underwater noise levels (dB) during daytime and nighttime periods during periods when vessels were present and when there were no known vessels.

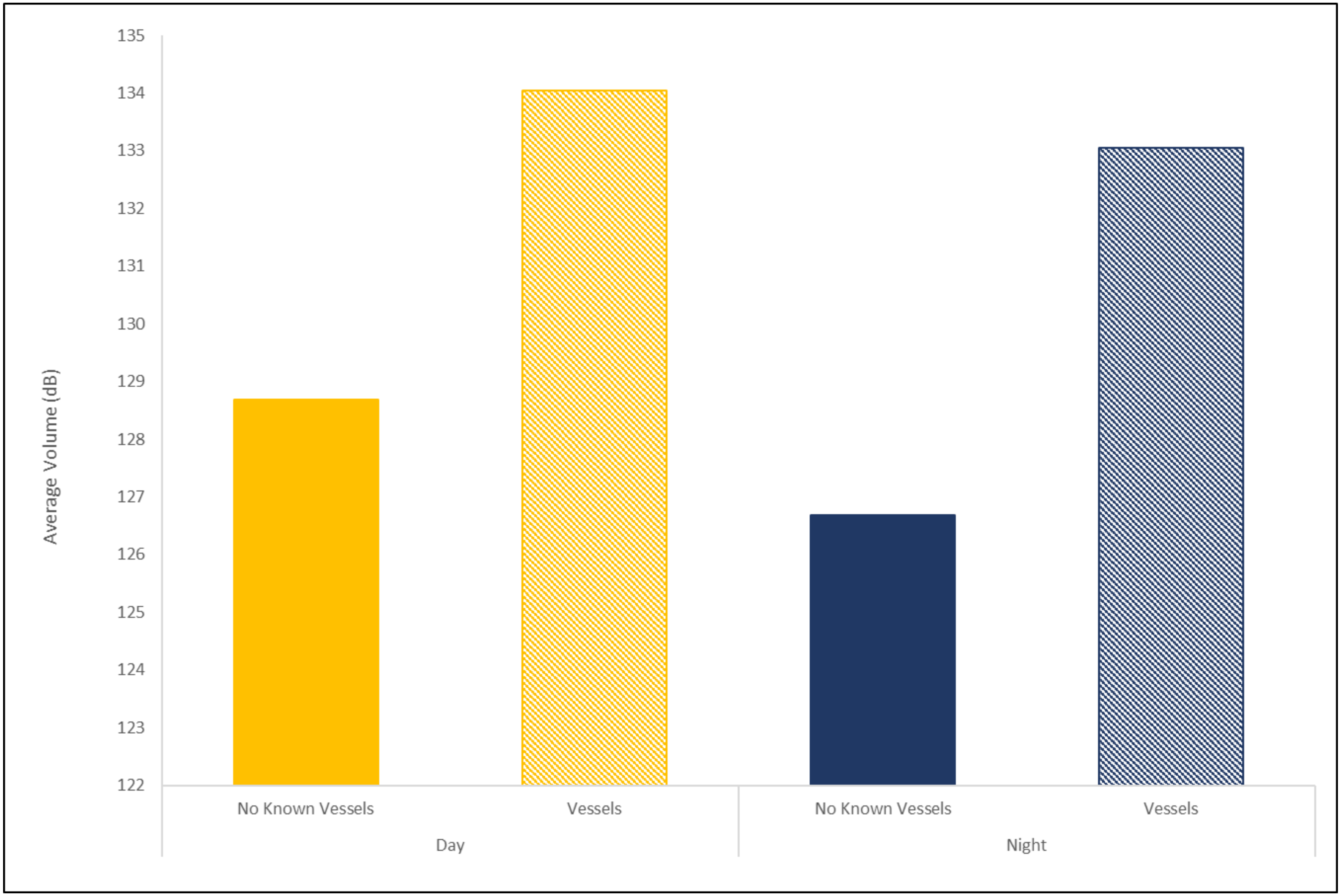
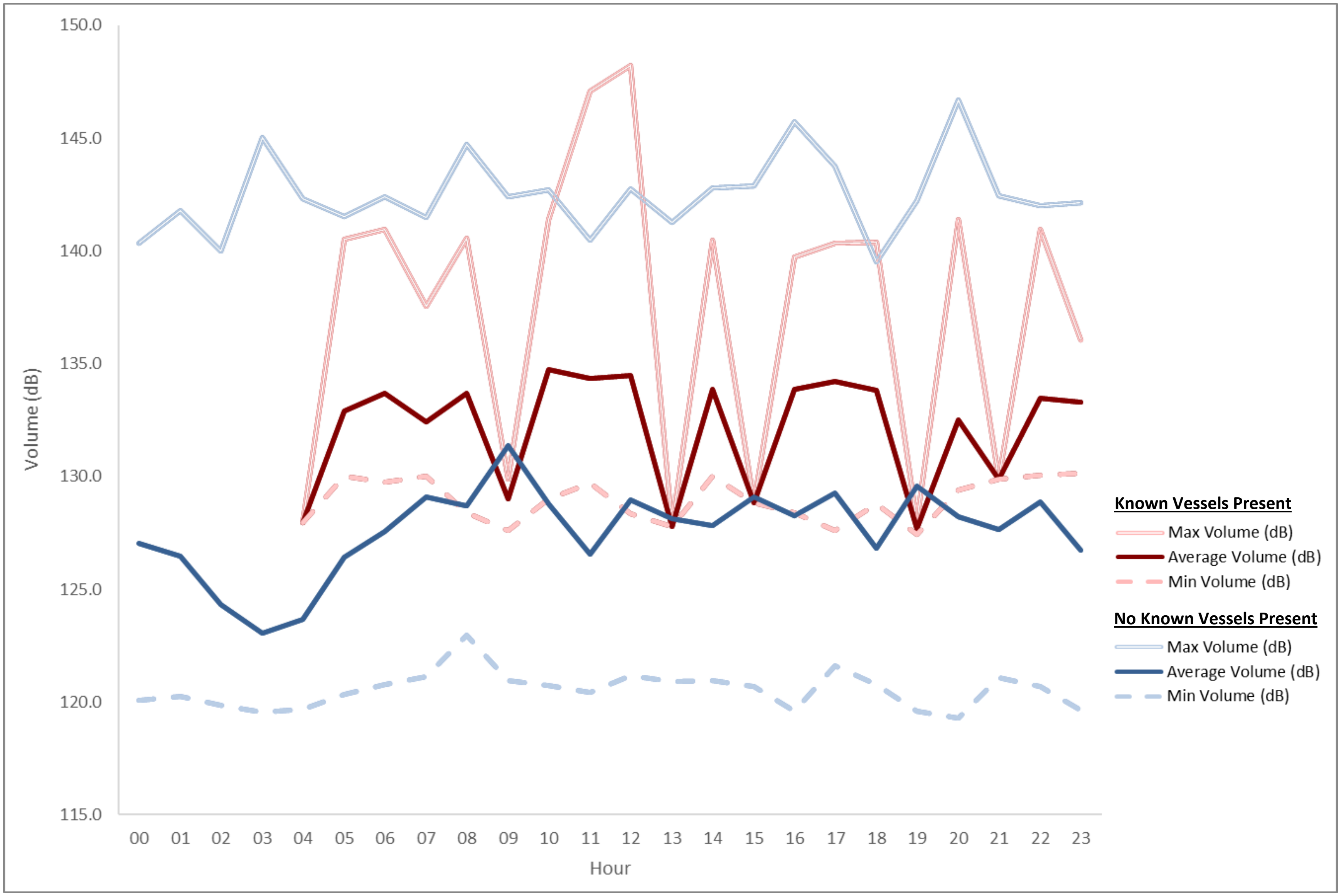


Figure 5. Average, maximum, and minimum underwater noise levels (dB) for each hour of the day when vessels were known to be present and not known to be present.



Deployment 2 – Recreational Vessels

The second hydrophone deployment occurred from 14:00 on Thursday, August 4 through 22:00 on Sunday, August 7, 2022. This deployment aimed to collect data during the summer period, when Elliott Bay is busy with recreational boaters. During this period, a recreational sailboat race was scheduled for Thursday night as part of the Elliott Bay Marina summer sailing series. Boaters race from Elliott Bay Marina at the north end of Elliott Bay south toward Terminal 5 at the south end of the bay and back to the Marina. August weekends tend to have nice weather, which leads to busier recreational boater activity in Elliott Bay. Additionally, ten cruise ship sailings – four from Pier 66 and six from Terminal 91, and six cargo vessels – five container vessels and one bulk grain carrier were scheduled during the deployment period.

The air temperature during the deployment ranged from a low of 55 to a high of 89 degrees Fahrenheit (°F) with the warmest temperatures occurring on Saturday and Sunday of the deployment. There was no measurable precipitation, and max wind speeds ranged from 12 to 16 (Tuesday afternoon) miles per hour (MPH). Winds during the sailboat race were 14 mph, which is strong enough to race under sail, rather than relying on engine power. Visibility was 10 miles (mi) throughout the deployment.

Eighteen types of vessel were identified by VesselFinder as being present in Elliott Bay during this deployment (Table 3). In descending order by volume (dB), the loudest vessel types were: cargo ships, pilot boats, tankers, bulk carriers, tugs, and Washington State Ferries. When comparing by size, container ships, cruise ships, and the fish factory ship were relatively quieter for how long they are (Figure 6). When comparing by speed, high speed passenger ferries, law enforcement boats, diving operations boats, the search and rescue boat, and the fish factory ship were relatively quiet for max travel speed within Elliott Bay (Figure 7).

During this deployment, the average daytime underwater noise level when vessels were not known to be present was 127.5 dB and when vessels were known to be present was 132.9 dB. The average nighttime noise level when vessels were not known to be present was 125.9 dB and when vessels were known to be present was 132.9 dB (Figure 8). There was a period between 02:00 and 08:00 during which average noise levels were considerably quieter than the rest of the day for both times with and without known vessel activity, and a spike in max underwater noise levels at 17:00, coinciding with afternoon commute hours (16:00-17:00; Figure 9).

Table 3. Sample size and average volume recorded (dB) during times when each type of vessel was present.

Vessel Category	Vessel Type	n	Average Volume (dB)
Cargo	Bulk Carrier	4	133.6
	Cargo	2	135.9
	Container Ship	11	132.9
	Tanker	1	133.9
	Vehicles Carrier	3	132.2
	Total Cargo	**21**	**133.2**
Cruise	Cruise	10	132.3
Ferry	Ferry	4	133.1
	High Speed Craft - Fast Ferry	10	132.2
	Total Ferries	**14**	**132.5**
Other	Fish Factory	1	121.4
	Search and Rescue	1	122.0
	Total Other	**2**	**121.7**
Sailboat	Pleasure Craft - Sail	2	126.7
Small High-Speed Craft	Pilot	2	135.0
	Law Enforcement	3	129.9
	Pleasure Craft	1	124.1
	Diving Operations	2	128.1
	Military Operations	3	132.5
	Total High-Speed Craft	**11**	**132.7**
Tour Boat	Harbor Cruise	4	132.7
Tug	Tug	39	133.1
No Known Vessels	No Known Vessels		126.7
	Grand Total	**103**	**127.4**

Figure 6. Average length and underwater noise volume for each type of vessel present during this deployment.

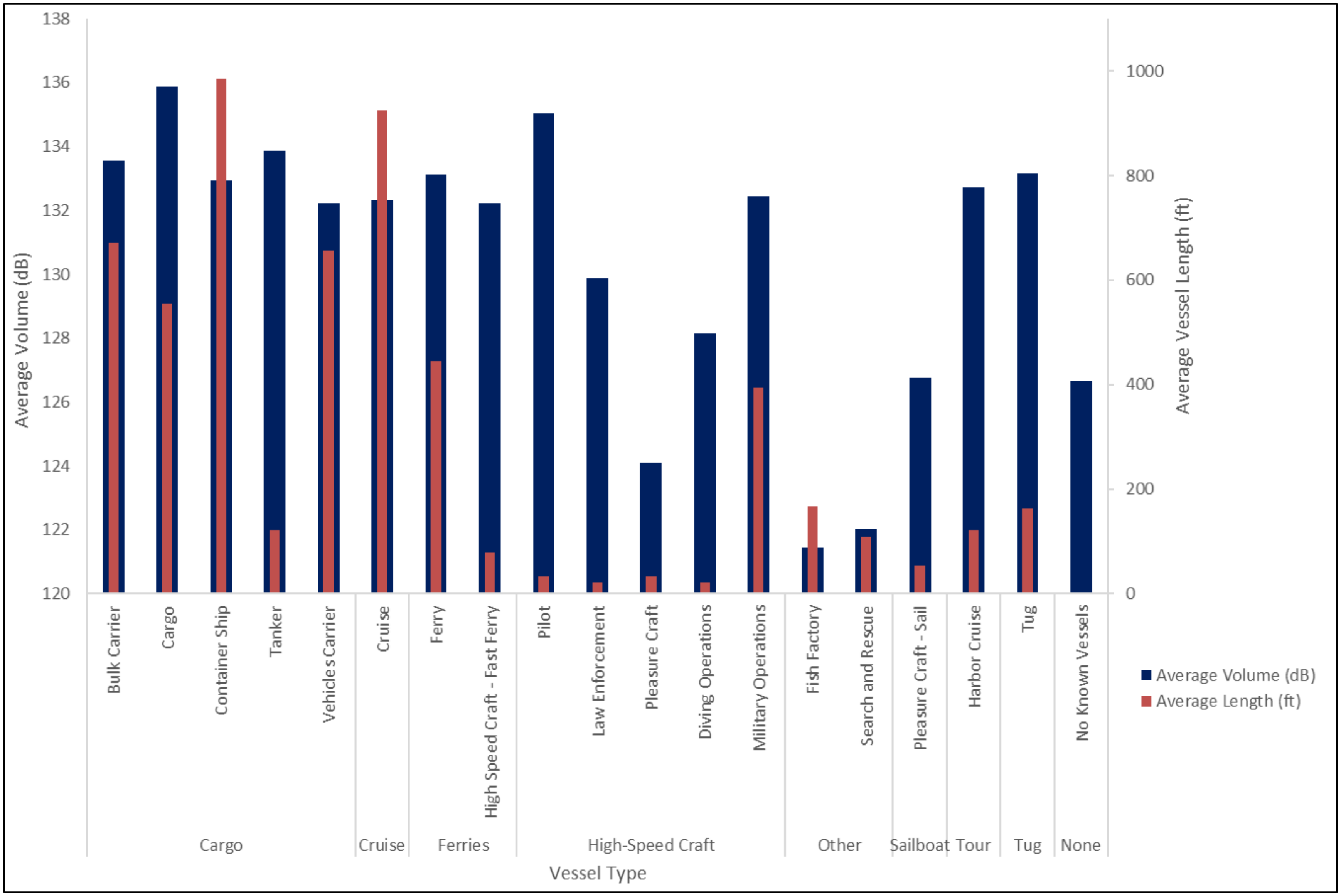


Figure 7. Average speed and underwater noise volume for each type of vessel present during this deployment.

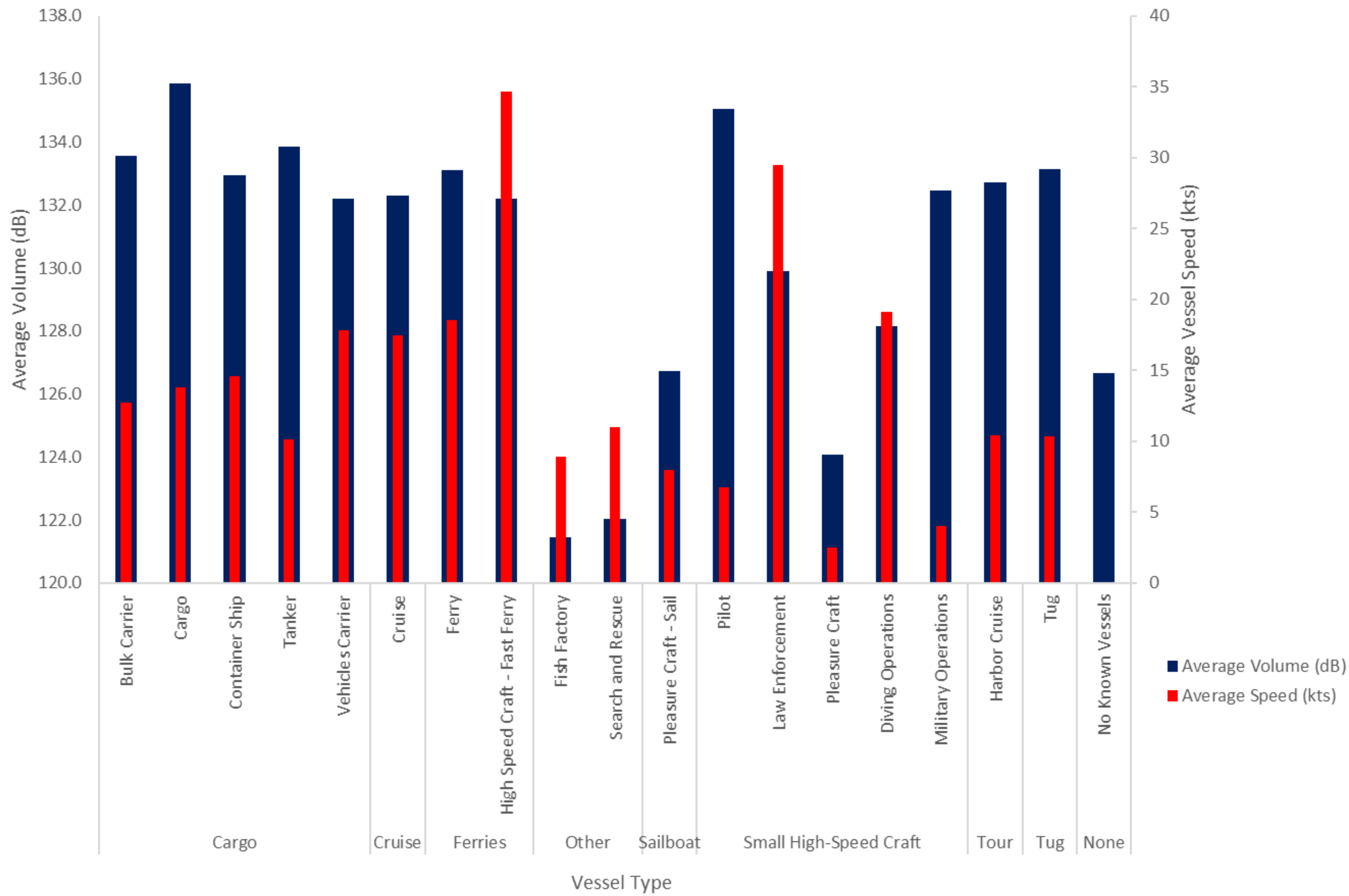


Figure 8. Average underwater noise levels (dB) during daytime and nighttime periods.

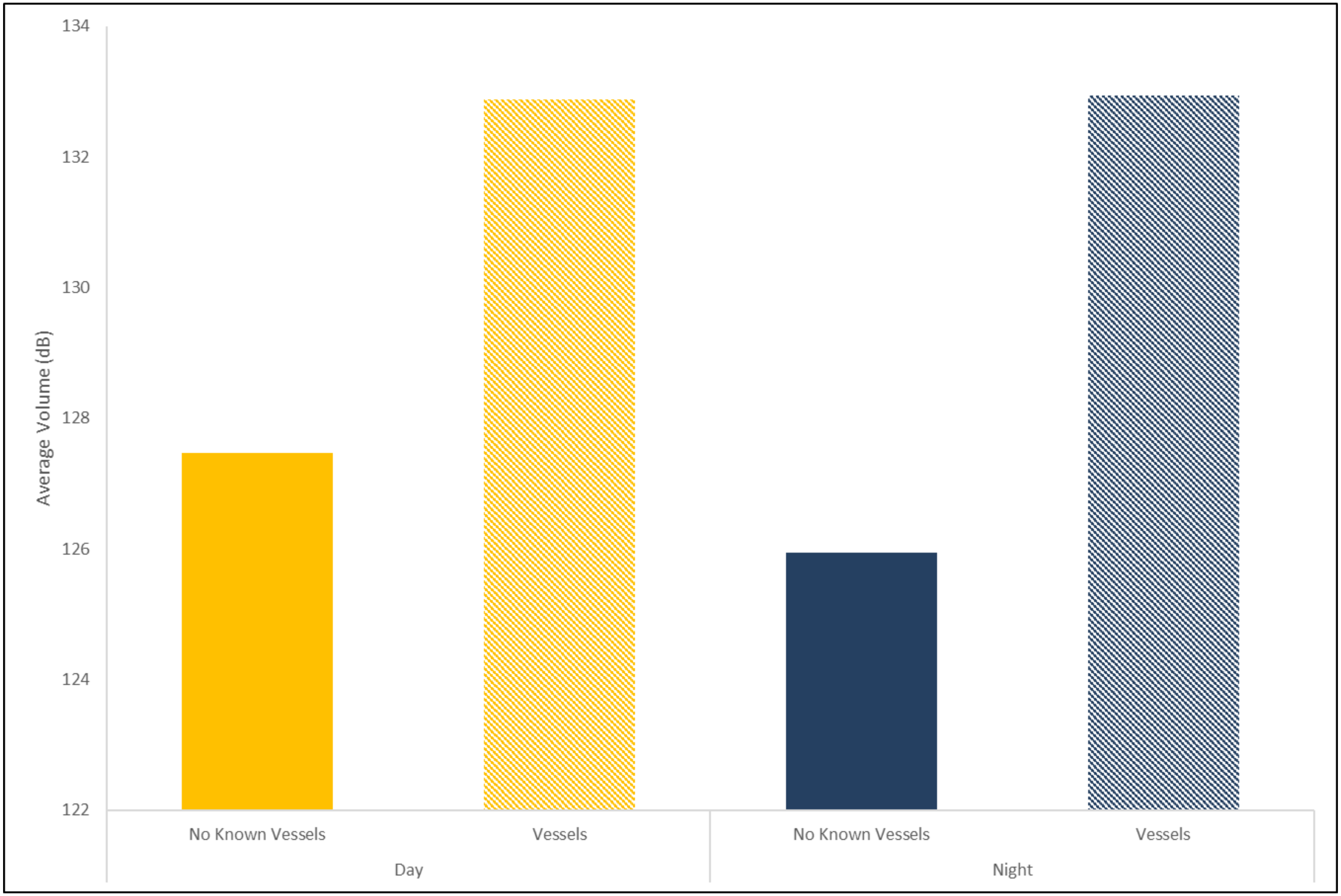
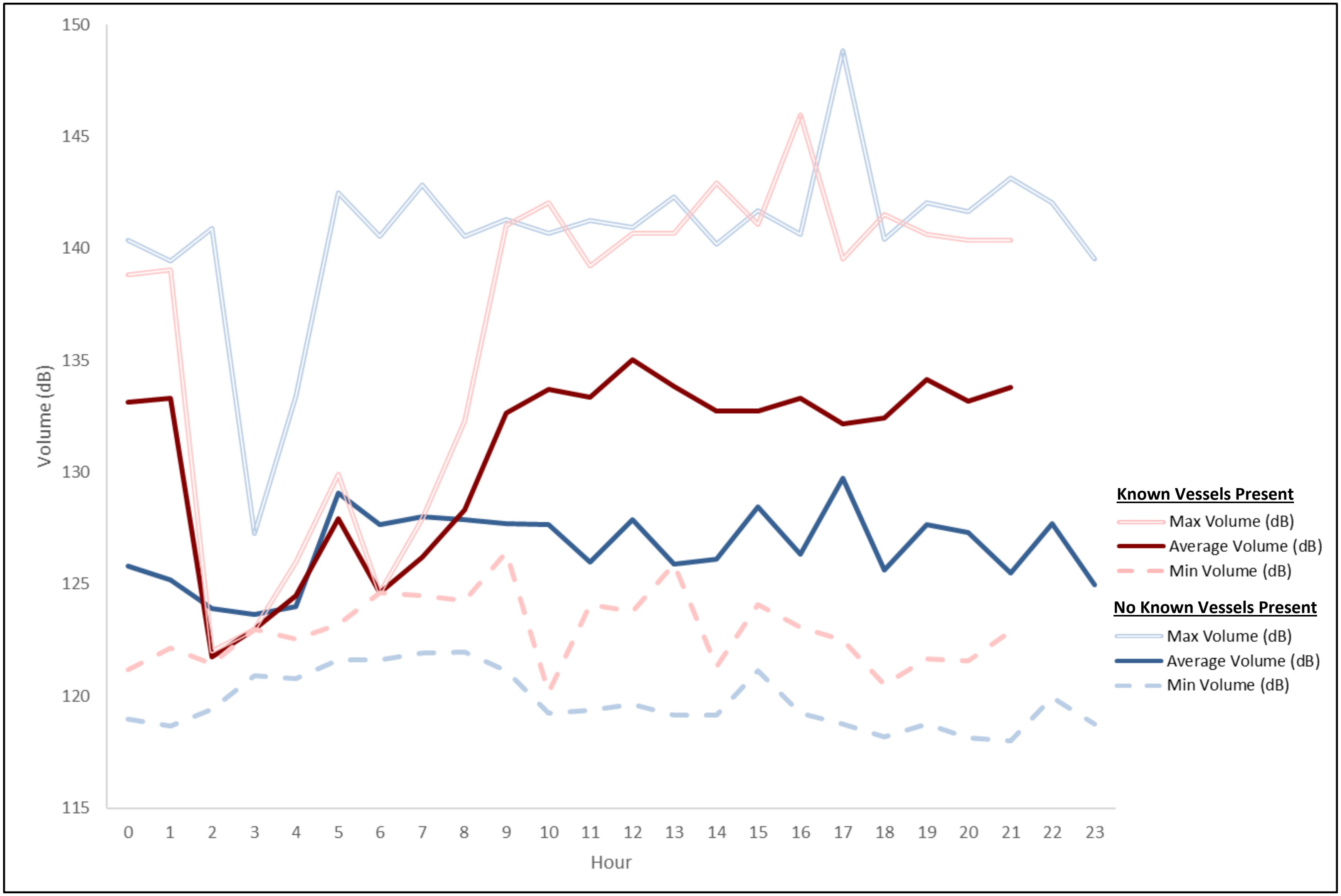


Figure 9. Average, maximum, and minimum underwater noise levels (dB) for each hour of the day for this deployment.



Deployment 3 – Cargo Ships

The third hydrophone deployment occurred from 14:00 on Thursday, November 3 through 22:00 on Sunday, November 6, 2022. This deployment aimed to isolate noise from cargo ships. During this period, ten cargo vessel trips were scheduled to call at Seattle terminals, including two very large vessels (over ten-thousand twenty-foot equivalent units [TEUs]). Weather in November is not typically conducive to recreational boating, and the cruise season was complete by this deployment.

The air temperature during the deployment ranged from a low of 37 to a high of 57 degrees Fahrenheit (°F). There was a short period of squally weather on Friday, November 4 between 12:30 and 14:00 (0.3 inches of rain and winds gusting 43 mph) and another on Sunday, November 6 at 08:00 (0.2 inches of rain and winds gusting 35 mph). Max wind speeds for the deployment period ranged from 14 to 28 miles per hour (MPH). Visibility was 10 miles (mi) throughout the deployment.

Nineteen types of vessel were identified by VesselFinder as being present in Elliott Bay during this deployment (Table 4). In descending order by volume (dB), the loudest vessel types were: a military operations vessel, law enforcement vessels, pilot vessels, tugs, and high-speed passenger ferries. When comparing by size, cargo ships, container ships, bulk carriers, vehicle carriers, tankers, and tugs with tows longer than 200 feet were relatively quieter for how long they are (Figure 10). When comparing by speed, the fishing support vessel was relatively quiet for max travel speed within Elliott Bay during this deployment (Figure 11).

During this deployment, the average daytime underwater noise level when vessels were not known to be present was 127.9 dB and when vessels were known to be present was 134.1 dB. The average nighttime noise level when vessels were not known to be present was 126.6 dB and when vessels were known to be present was 133.8 dB (Figure 12). Average underwater noise levels when vessels were known to be present were relatively consistent throughout the 24-hour day, except for three quiet hours at midnight, 04:00, and 13:00 (Figure 13). Average underwater noise levels during which no vessels were known to be present gradually increased throughout the day from a low at 03:00 to a peak at 22:00.

Table 4. Sample size and average volume recorded (dB) during times when each type of vessel was present.

Vessel Category	Vessel Type	n	Average Volume (dB)
Cargo	Bulk Carrier	4	126.5
	Cargo	1	123.3
	Container Ship	14	134.1
	Tanker	1	121.9
	Vehicles Carrier	2	124.2
	Total Cargo	**22**	**134.1**
Ferries	Ferry	4	133.0
	High Speed Craft - Fast Ferry	6	134.0
	Total Ferries	**10**	**133.9**
Other	Fishing Support Vessel	1	133.1
	Landing Craft	1	133.5
	Other - Port Tender	1	121.5
	Total Other	**3**	**133.4**
High-Speed Craft	Pilot	2	134.4
	Law Enforcement	4	134.8
	Search and Rescue	1	127.7
	Pleasure Craft	1	133.3
	Total High-Speed Craft	**8**	**134.4**
Tour	Harbor Cruise	4	133.8
Tug	Tug	39	134.0
	Tug >200	1	121.8
	Total Tug	**40**	**134.0**
	Grand Total	**87**	**134.0**

Figure 10. Average length and underwater noise volume for each type of vessel present during this deployment.

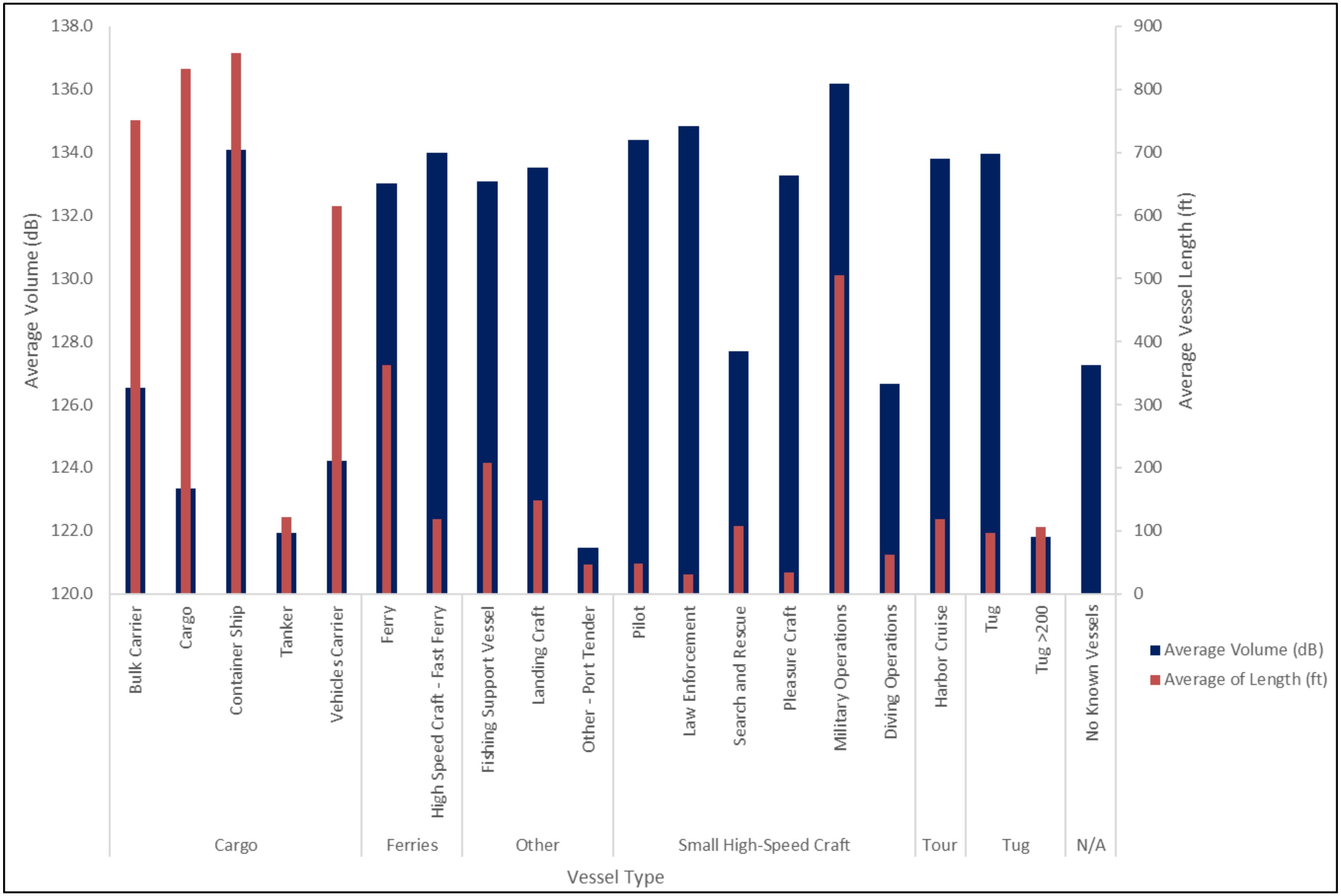


Figure 11. Average speed and underwater noise volume for each type of vessel present during this deployment.

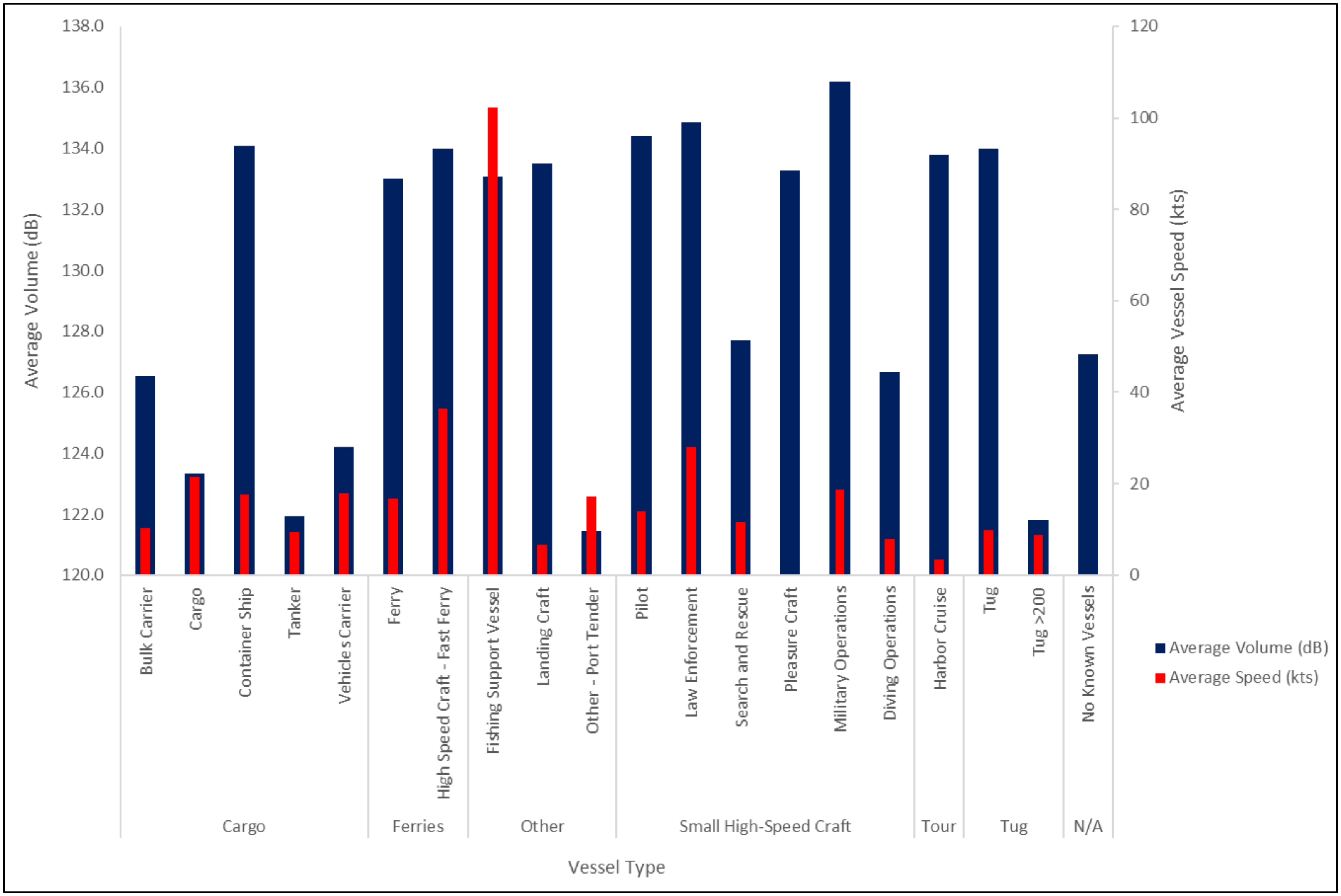


Figure 12. Average underwater noise levels (dB) during daytime and nighttime periods.

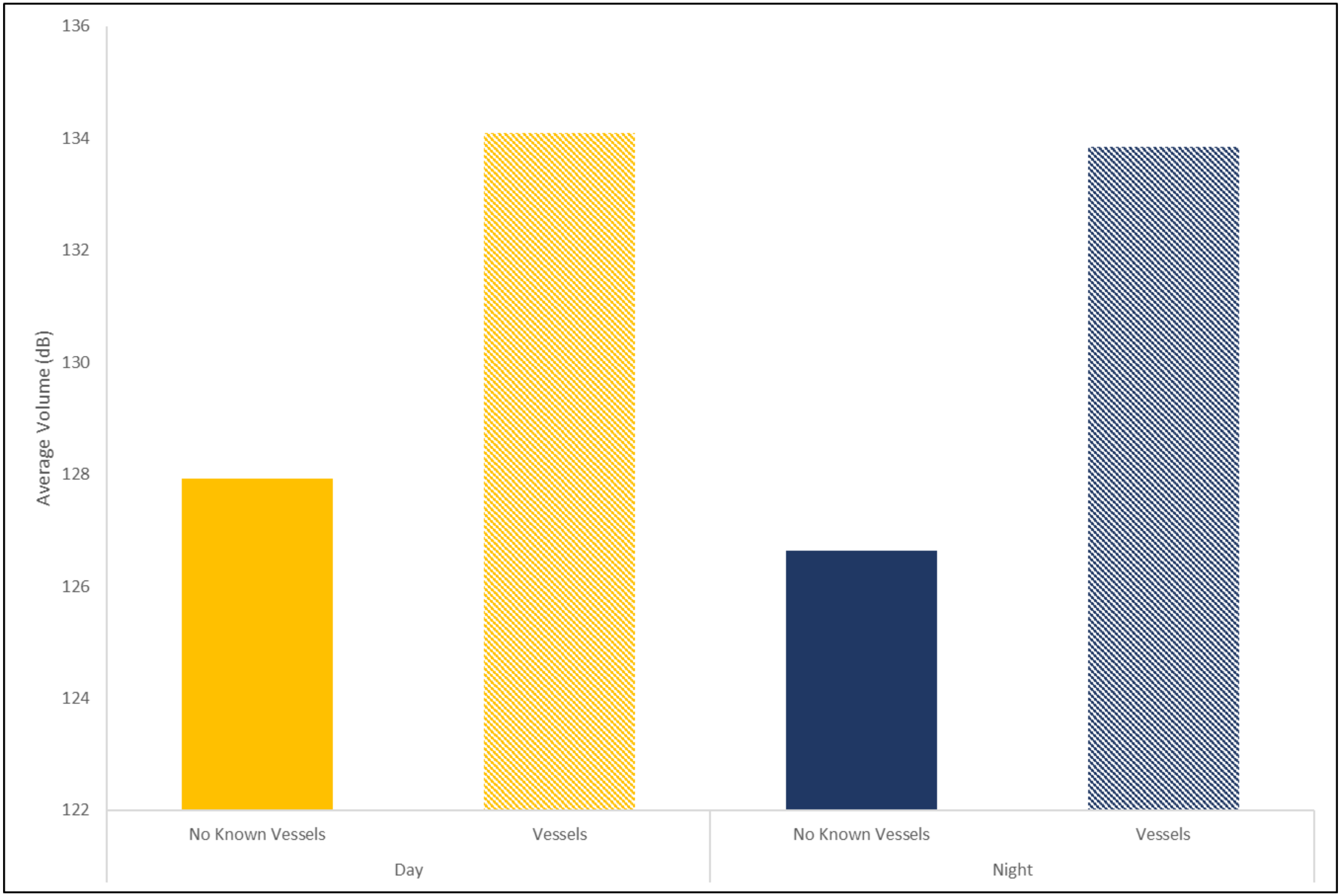
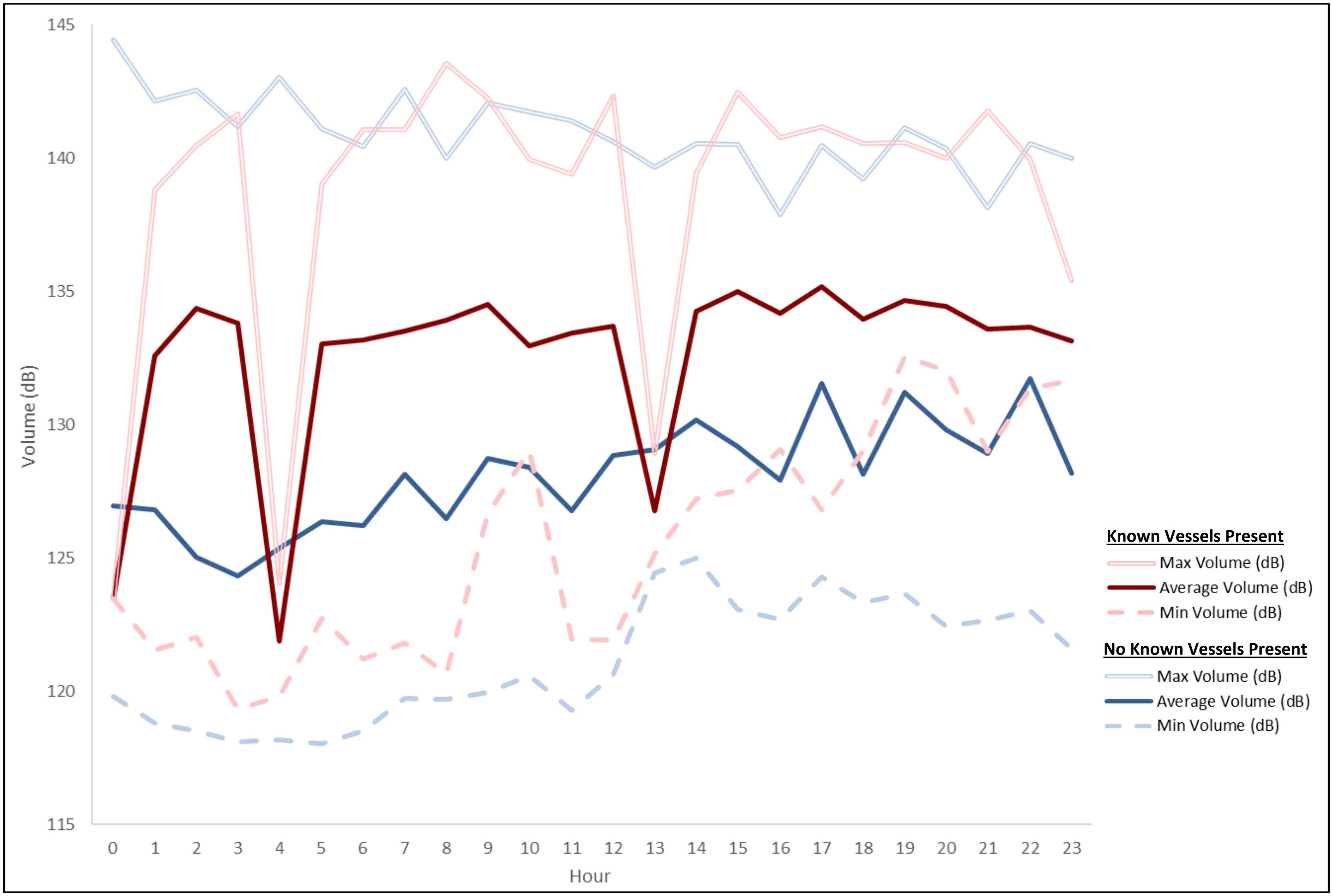


Figure 13. Average, maximum, and minimum underwater noise levels (dB) for each hour of the day for this deployment.



Deployment 4 – "Quiet" – no major vessels

The final hydrophone deployment occurred from 14:00 on Wednesday, November 23 through 09:00 on Monday, November 28, 2022. This deployment was timed to occur over the Thanksgiving/Native American Heritage Day holiday weekend, which was expected to be a time of reduced vessel activity in Elliott Bay. No cargo vessels were scheduled for November 23-25, the cruise season was over, and recreational vessel traffic was expected to be minimal due to time of year. Construction was occurring on utilities under the pier apron from which the hydrophone was deployed, so deployment was further timed around this construction work.

The air temperature during the deployment ranged from a low of 34 to a high of 52 degrees Fahrenheit (°F). There was a period of rain and wind on Friday, November 25 between 10:00 and 15:00 (1.0 inches of rain and winds gusting 30 mph) and overnight on Saturday, November 26 to Sunday, November 27 (0.3 inches of rain and winds gusting 44 mph). Max wind speeds for the deployment period ranged from 8 to 22 miles per hour (MPH). Visibility was 10 miles (mi) throughout the deployment.

Twelve types of vessel were identified by VesselFinder as being present in Elliott Bay during this deployment (Table 5). In descending order by volume (dB), the loudest vessel types were: tugs, container ships, the passenger craft, and both types of ferries. When comparing by size, container ships, the vehicles carrier, and the refrigerated cargo ship were relatively quieter for how long they are (Figure 14). When comparing by speed, high speed passenger ferries, the vehicles carrier, the refrigerated cargo ship, and the tanker were relatively quiet for max travel speed within Elliott Bay (Figure 15).

During this deployment, the average daytime underwater noise level when vessels were not known to be present was 127.4 dB and when vessels were known to be present was 134.7 dB. The average nighttime noise level when vessels were not known to be present was 127.4 dB and when vessels were known to be present was 134.7 dB (Figure 16). Average noise levels were relatively consistently throughout the day for this deployment; max underwater noise levels were elevated at 19:00 and 21:00 (Figure 17).

Table 5. Sample size and average volume recorded (dB) during times when each type of vessel was present.

Vessel Category	Vessel Type	n	Average Volume (dB)
Cargo	Bulk Carrier	2	133.7
	Refrigerated Cargo Ship	1	123.7
	Container Ship	9	135.1
	Tanker	1	122.8
	Vehicles Carrier	1	126.2
	Total Cargo	**14**	**134.8**
Cruise	Passenger	1	135.0
Ferries	Ferry	4	134.9
	High Speed Craft - Fast Ferry	6	134.9
	Total Ferries	**10**	**134.9**
Small High-Speed Craft	Pleasure Craft	1	124.2
Tour	Harbor Cruise	4	133.7
Tug	Tug	26	135.8
	Tug >200	1	127.2
	Total Tug	**27**	**135.8**
	Grand Total	**57**	**128.5**

Figure 14. Average length and underwater noise volume for each type of vessel present during this deployment.

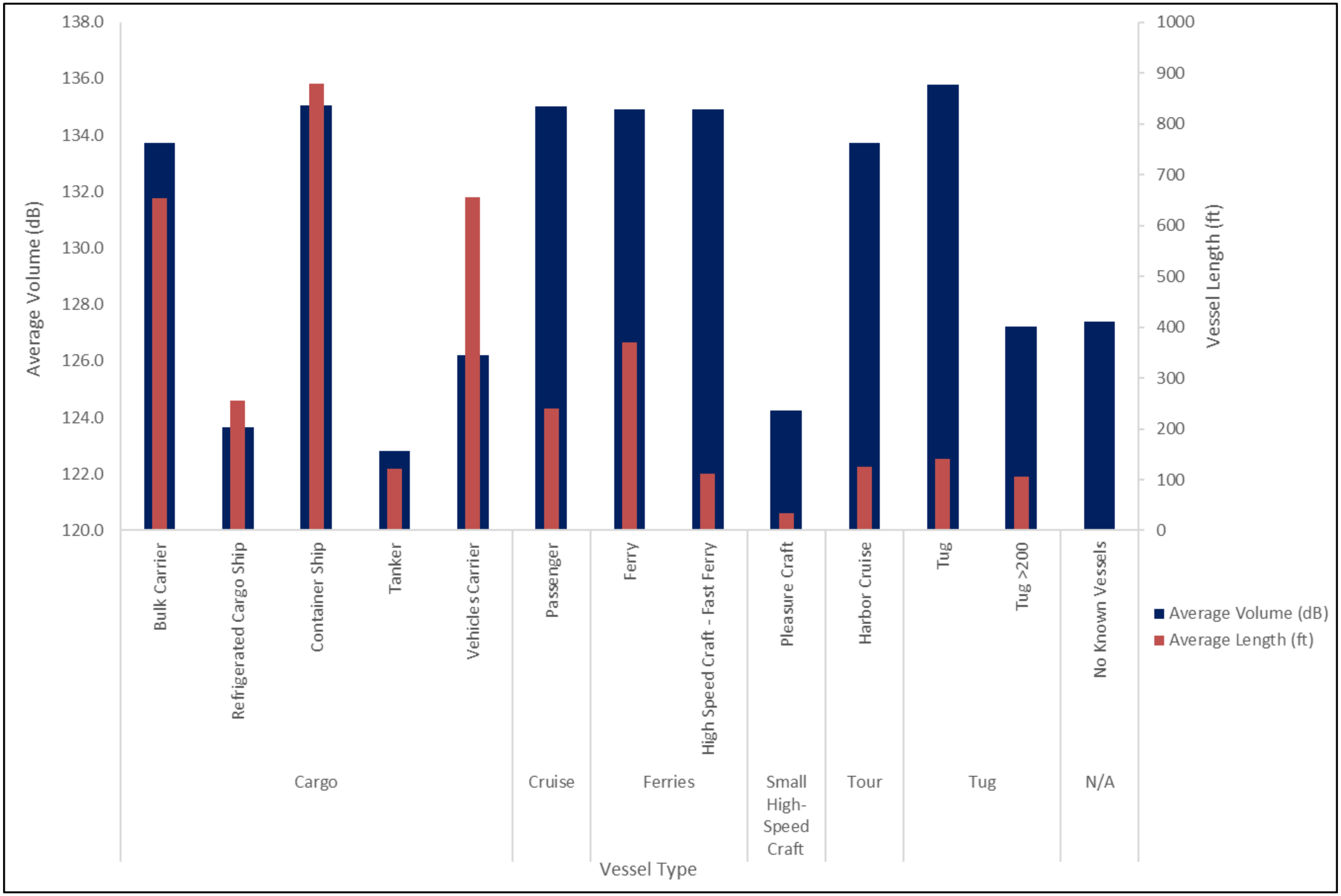


Figure 15. Average speed and underwater noise volume for each type of vessel present during this deployment.

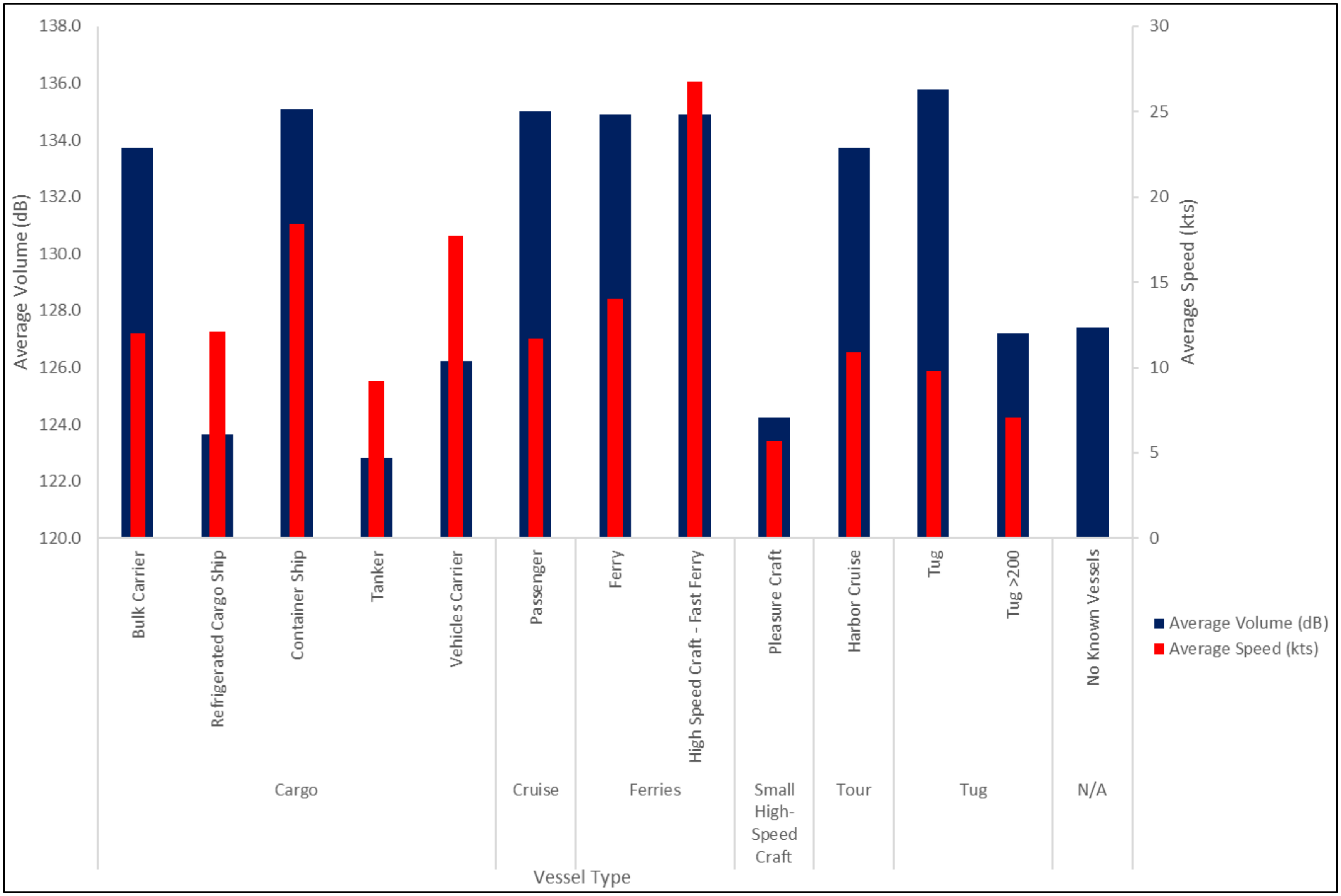


Figure 16. Average underwater noise levels (dB) during daytime and nighttime periods.

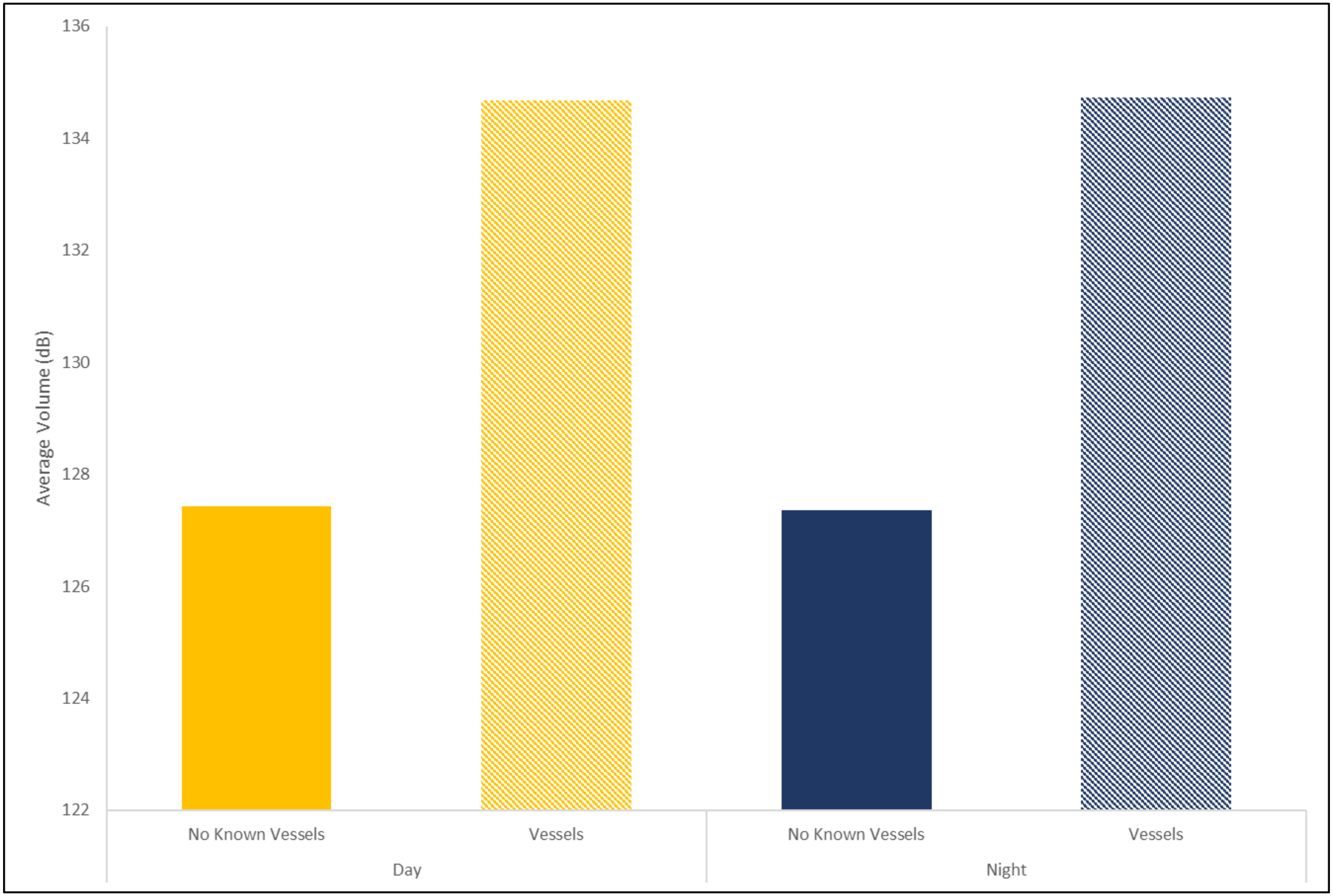
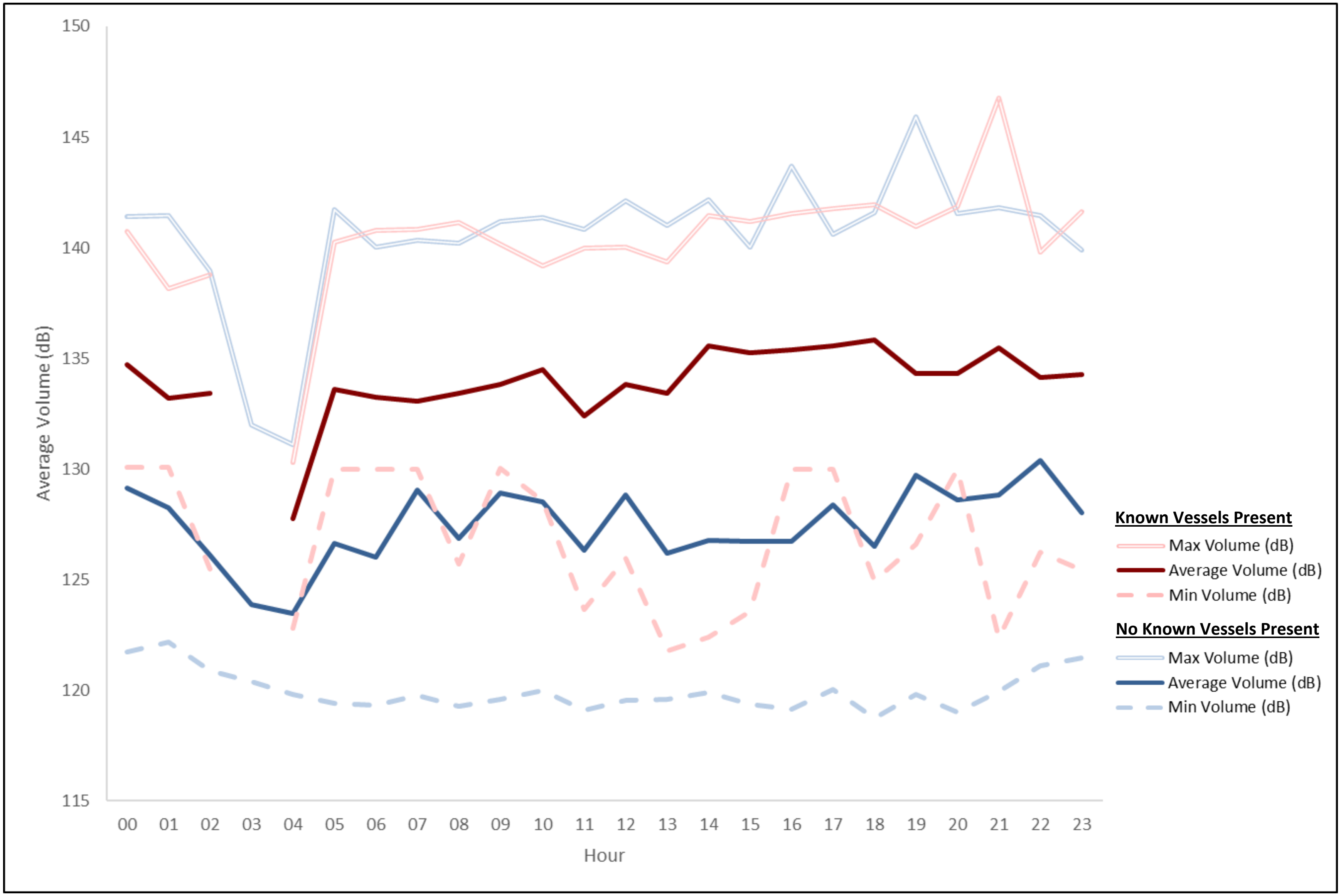


Figure 17. Average, maximum, and minimum underwater noise levels (dB) for each hour of the day for this deployment.



DISCUSSION

Findings

This "pilot" study had a number of limitations, as discussed in depth above in the Methods section. These include limited time and budget for collecting data and conducting comprehensive analyses. The position of the hydrophone at Pier 69 was chosen out of practicality, and may have resulted in greater noise detection than if the equipment were placed mid-bay in deeper water to reduce detection of airplane, traffic, weather, surface noise, etc. (WSF 2020). Further, a single hydrophone rather than an array forecloses triangulation of noise sources. Nonetheless, these descriptive results are useful for informing future data collection efforts toward establishing baseline ambient noise figures.

This study was designed to investigate how different conditions, including different types of vessel traffic patterns, inform the hydroacoustic environment in Elliott Bay. Average noise levels in the Bay were quietest during the August deployment and louder during April and November. This could be due to water temperature; sound travels faster in cold water than warm water. Diel trends were different in all four periods with louder periods around commuter hours during spring and summer and around afternoon and evening hours in November.

During the first approximately ten hours of the fourth deployment, noise levels did not drop below 135 dB. The reason for this is unknown—weather conditions were not consistent with increased noise (wind or rain). A vessel may have been at the berth on the north side of Pier 69 for that period, or other equipment may have been left running by construction crews. This likely artificially inflated the average noise levels for this deployment.

Cruise ships, cargo-type vessels (cargo, bulk carrier, container, etc. ships), tugs, ferries (both WSF and high-speed passenger), military operations vessels, and pleasure craft were among the loudest recorded vessels for all deployments. Isolation of one type (as was the intent of the four different deployments) was not necessary; vessels are only transiting the Bay for a finite period of time, so it was possible to record them regardless of whether other vessels may be transiting during the three-day deployment.

Certain vessels (primarily the cargo-type vessels and cruise ships) were relatively quiet for their size. This suggests that they are able to carry more cargo and/or a higher number of passengers relative to their acoustic impacts on the underwater environment. Similarly, high speed passenger ferries, law enforcement/search and rescue/diving operations vessels, and fishing support/factory vessels appeared to be traveling at optimal speed to minimize underwater noise, as has been shown with cavitation studies. These vessels were able to travel at a relatively fast speed compared to the amount of noise recorded while they were present in Elliott Bay.

Diel patterns in underwater noise volumes varied by deployment, which could have been a factor of time of year. During the first deployment in April and the third deployment in early November, underwater noise levels when vessels were known to be present were considerably higher both during the day and during the night than when no vessels were known to be present. During the second deployment in August, daytime noise levels when no known vessels were present were higher than nighttime levels; however, during times when known vessels were present, there was no difference in underwater noise levels between daytime and nighttime. During the final deployment in November, underwater noise levels for both times when known vessels were present and when no known vessels were present were the same during daytime and nighttime.

Hourly max underwater noise data for this study revealed that max noise levels were typically higher during periods with no known vessel traffic than they were when there was known vessel traffic. This is likely a factor of limitations in data collection; had an observer been onsite for these times, more sources of noise and specific time frames of the presence of those sources would have been identified.

Future Study Ideas

Strategies to allow for more robust analysis of the acoustic environment in Elliott Bay/the Port operations area include longer and/or more frequent deployments in a more central location, and obtaining more detailed vessel data. Visual observation during deployments would allow for a detailed understanding of what sources of noise are contributing to results. Visual observations would also help to account for other non-vessel sources of noise, including aircraft, construction noise, etc.

Deployments could also be chosen randomly by using a random number generator to provide a week number during which the deployment would happen. This study provided data for April, August, and November (two deployments), but data are lacking for the winter period, in addition to the months between these deployments. Replicating the study under a more randomized and representative set of conditions would also provide more robust results, and would generate a more comprehensive range of hydroacoustic conditions in Elliott Bay.

Strategy for Utilizing These Results to Reduce Underwater Noise

Combined with future data collection efforts, these data can be used to create a better generalized understanding of the current hydroacoustic environment in Elliott Bay. Data collected during these four preliminary deployments are "moment-in-time" samples which provide a general sense of some of the types of hydroacoustic conditions present in Elliott Bay during various times of the year and under various vessel traffic scenarios. These data may supplement future additional data to inform a more complete picture of existing hydroacoustic conditions in Elliott Bay, from which a range of baseline ambient conditions may be identified. This range of baseline ambient conditions may be used to establish underwater noise reduction targets and compare against future underwater noise data to measure progress toward achievement of targets.