Determining a historic baseline of anthropogenic noise in spinner dolphin resting bays along the Kona Coast of Hawaii

by

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Abstract

On March 11th, 2011, the 9.03 magnitude Tohoku earthquake struck off the coast of Japan and caused a tsunami event that crossed the Pacific. Using this event opportunistically to assess how it altered anthropogenic ambient noise in the waters of four bays of Hawaii (Kauhako, Honaunau, Kealakekua and Makako Bays), valuation of what the currently unmeasured baseline noise levels were prior to human existence or influences was attempted. Though a baseline has not yet been found, the results presented will assist in furthering our understanding of oceanic soundscapes and can aide in future soundscape models and research. Once found, the historic baseline will provide information that will help in referencing acceptable levels of anthropogenic noises in future policy-making decisions in Hawaii and elsewhere. Data was recorded on bottom-mounted archival hydrophones for years 2011-2013 in all four bays at 4-minute intervals with 30-second durations. A two-week window (March 4-18th) was completely analyzed for the years 2011 and 2012 (2012 being the control) in efforts to find an associated drop in noise level around the tsunami event. Values for typical bay sounds were found by averaging a one year span of data (January 8, 2011-January7, 2012) for 4 different categories: whales present, dolphins present, both present, and neither present (presence determined through acoustic data interpretation) in all 4 bays. Had a significant drop in noise level been found within the 2011 two-week time period, a comparison between it and the typical noise level under that biological category and bay could have illustrated how humans are currently influencing the oceanic soundscape in the area of study.

Key Words

Anthropogenic noise; Hawaii; Spinner dolphin; Tsunami; Tohoku earthquake

Introduction

The level of noise that humans are introducing into the oceans is of increasing concern for the marine life that inhabits these environments. Many studies relate signs of distress in marine mammals, specifically cetaceans, to anthropogenic noise (DeRuiter et al. 2013; Goldbogen et al. 2013; Richardson and Wursig 1997; Rolland et al. 2012; Weilgart 2007). There is also evidence that supports anthropogenic noise impacting the survival of non-mammalian aquatic species (Chan et al. 2010; Stocker 2002). Though it is definitively known that human activities are continuously increasing in, on and around the oceans, and heavily speculated to be influencing ocean organisms through the associated noise, there has been little effort to measure what the ocean soundscape sounds like and may have sounded like prior to these anthropogenic influences. This type of baseline data for coastal waters has never been assessed, as most studies reveal how much anthropogenic sounds have multiplied through time, rather than offering a working natural baseline prior to human influences (Hildebrand 2009).

Using passive acoustics data obtained from four different bays on the Kona Coast of Hawaii (Kauhako Bay, Honaunau Bay, Kealakekua Bay and Makako Bay), this study measured the total amount of noise present (in decibels or dB) in each bay for different classifications of biological presence: dolphins present, whales present, both present, and neither present. Additionally, by utilizing the March 11, 2011 Hawaiian tsunami caused by the 9.0 magnitude Tohoku earthquake as an isolated event that presumably reduced the number of vessels in the water at the time, a significant decrease in noise level was sought after. This discovery would have provided a previously unmeasured ancient aquatic ambient noise baseline had it been found, and could have allowed a glimpse into the past as to what these waters sounded like prior to the technological arrival of the motorboat. However, this noise decrease into previously unmeasured territory was not found. Had it been discovered, this baseline data would have helped in referencing acceptable levels of anthropogenic noises in future policy-making decisions. The results presented including typical noise levels of these bays can be beneficial to those working in the locations the measurements are from, as well as those in the marine acoustic community.

Methods

Data: The acoustic data for all four locations on the Kona Coast were captured using DSG-Ocean Acoustic Dataloggers manufactured by Loggerhead Instruments (Table 1). All of these instruments were set to record for the first 30 seconds of every 4 minutes continuously, starting on the 8th of January 2011. Daily data from this date forward for one calendar year (through January 7, 2012) were individually acoustically monitored for presence of (and consequently lack of) general dolphin and whale noises (Table 2). Data presented in Table 2 do not include malfunction days, beginning/ending logger deployment days or days that data were recorded outside of this year as these have yet to be analyzed. In addition to the one-year span of analyzed data, a specific two-week window of time (March 4-18) was also intensively analyzed for the biological presence of whales and dolphins in years 2011 and 2012. This same two-week window was reviewed for 2013, but was later dismissed from the series due to large amounts of hydrophone malfunctions in three of the four bays. Years 2012 and 2013 were the planned controls in the analysis of 2011.

Table 1: DSG-Ocean Acoustic Logger Information

Bay	**Serial Number**	**Lat (decimal degrees)**	**Long (decimal degrees)**	**Depth (meters)**	**Hp On (y/n)**
Kauhako (Bay 1)	1007	N19°22.602'	W155°53.902'	15.80	Yes
Honaunau (Bay 2)	1041	N19°25.451'	W155°54.738'	24.60	Yes
Kealakekua (Bay 3)	1006	N19°28.816'	W155°55.669'	18.80	
Makako (Bay 4)	1043	N19°44.218'	W156°03.258'	24.00	

Table 2: Analysis of Number of Days (1/8/2011-1/7/2012) with Biological Presence

	Bay 1 Kauhako	**Bay 2 Honaunau**	**Bay 3 Kealakekua**	**Bay 4 Makako**
Dolphins Only	132*(44)	103*(34)	158*(52)	230*(76)
Whales Only	32	31	21	3
Whale and Dolphins	26	13	23	57*(19)
Neither	115*(38)	160*(53)	80*(26)	34
Totals	305	307	282	324

*(#) Represents the 33% of the total number of days that were randomly sampled from total values to obtain average dB level of that category

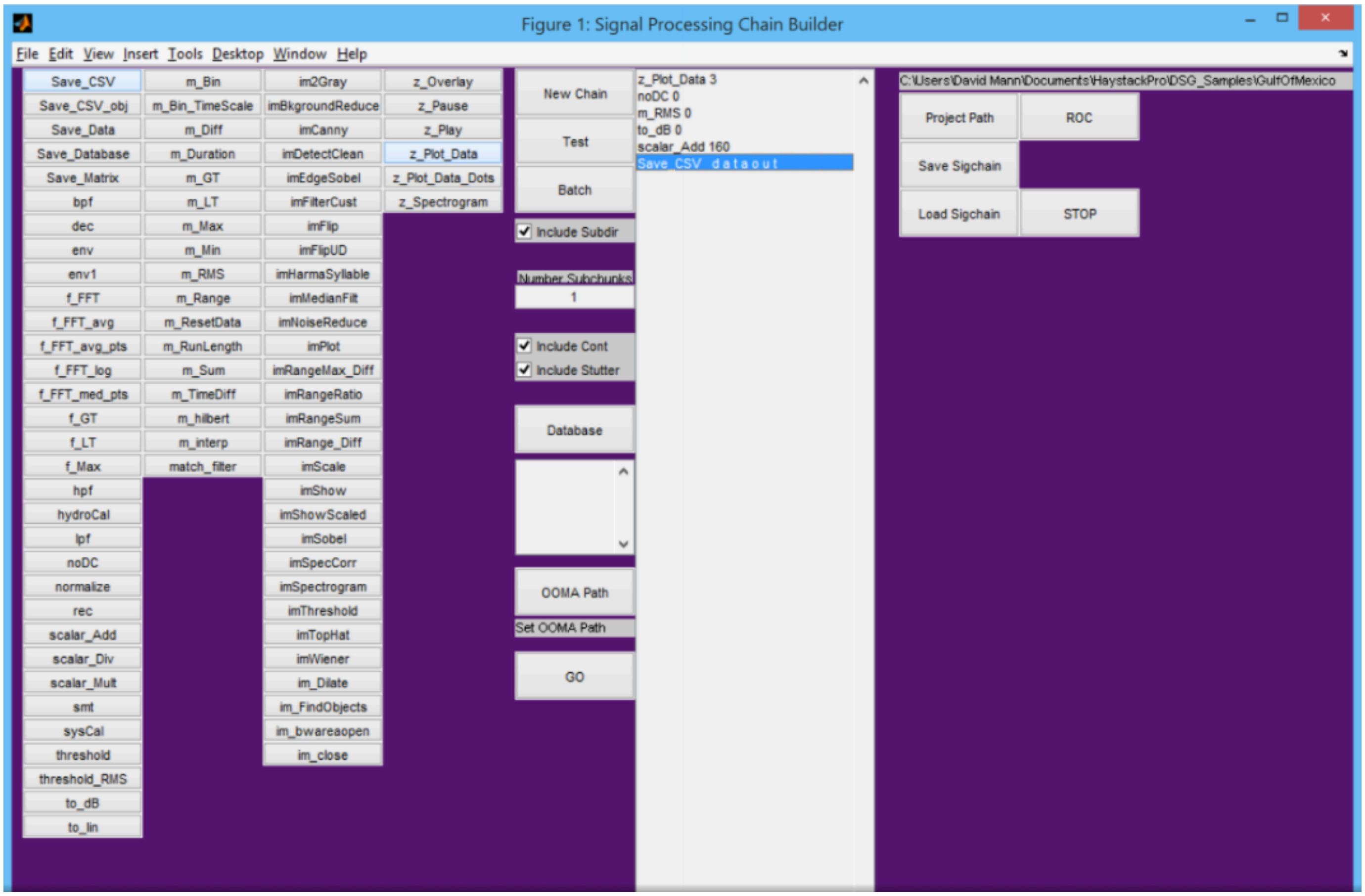
Procedure: Upon receiving the full year of data for each of the four bays, each file was individually acoustically analyzed for sounds associated with dolphins and/or whales. The presence of such noises was documented in a Microsoft Excel 2011 spreadsheet along with a note of when the first sound occurred and in which file. This same exercise was completed for the two-week period in 2012. This allowed for the dissection of the year of data by day into the proper categories listed in Table 2. For those categories consisting of greater than 45 days (e.g. Bay 1 Dolphins only: 132 days), a randomly generated sample of 33% of those days were taken using Excel; only those days' files were analyzed for their decibel (dB) levels, which were then cumulatively averaged into a single dB level for that category. Randomly generated numbers were assigned to each of the available dates (from January 8, 2011 through January 7, 2012) for that category, arranged into ascending order, and then the 33% was taken from the lower end. The final averaged dB level for each category in each bay represented the average proposed sound level for that bay at any given time in the 2011-2012 year under those conditions. For the categories consisting of 45 or fewer days (e.g. Bay 1 Whales only: 32 days), all data available was included in finding an average proposed sound level (dB) for that bay at any given time in the 2011-2012 year under those conditions.

The two-week period of time for both 2011 and 2012 was analyzed intensively in a similar fashion. Each of the files for each of the days from March 4th through the 18th was evaluated and produced a dB level. The dB levels found for each of these files were then averaged on both a daily and an hourly scale (360 files or dB levels per day, 15 files or dB levels per hour). For the daylight hour daily average, this same technique was used, but only for the files that were recorded between sunrise and sunset of each location according to local weather reports for that time period. These averages could then be graphed in Excel and evaluated for a drop in sound around the time of the tsunami event.

The dB levels were calculated from the DSG hydrophone files in MATLAB version R2009B. The method of extracting the dB level was root mean square as this is both a common practice and was already integrated within the utilized software package. Using a downloaded interface package created by Dr. David Mann, president of Loggerhead Instruments, signal processing chains (sigchains) were calculated for each of the bays and gave the dB level as their product (Figure 1). The sigchains all consisted of the same components, which were sequentially important as the file passed from the first to the next command until the chain was completed: noDC (removed the DC offset in the data), m_RMS (calculated the root mean square), todB (calculated the 20*log(10) or the dB level), scalar_Add (adjusted the calculated dB level for the sensitivity of the specific hydrophone within each of the bays) (Table 3), and Save_CSV (saved the output into an Excel CSV file).

Table 3: Proper scalar add according to each of the hydrophones within each of the bays.

Bay	**1** **Kauhako**	**2** **Honaunau**	**3** **Kealakekua**	**4** **Makako**
Scalar Add	169.22	170.13	169.58	172.11



z_Plot_Data 3
noDC 0
m_RMS 0
to_dB 0
scalar_Add 160
Save_CSV dataout

C:\Users\David Mann\Documents\HaystackPro\DSG_Samples\GulfOfMexico

☑ Include Subdir
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Figure 1: Example of signal processing chain builder interface used to calculate dB levels in MATLAB version R2009B

Results

When reviewing the results of the first inquiry of each of the bays under varying biological conditions, it was discovered that Bay 4 (Makako) was the loudest bay (on average 2dB louder than the second loudest bay in each category) (Table 4). Also, Bay 1 (Kauhako) was the most consistent across the situations (all categories being within .6dB of each other), while Bay 2 (Honaunau) was the most variant with a 6dB difference between the quietest category and the loudest (Table 4).

Table 4: Typical decibel level (in dB) on a given day for each of the bays under various biological conditions

	Bay 1 Kauhako	**Bay 2 Honaunau**	**Bay 3 Kealakekua**	**Bay 4 Makako**
Dolphins Only	118.2822	116.784	117.2759	121.6658
Whales Only	118.8878	120.9961	116.8432	123.8866
Whale and Dolphins	118.8515	122.7887	115.5373	123.8527
Neither	118.5798	117.3827	117.4871	120.7591

Evaluating the graphs (daily and hourly averages) that were produced during the two-week time period for both 2011 and 2012 illustrated no observable relevant drop in sound level around the time of the tsunami event in any of the bays. Bay 1 experienced a spike in noise level in 2011 (Figure 2 and Figure 6). Though Bays 2, 3, and 4 all had drops during the day of the event, none of them were applicable to historic lows (Figures 3, 4, and 5 respectively). Furthering the search for a drop in noise levels by highlighting only the day light hours during the two-week time period showed a lowered overall noise level, but mirrored the other daily averages and thus did not provide an observable drop in noise in any of the bays (Figures 11, 12, 13, and 14). Noise levels within the control year (2012) were lower than the levels in 2011 in three of the four bays (Bays 1, 2, and 4) (Figures 2, 3, 4, and 5).

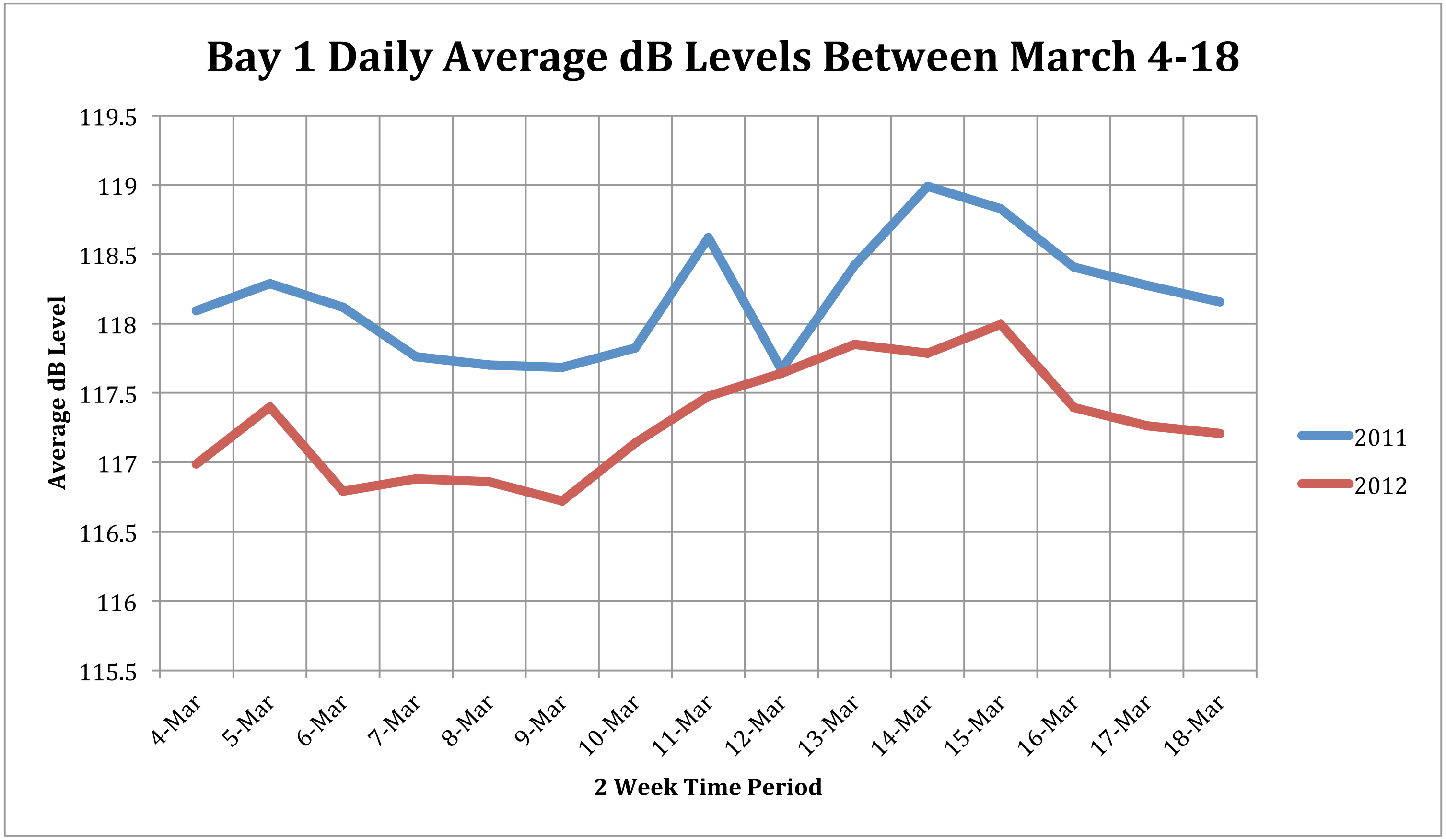

Figure 2: Two-week daily average decibel levels for years 2011 and 2012 in Bay 1.

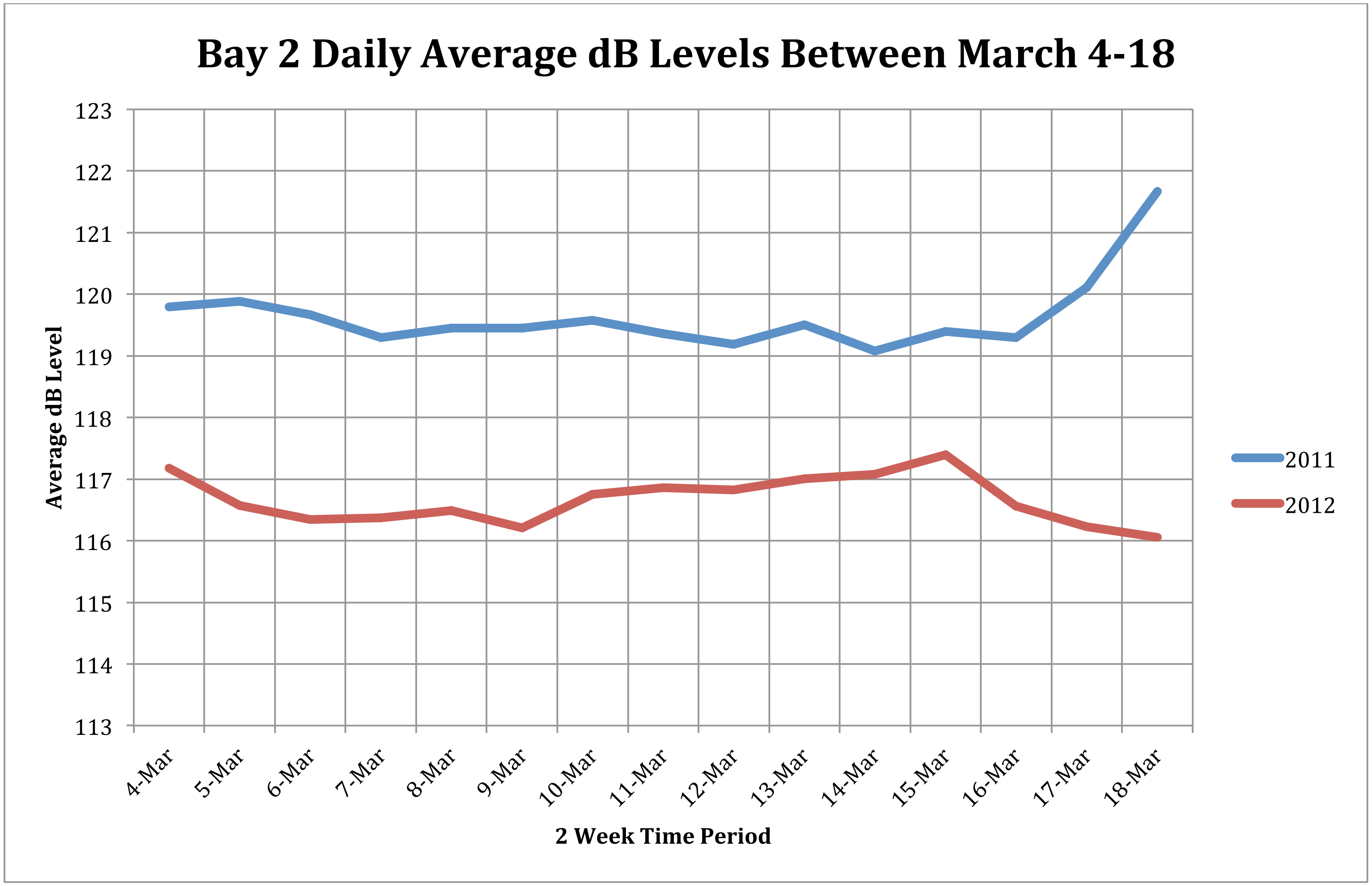

Figure 3: Two-week daily average decibel levels for years 2011 and 2012 in Bay 2.

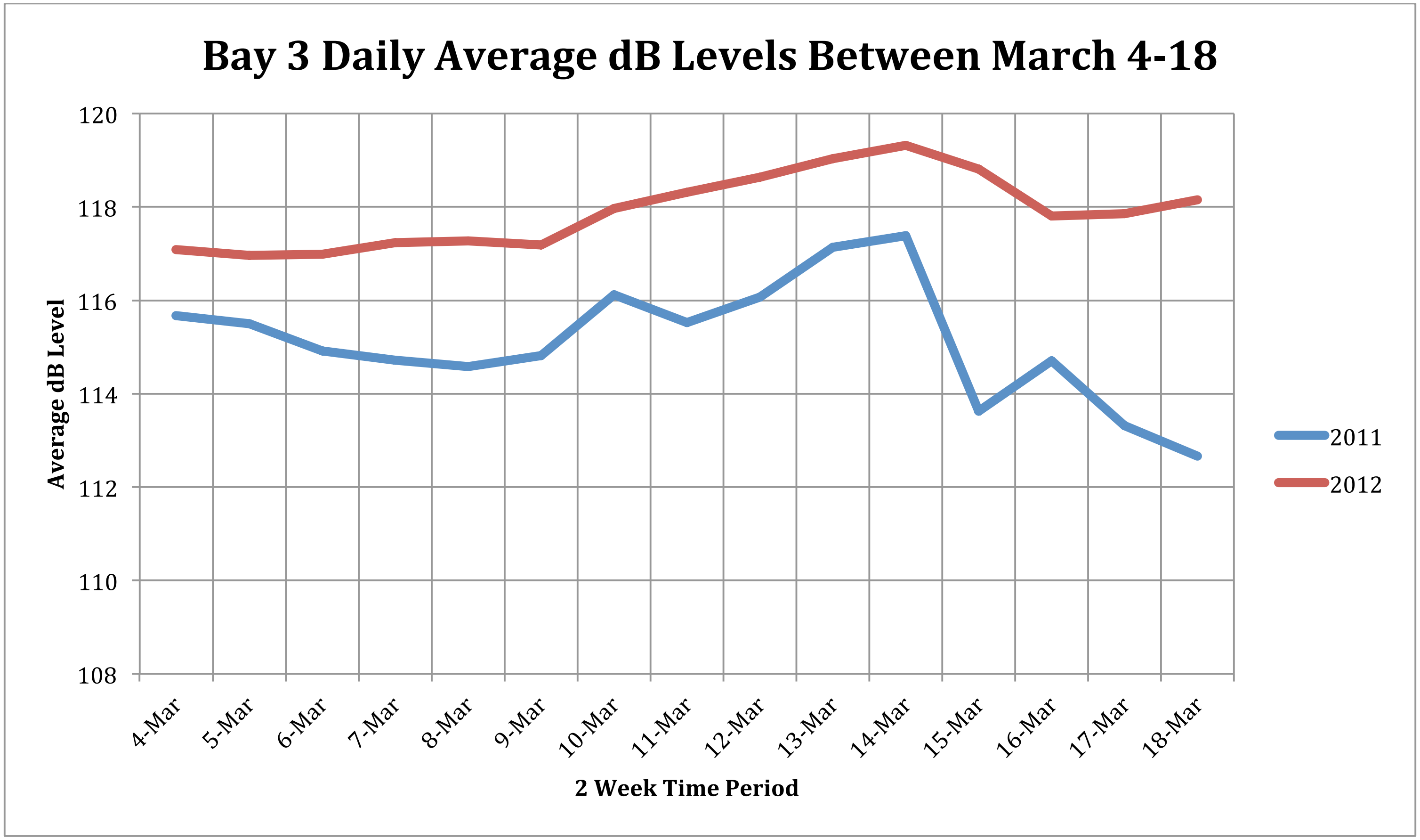

Figure 4: Two-week daily average decibel levels for years 2011 and 2012 in Bay 3.

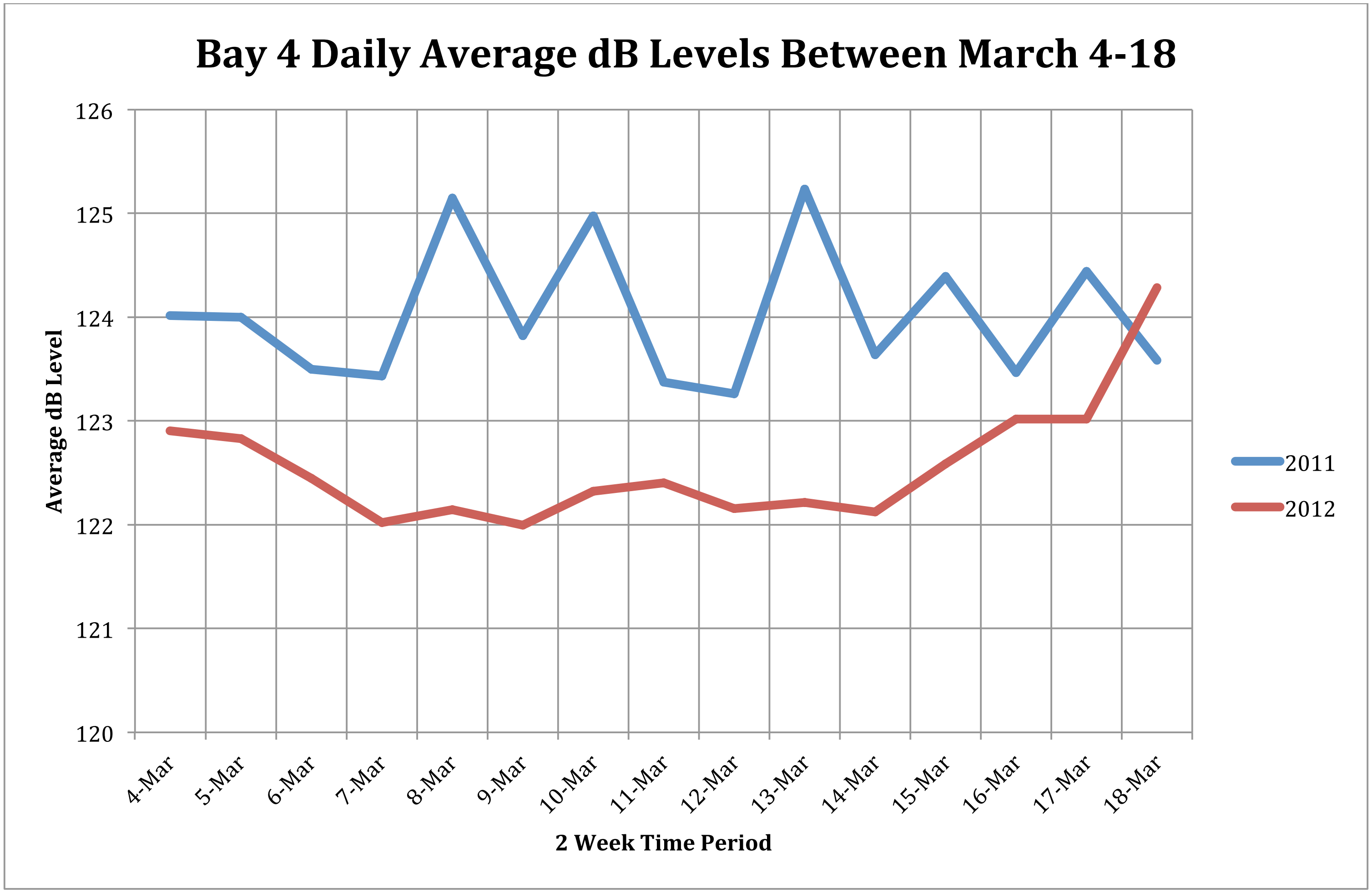

Figure 5: Two-week daily average decibel levels for years 2011 and 2012 in Bay 4.

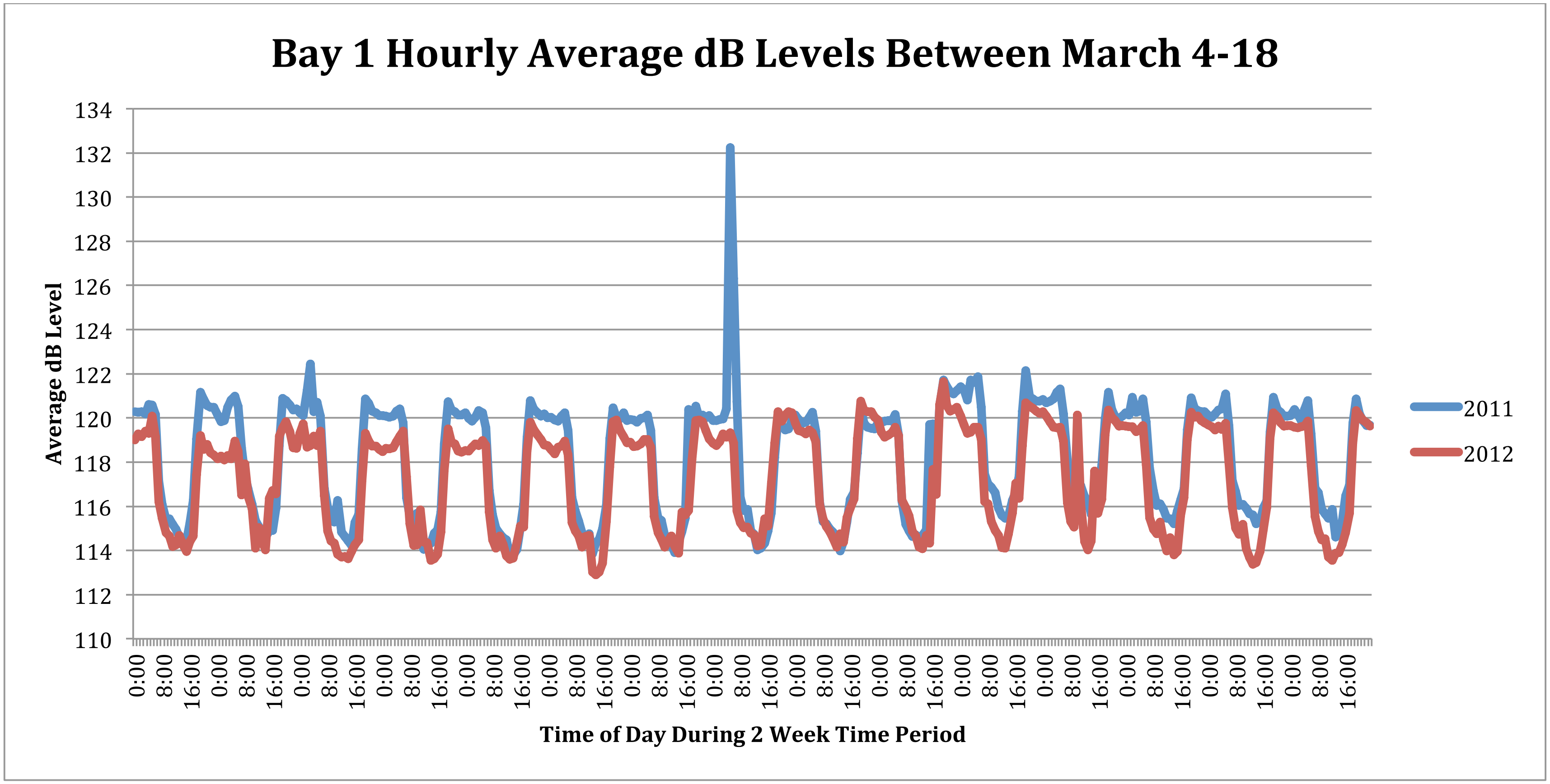

Figure 6: Two-week hourly average decibel levels for years 2011 and 2012 in Bay 1.

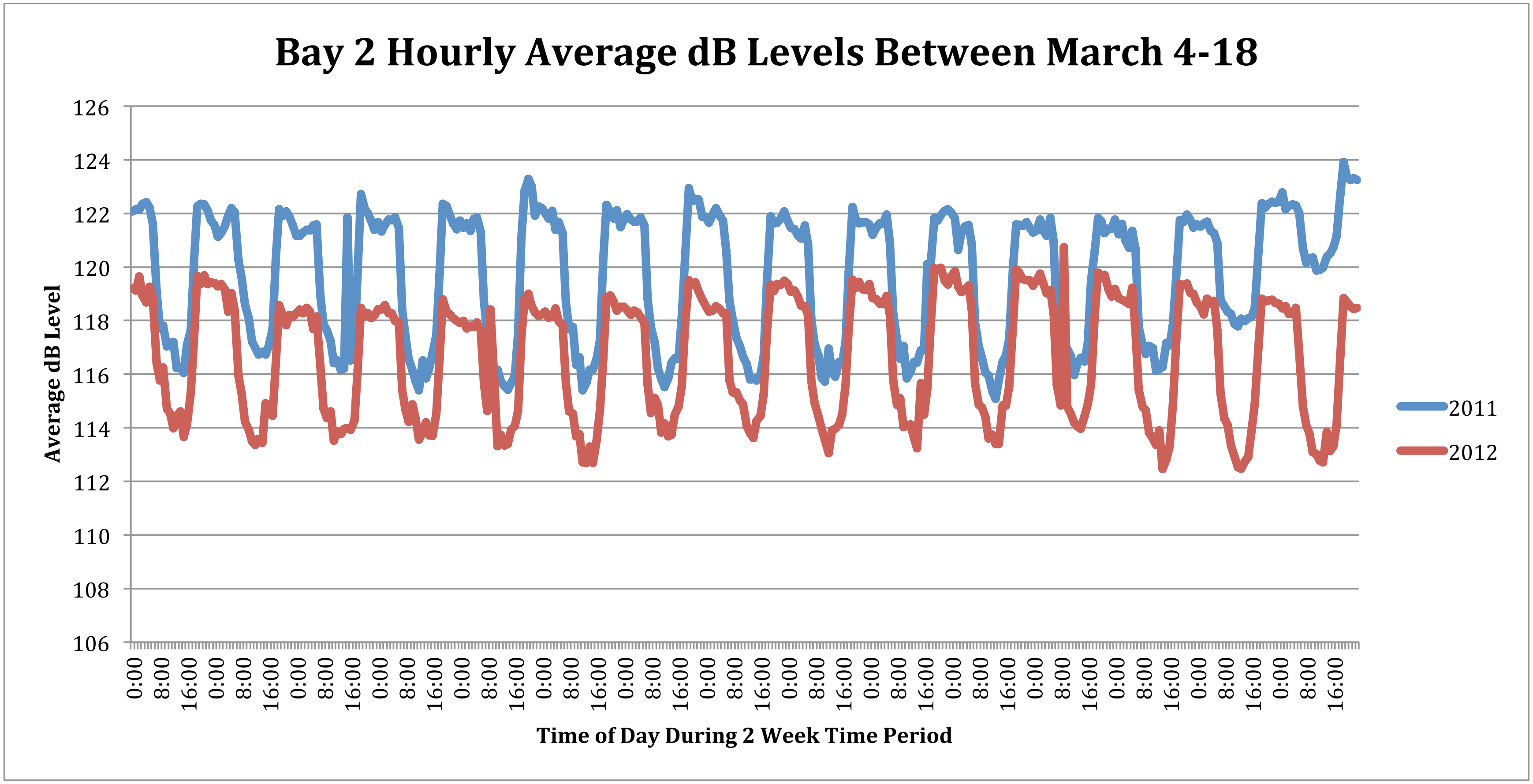

Figure 7: Two-week hourly average decibel levels for years 2011 and 2012 in Bay 2.

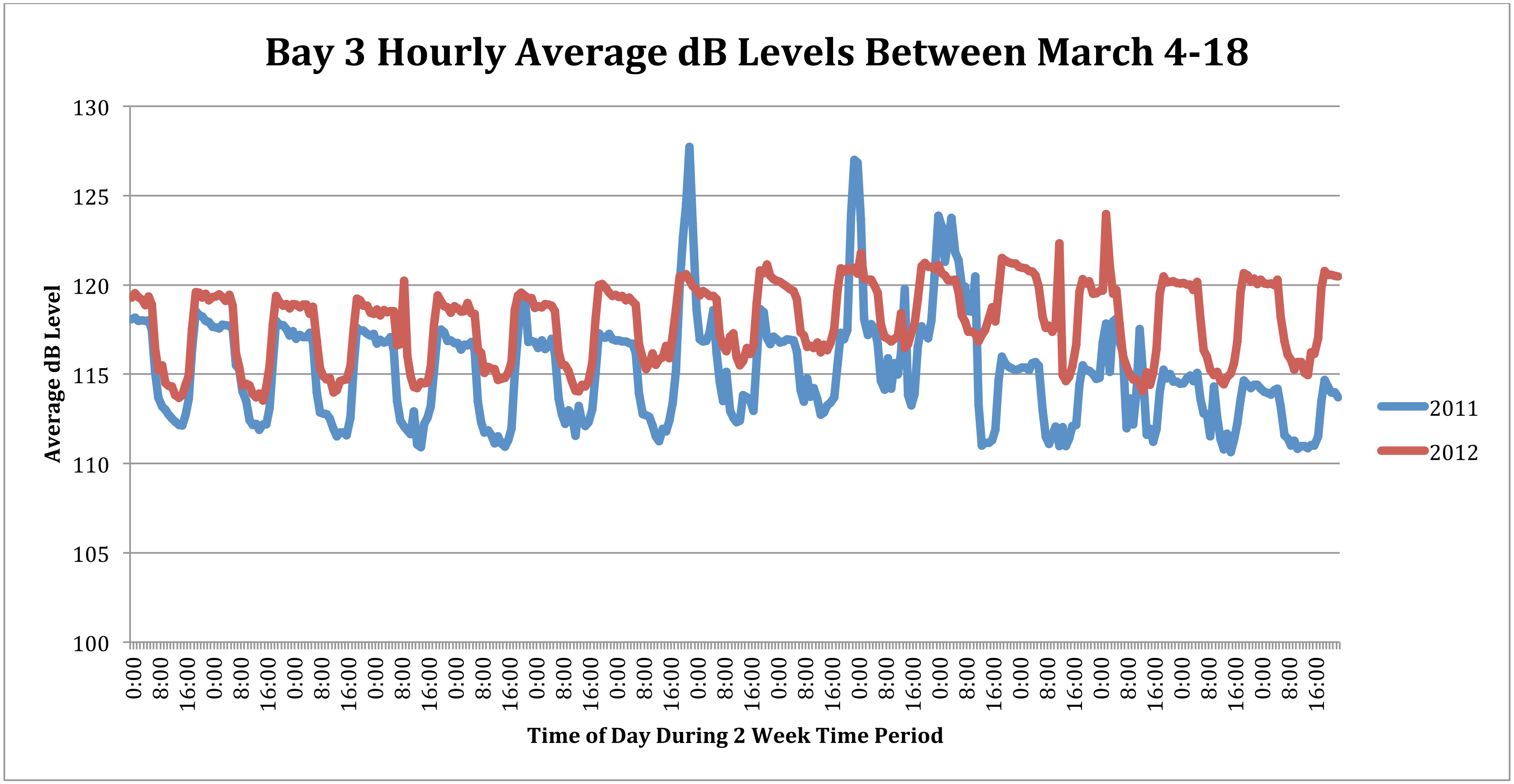

Figure 8: Two-week hourly average decibel levels for years 2011 and 2012 in Bay 3.

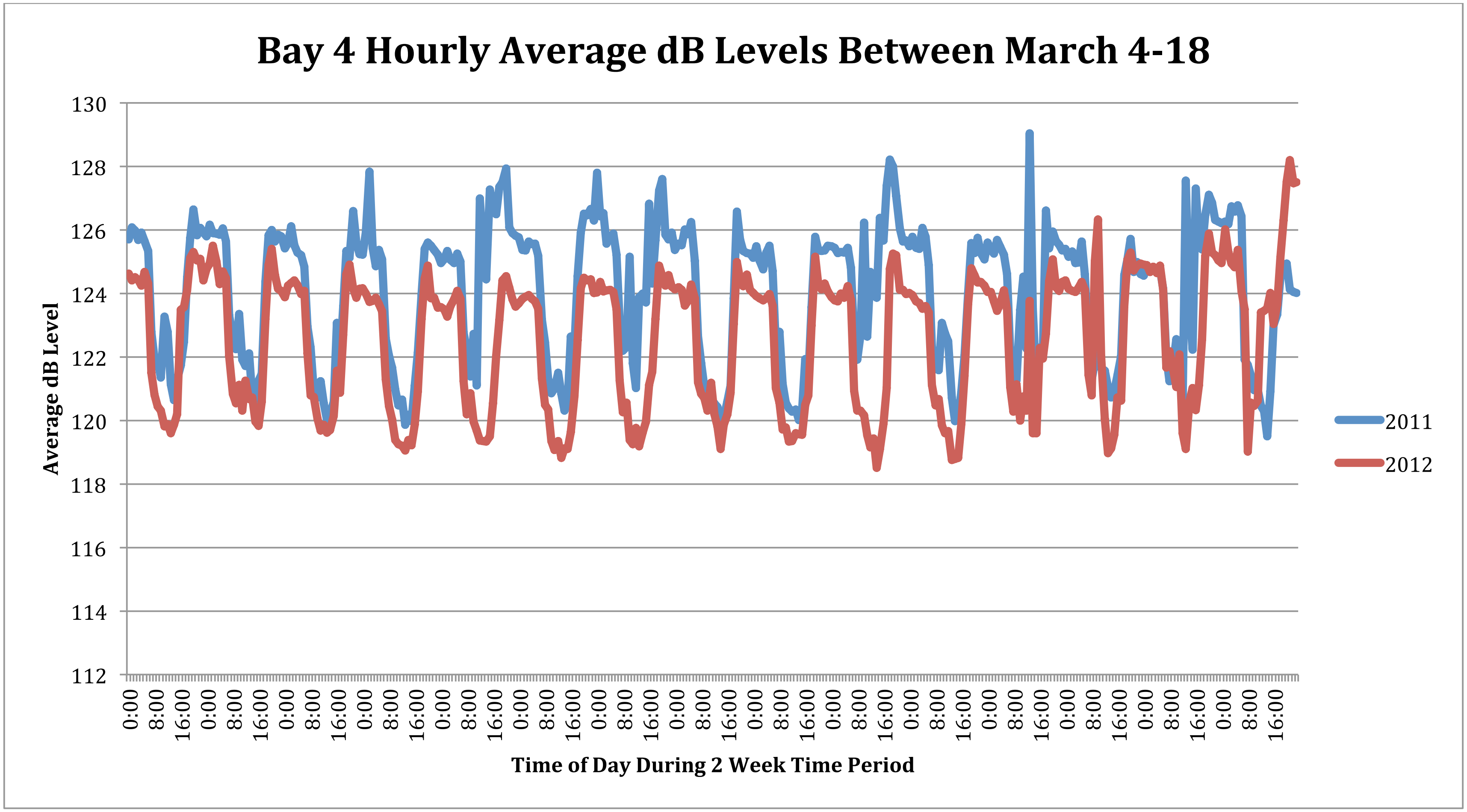

Figure 9: Two-week hourly average decibel levels for years 2011 and 2012 in Bay 4.

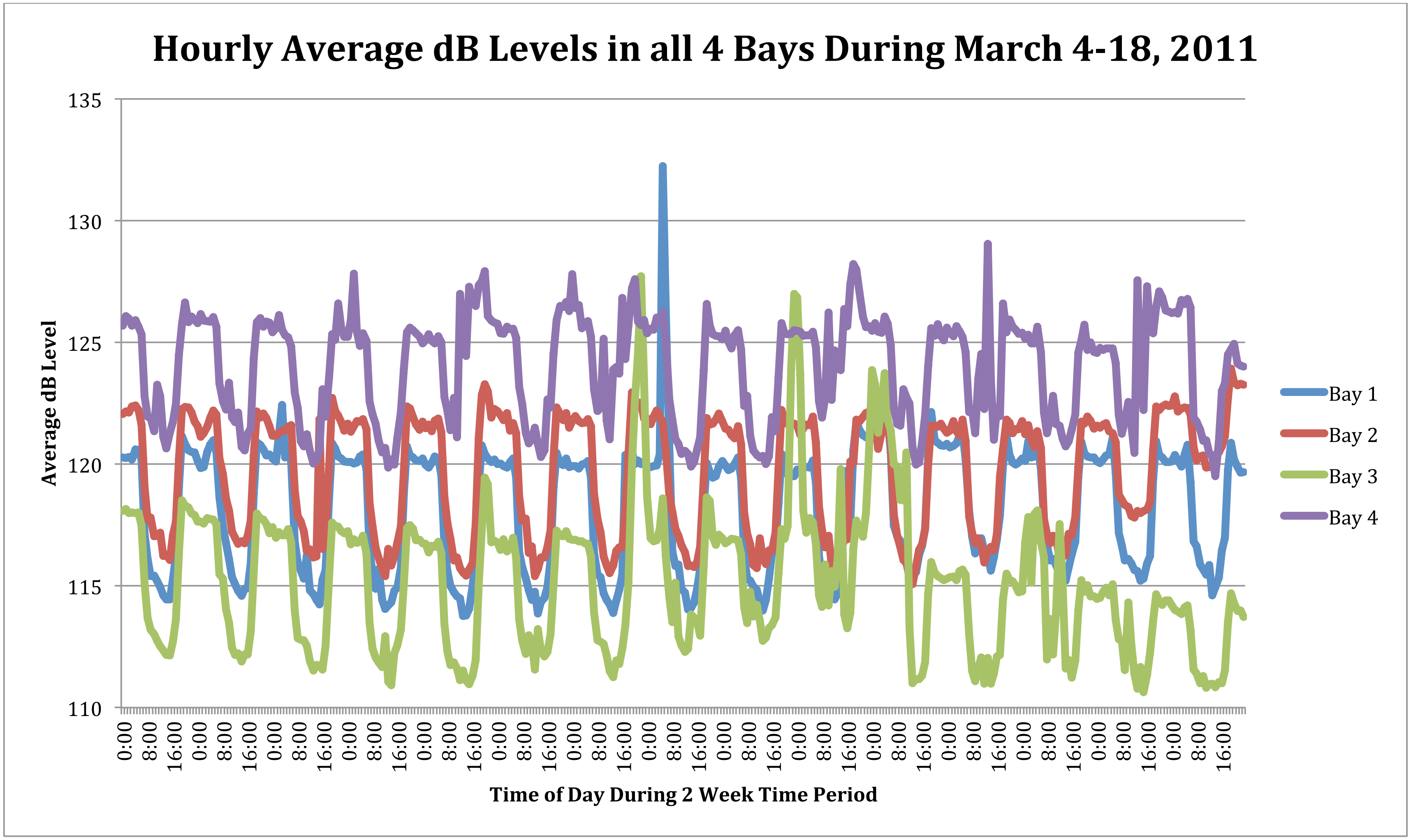

Figure 10: Two-week hourly average decibel levels for year 2011 in all study sites.

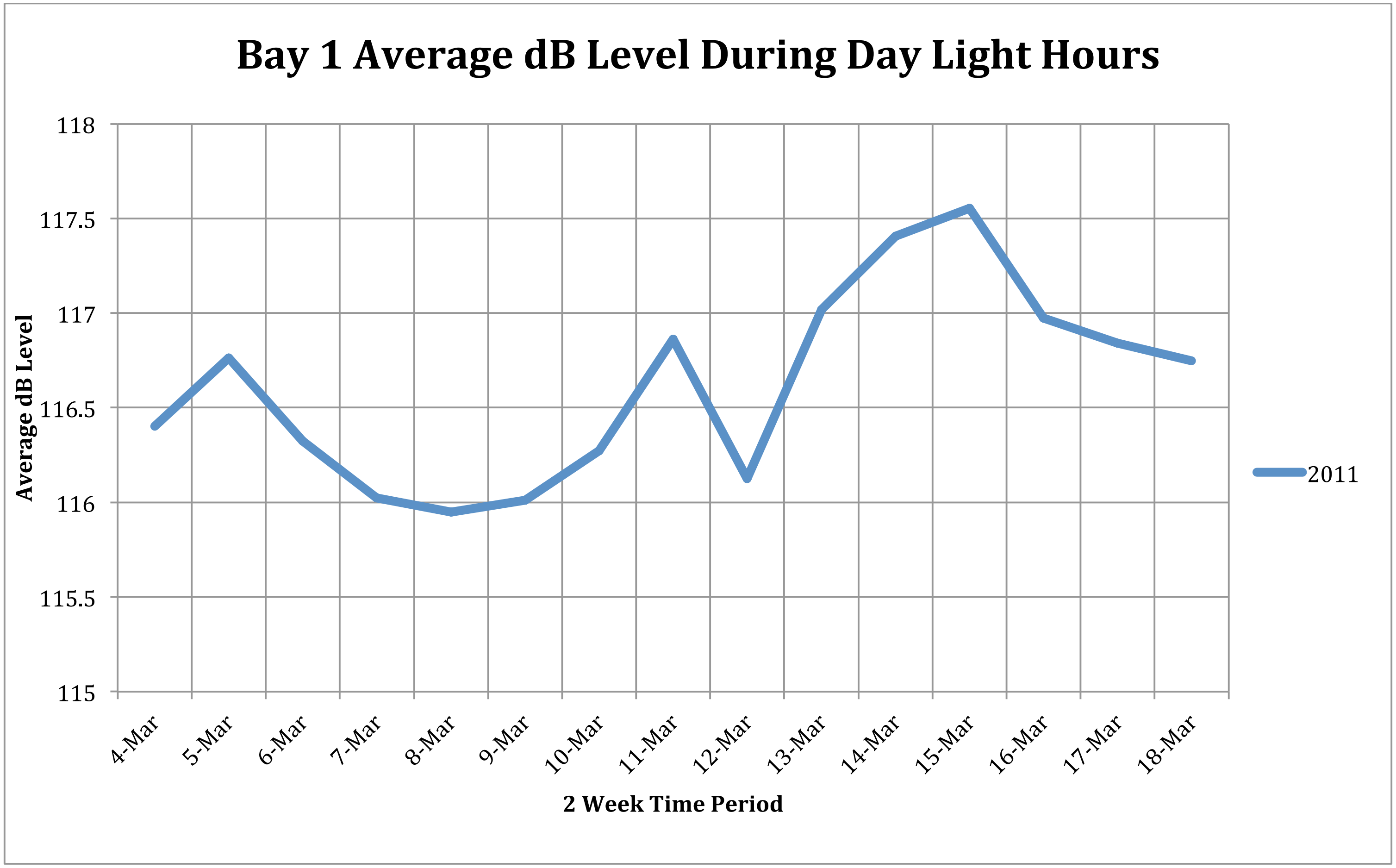

Figure 11: Two-week daily average decibel levels for 2011 during day light hours in Bay 1.

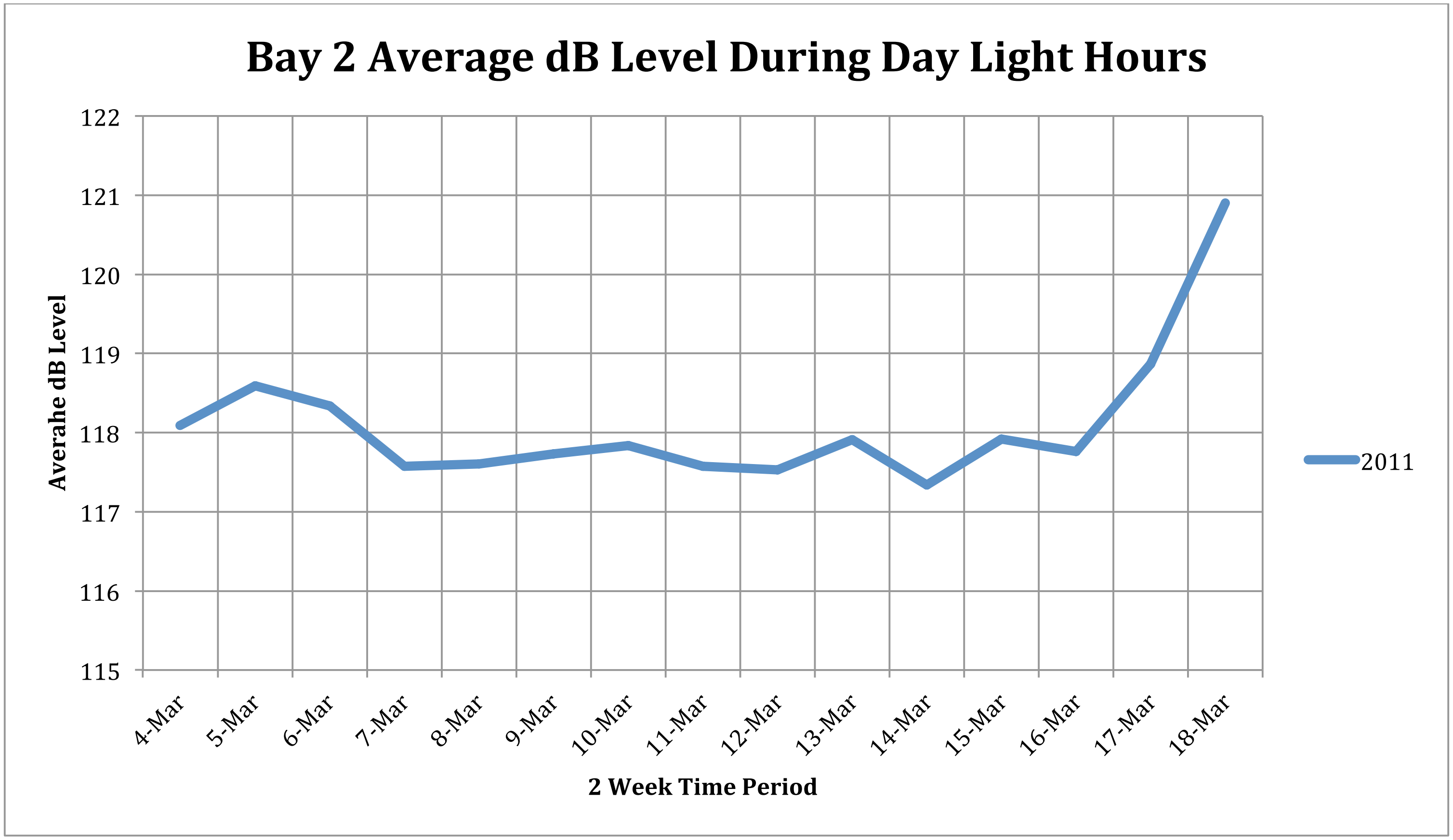

Figure 12: Two-week daily average decibel levels for 2011 during day light hours in Bay 2.

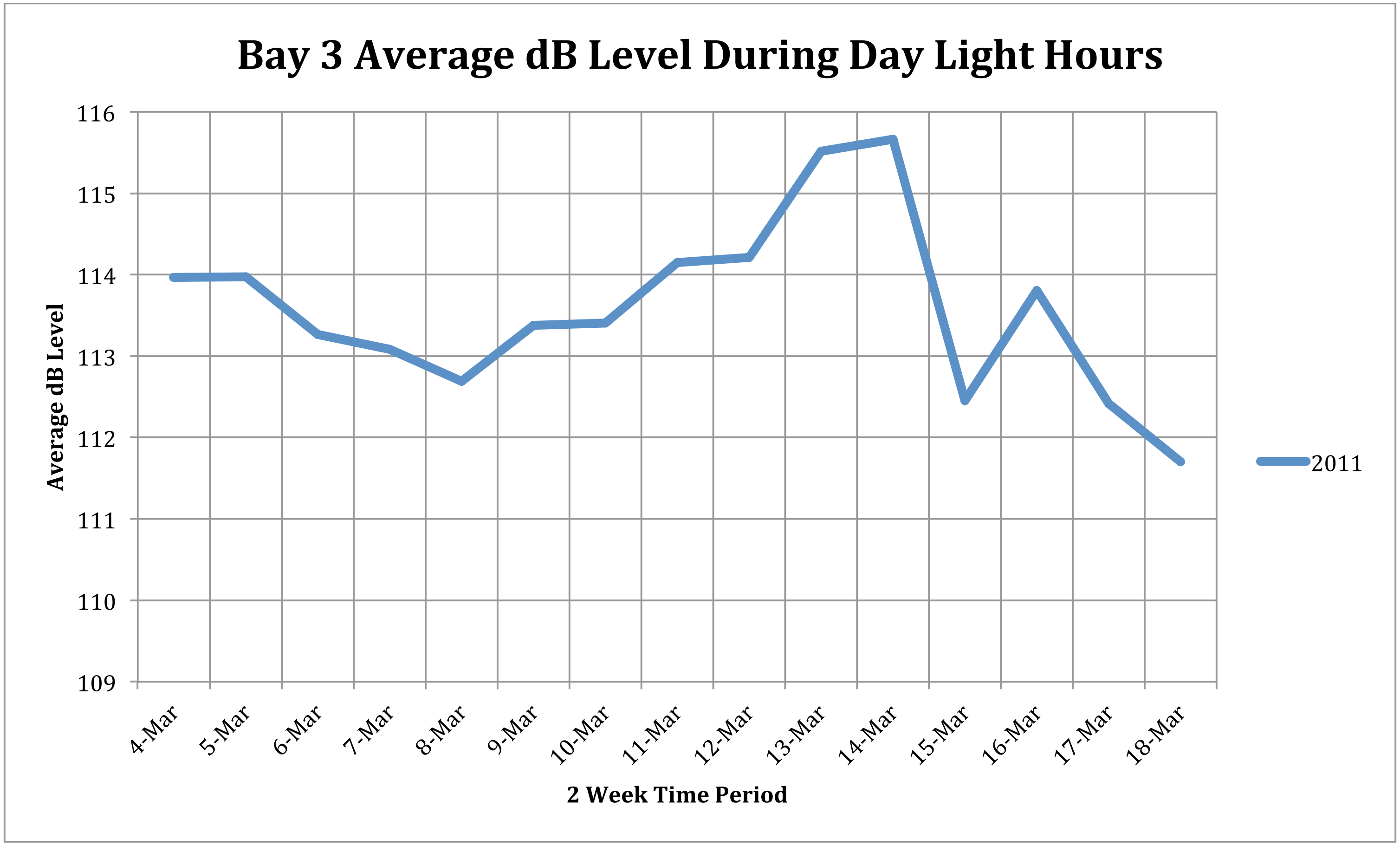

Figure 13: Two-week daily average decibel levels for 2011 during day light hours in Bay 3.

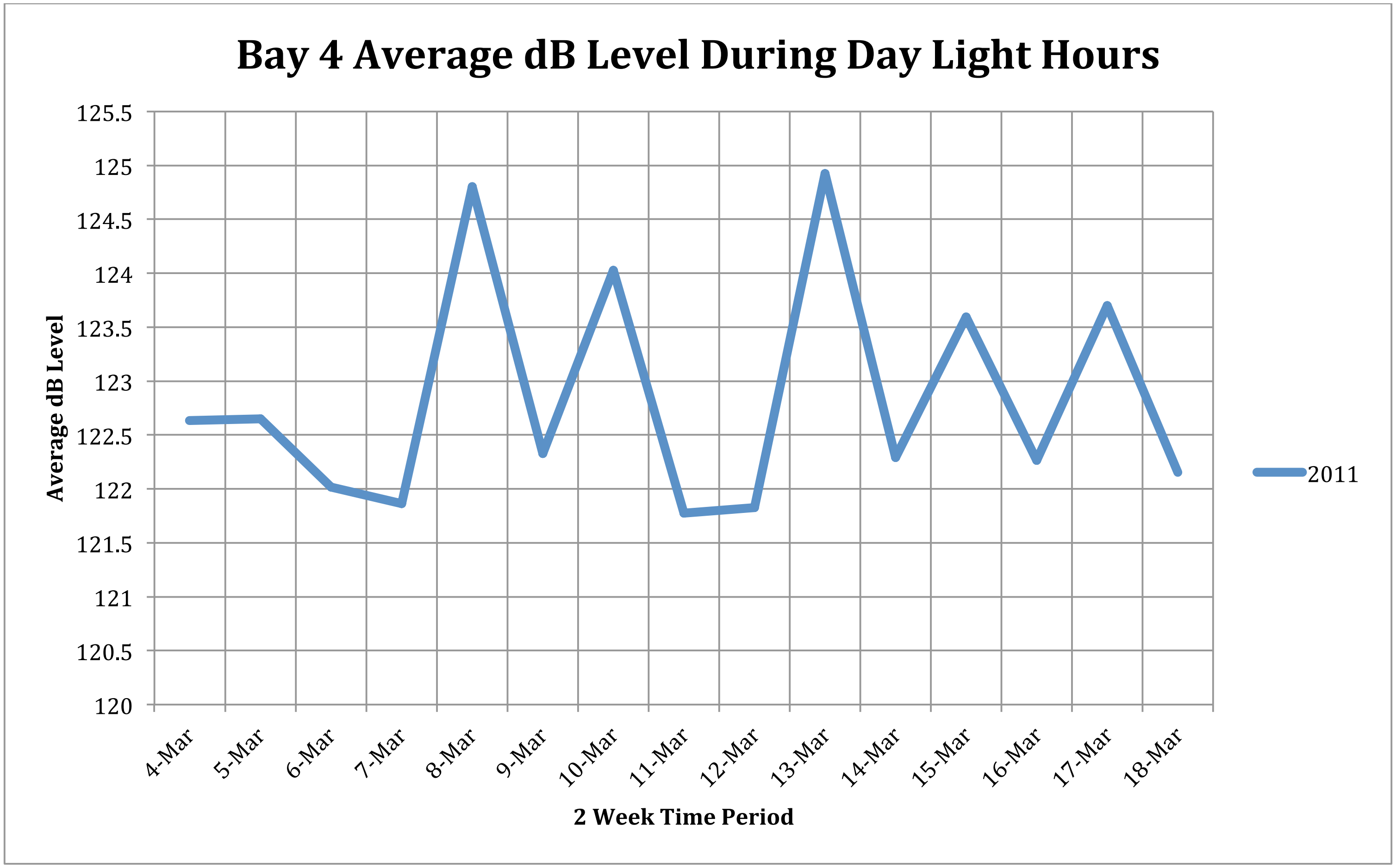

Figure 14: Two-week daily average decibel levels for 2011 during day light hours in Bay 4.

Discussion

In Rolland et al. 2012, it was concluded that the September 11, 2001 terrorist attacks on New York City had decreased shipping so dramatically in the Bay of Fundy that the North Atlantic Right Whales had experienced a drop in fecal related stress hormones. This finding supported the heavily speculated correlation between shipping noise (anthropogenic noise in general) and marine mammal stress. Knowing that humans are impacting the wildlife that utilize these soundscapes for basic functions like communicating, navigating and feeding, it is important to discover how much we are contributing to the problem. This study aimed to measure a baseline of what the marine soundscape may have sounded like in Hawaii prior to human influence by utilizing the Tohoku tsunami, much like Rolland et al. used the terrorist attacks. The findings currently suggest that this tsunami event was not as influential as previously hypothesized and has not provided the baseline sought after.

After evaluating the results for total, broad-spectrum sound in the bays, it was discovered that a relevant drop in noise was not recorded and thus could not provide a look into the past as to what the area sounded like prior to human influences. Bay 1 was the only bay that exhibited a spike in noise on the day of the event rather than a drop (Figure 2 and Figure 6). When looking at the hourly average, a dramatic spike in noise occurred at 05:00 or approximately 1-1.5 hours after the tsunami struck the Kona coast of Hawaii (Figure 6). The cause of this spike in noise is unknown, but the spike is not found in any other bay and thus is a localized, isolated event. It is this morning event that has influenced the daily average and caused this to spike (Figure 2).

Bays 2, 3, and 4 all had decreases in their daily average noise on March 11th (Figures 3, 4, and 5 respectfully). Bay 4 had the greatest decrease in noise (nearly 2dB) from March 10th to the 11th (Figure 5), but this extreme change is typical for this location judging from the rest of the two-week graph. Also, this decrease did not drop below the 2012 levels and consequently was not a viable option for a historic low possibility. Bay 3 had a 1.0dB decrease from March 10th to the 11th and was below the 2012 level, but not below previous (March 6-9) and future (March 15-18) levels and therefore also was not a viable option for a historic low possibility (Figure 4). Bay 2 dropped approximately 0.5dB, but like Bay 4, did not drop below the 2012 measured levels (Figure 3). Since the tsunami occurred at such an early time in the morning, it is presumed that there was not a fewer number of people out on the water than a normal day at 03:00. Additionally, with the tsunami ranging from 1.4-4.0 feet in height (depending on location), it was not very destructive and thus did not prohibit normal day activities during the day light hours of March 11th (Figures 11, 12, 13, and 14).

Though there has yet to be any evidence of a drop in human activity, further evaluation of the data will prove helpful. The use of filters to narrow and isolate the focus on acoustic bands that small boats are known to operate at could show that there was a lack of human activity after the tsunami that was filled by another acoustic producer. This may explain why there was a lack of reduced noise following this event. Additionally, other sound measuring techniques such as sound exposure level can be used to reevaluate the data that were used in this study. Finally, it would be useful to continue to look at all the data for these areas (not just during this time period) and identify patterns such as louder/quieter times of the year, which bays are habitually quiet or loud, and specific events that deviate from the norm as well as the causation for these events. If the documentation of what the past may have sounded like in these areas cannot be found after further evaluation of the available data, the present sounds should be documented so that as humans further influence the area, we can understand how it may be impacting the local oceanic soundscape and the wildlife that utilizes this acoustic community.

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