# Long-time trends in oceanic ambient noise along the western North American coast

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## I. BACKGROUND

Ambient noise studies along the North American west coast benefit greatly from the efforts of Wenz in the 1960s to collect, compile and publish [1] ambient noise levels measured from then-newly deployed U.S. Navy hydrophone systems. In the early 1990s, the Applied Physics Laboratory (APL-UW) was granted access to these systems and began a long-term program collecting short-time ambient noise autospectra. This paper addresses comparisons between the Wenz levels and recent measurements for four receivers systems denoted **D**, **F**, **G** and **H**. (See Fig. 1.) Systems **D** and **F** are decommissioned: **G** and **H** remain classified.

Although the Wenz and APL-UW datasets are unique in that both use the same in-water components (hydrophones, cables), the shore-side electronics have changed over the decades. A representative instrumentation diagram is shown in Fig. 2. The APL-UW effort introduced $G_{FG}$ , $F_{ADC}$ and $H_{pf}(f)$: $TS(f)$ was given in Navy documentation. The first published findings from this effort [2] involved relative statistics, but not absolute levels, because $H_{SS}(f)$, $G_{VG}$ and $H_{pf}(f)$ were unknown. This problem was circumvented [3] for system **D** using a nearby system, and again for system **F** using a co-located recorder deployed by McDonald *et al*. [4]. Motivated by the McDonald data, $H_{SS}(f)$ and $H_{pf}(f)$ were recently recovered. Calibrations (with the exception of $G_{VG}$ , of order +/- 2 dB) now exist for all four systems, allowing comparison against the Wenz data.

## II. ANALYSIS AND SUMMARY

One-third octave (OTO) band levels were synthesized from each autospectrum, and the median level for each month in each band retained as "raw time series data". Figs. 3, 4, 5, and 6 show raw data for all four sites. The data were conceptualized as annual baleen whale vocalizations riding atop a background due to distant shipping, and thus were modeled (in the decibel domain) as a sum of Gaussian functions plus a linear trend. At 16 and 20 Hz (not shown), the whalesong contribution overwhelms the distant shipping. However, at 31 Hz, penalized least-squares estimates of model parameters demonstrate that an underlying "distant shipping" linear trend can be determined. These values are presented in Table I.

The first long-term comparison for system **D** [3] revealed an increase in noise levels of up to 10 dB, but less than what would have been indicated following a simple linear trend from the 1960s, corroborating predictions by Ross [5]. The levels reported here for systems **F**, **G** and **H** provide further validation. The recent decadal trends at **D** and **F** suggest a continuing rise in ambient noise levels, but not nearly at the rate witnessed in the middle of the last century. The records at **G** and **H** are less informative in this respect. The influence of the vari-gain $G_{VG}$ must be investigated here, as well as possible changes in coastal shipping lanes.

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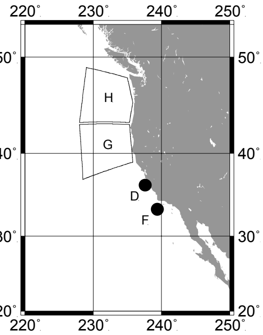


Fig. 1. Geography of measurement sites. Receivers **D** and **F** are shown exactly, but only approximate coverage for receivers **G** and **H** are shown.

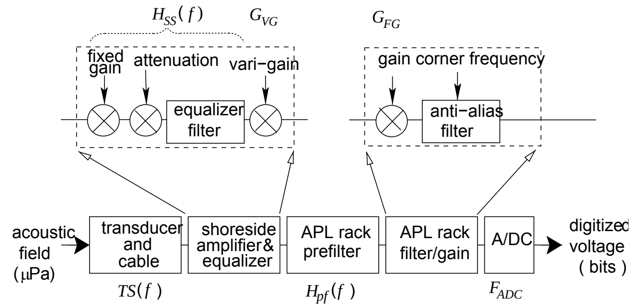


Fig. 2. Generalized schematic diagram of signal conditioning circuitry for all receiver systems described in this paper.

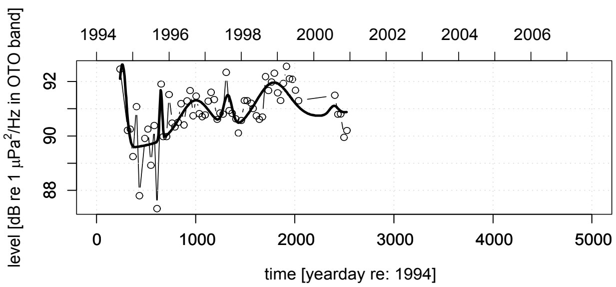


Fig. 3. Spectral OTO levels and model (heavy black line), 31 Hz, site **D.**

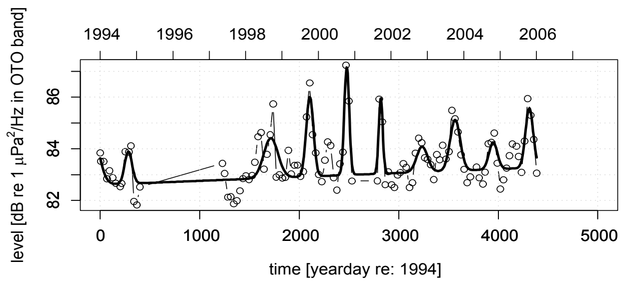


Fig. 4. Spectral OTO levels and model (heavy black line), 31 Hz, site **F.**

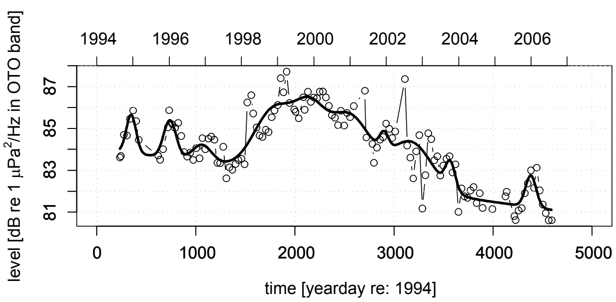


Fig. 5. Spectral OTO levels and model (heavy black line), 31 Hz, site **G.**

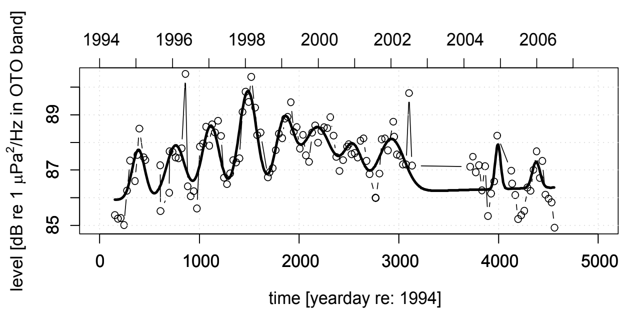


Fig. 6. Spectral OTO levels and model (heavy black line), 31 Hz, site **H.**

Table I: Trend statistics in a one-third octave band centered at 31 Hz. Slope errors are estimated standard errors. The intercept is the level in decibels for mid-1994. The slope units are dB/year.

| Site | Intercept | Slope |
|---|---|---|
| **D** | 89.3 | 0.22 +/- 0.169 |
| **F** | 82.6 | 0.05 +/- 0.018 |
| **G** | 84.0 | -0.23 +/- 0.111 |
| **H** | 85.9 | 0.04 +/- 0.052 |

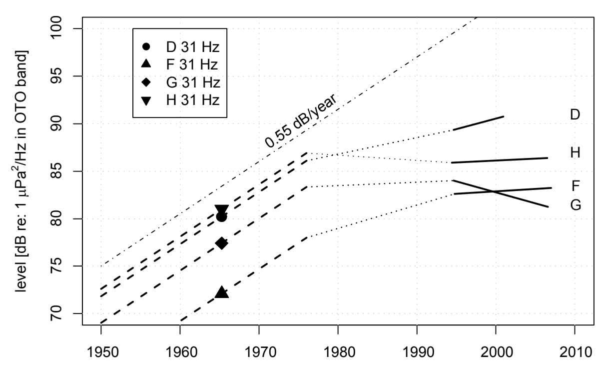


Fig. 7. Comparison of Wenz points versus APL/UW trends for a OTO band centered at 31 Hz. Dashed lines indicate the early trend as suggested by Ross, dotted lines indicate the connection to the actual recent trends (solid black).