

Underwater Visibility Maps – a New Tool for SCUBA Divers

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Introduction

You're underwater and wondering if the visibility could get any worse. You could have checked *Eyes Over Puget Sound* (EOPS) as part of your pre-dive planning!

We've created underwater visibility maps of Puget Sound using light transmissometer data collected during routine monitoring of our marine waters.

The light transmissometer is an electronic instrument that measures how far light travels under water. Light does not travel as well in murky water. Bad visibility takes away enjoyment from a dive, although it may keep prey from being eaten.

Underwater visibility in Puget Sound has increased during the past ten years. Will it be better for divers and fish?

Visibility Maps for Divers



Figure 1. CTD package with arrow locating the light transmissometer.

The Department of Ecology collects marine data to determine long-term patterns in water quality related to estuarine eutrophication processes. We use a Sea-Bird CTD package equipped with sensors for vertical water column profiles. One of these sensors, the light transmissometer (Figure 1), can be used to determine horizontal water visibility, information that can be useful to SCUBA divers. Divers benefit by knowing the horizontal distance over which they can expect to see underwater during their dive.

Each month we create a map with site-specific visibility from our monitoring data (Figure 2). This map shows the distance in feet of the best visibility at each location, indicated by the shaded diver. The darker the diver, the better the water visibility. For each location, we report the distance and depth of the best and worst visibility.

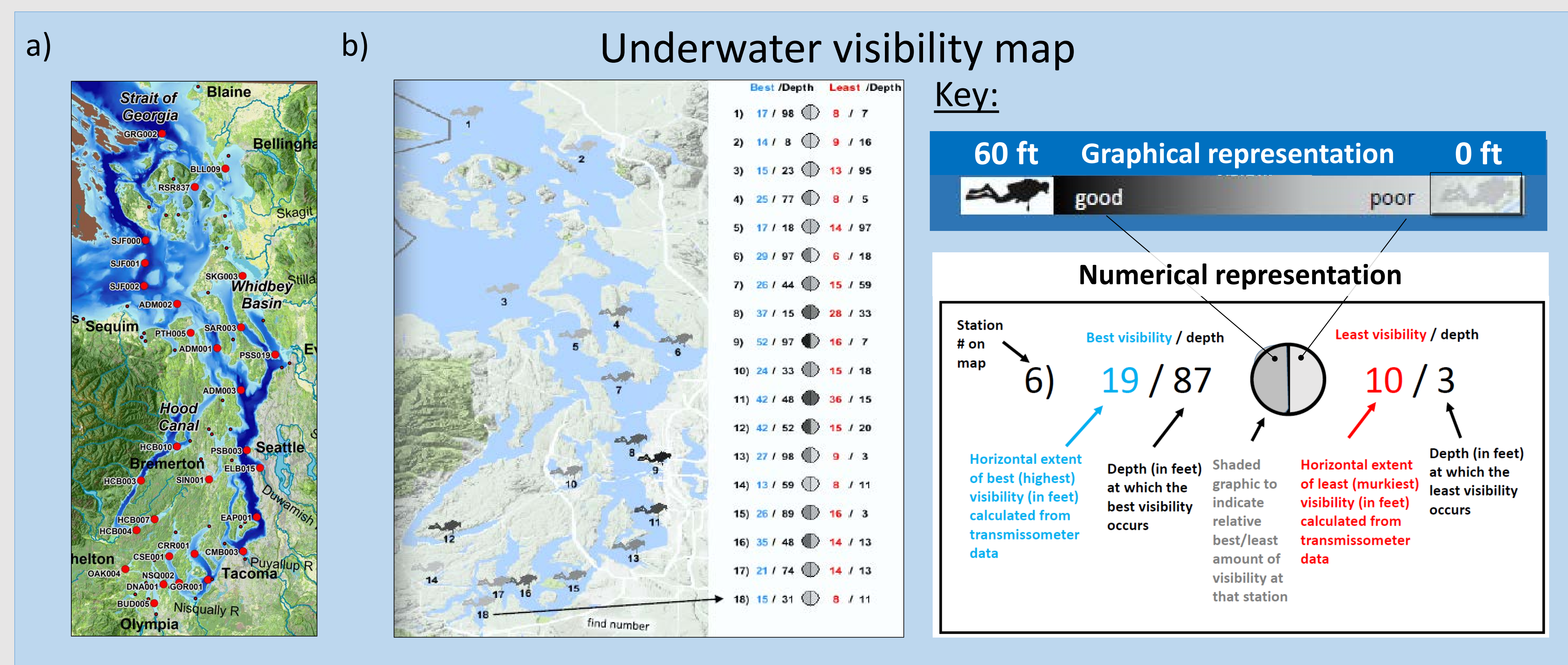


Figure 2. a) Ecology's Puget Sound monitoring station locations, b) example of an underwater visibility map showing the horizontal extent of **Best** and **Least** visibility and the depths (ft) at which they occur (in black) using a graphical (diver) and numerical approach.

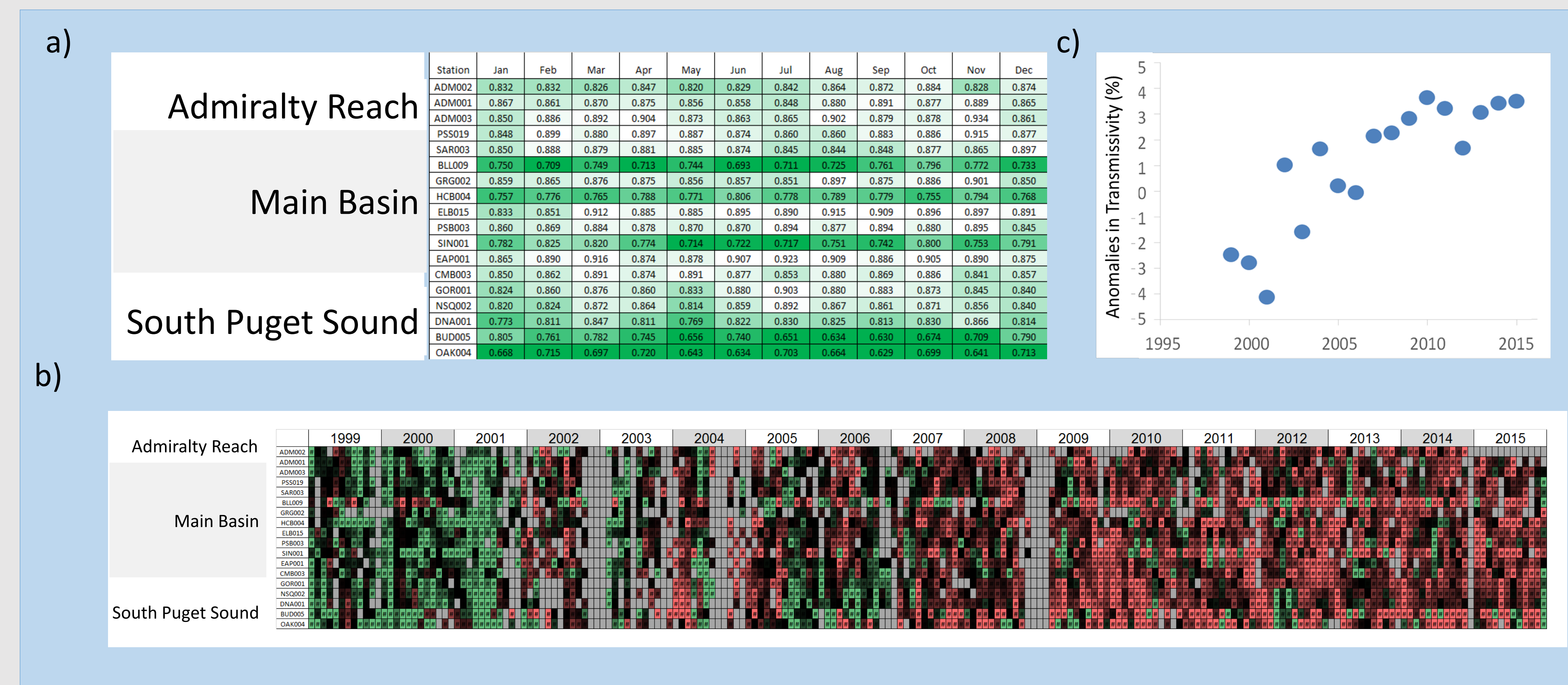


Figure 3. a) Monthly mean light transmission for 1999-2008 at our monitoring stations, grouped by basin and arranged from north to south. Green color depicts lower visibility. b) Puget Sound monthly anomalies in transmissivity (0-50m) calculated by subtracting the means (a) from the observations at each station. Red shows above average visibility and green below average. Black is expected values and gray means there were no data, c) Long-term, inter-annual anomalies across all stations averaged, showing an increasing trend in transmissivity (on average the water is getting clearer).

Converting Light Transmission to Visibility

The conversion to visibility shown for selected stations in Figure 2 is estimated from the beam attenuation coefficient (commonly called Beam-c) of the transmissometer (Zaneveld and Pegau, 2003) using the following equations:

$$\text{Beam-c} = - (1 / z) * \ln (\% \text{ light transmission}/100)$$

and either

$$V = 3.7 / (1.18 * \text{beam-c} + 0.081), \text{ in meters}$$

$$V = 12.14 / (1.18 * \text{beam-c} + 0.081), \text{ in feet}$$

where z is the transmissometer path length (meters), and light transmission [decimal] is light transmission in percent [%] divided by 100. The relationship beam-c and horizontal visibility seen by a diver involves several factors that relate to the photopic response function of the human eye. The WetLabs transmissometer used by Ecology uses a general red (~660 nm) light source through a 25-cm light path. Ecology calibrates instruments relative to water so that water effects due to the index of refraction are removed.

Patterns and Trends in Visibility

Underwater visibility changes in response to anything that increases particles in the water, such as shifts in plankton density and riverine inputs of suspended sediment, including glacial flour and humics (brown water). Seasonal and spatial variations throughout Puget Sound can be seen over monthly intervals in Figure 3a. These overall spatial patterns were derived from a ten-year average (1999-2008) of results. Lower visibility is shown by more intense green color, which primarily occurs inside of embayments and inlets.

Admiralty Reach has good visibility in general, as does the Main Basin outside of locations like Sinclair Inlet, Bellingham Bay, and Lynch Cove (showing dark green for low light transmission). South Puget Sound generally has better visibility to the north (seaward), which might increase predation risk for fish in that region. Seasonally, South Puget Sound has better visibility during summer and at the end of winter. May and December have the lowest visibility in South Puget Sound, which might provide an advantage to fish from visual predators during those periods.

Long-term visibility trends are shown in Figure 3b, and have increased over the past 15 years as indicated by more red highlights. Figure 3c shows this trend averaged over all stations in our network.

Reference:

Zaneveld, Ronald, J. V., and W. Scott Pegau, "Robust underwater visibility parameter," Opt. Express 11, 2997-3009 (2003)