Particle size distributions (PSDs)

Fundamental need in biogeochemistry.

Different PSD methods are 'sensitive' to different sizes.

Different PSD methods measure different parameters relating to 'size'.

The choice of PSD (number vs. area or volume) is important.

In-situ measurements vs. sample handling and single particle counters.

Why do we want to know the PSD?

What parameters can we infer from size?

What processes are affected by size?

Different PSD methods are 'sensitive' to different sizes.

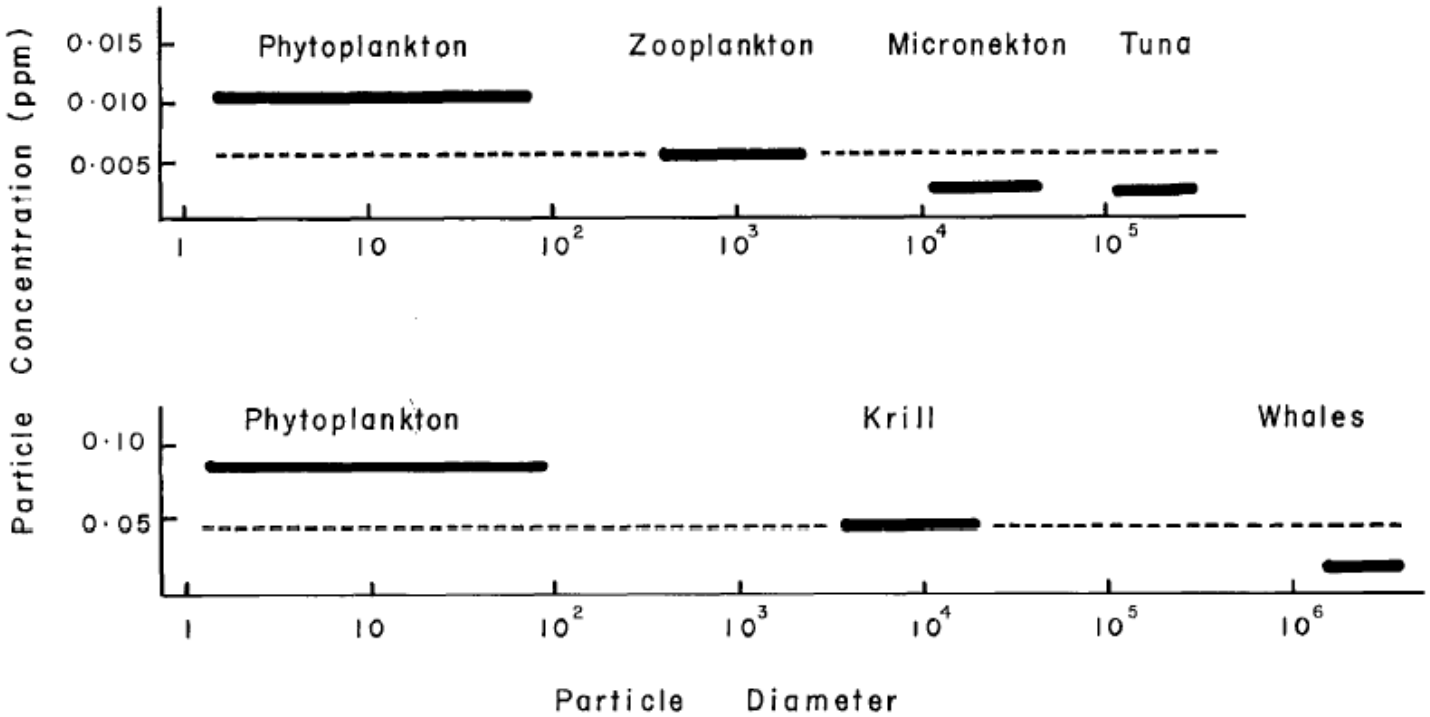
In general, a physical measurement associated with waves (sound, EM) will be most affected by 'homogeneities' in the environment which have sizes similar to its wavelength (resonance).

In addition, issues of resolution (e.g. pixel size) may limit the smallest resolvable size.

Hence, if we want to sense particles of a certain size we need to choose a tool that will be sensitive to that size range.

Sheldon et al., 1972:

A hypothesis is presented to show that, to a first approximation, roughly equal concentrations of material occur at all particle sizes within the range from 1 μ to about 10^6 μ, i.e. from bacteria to whales.



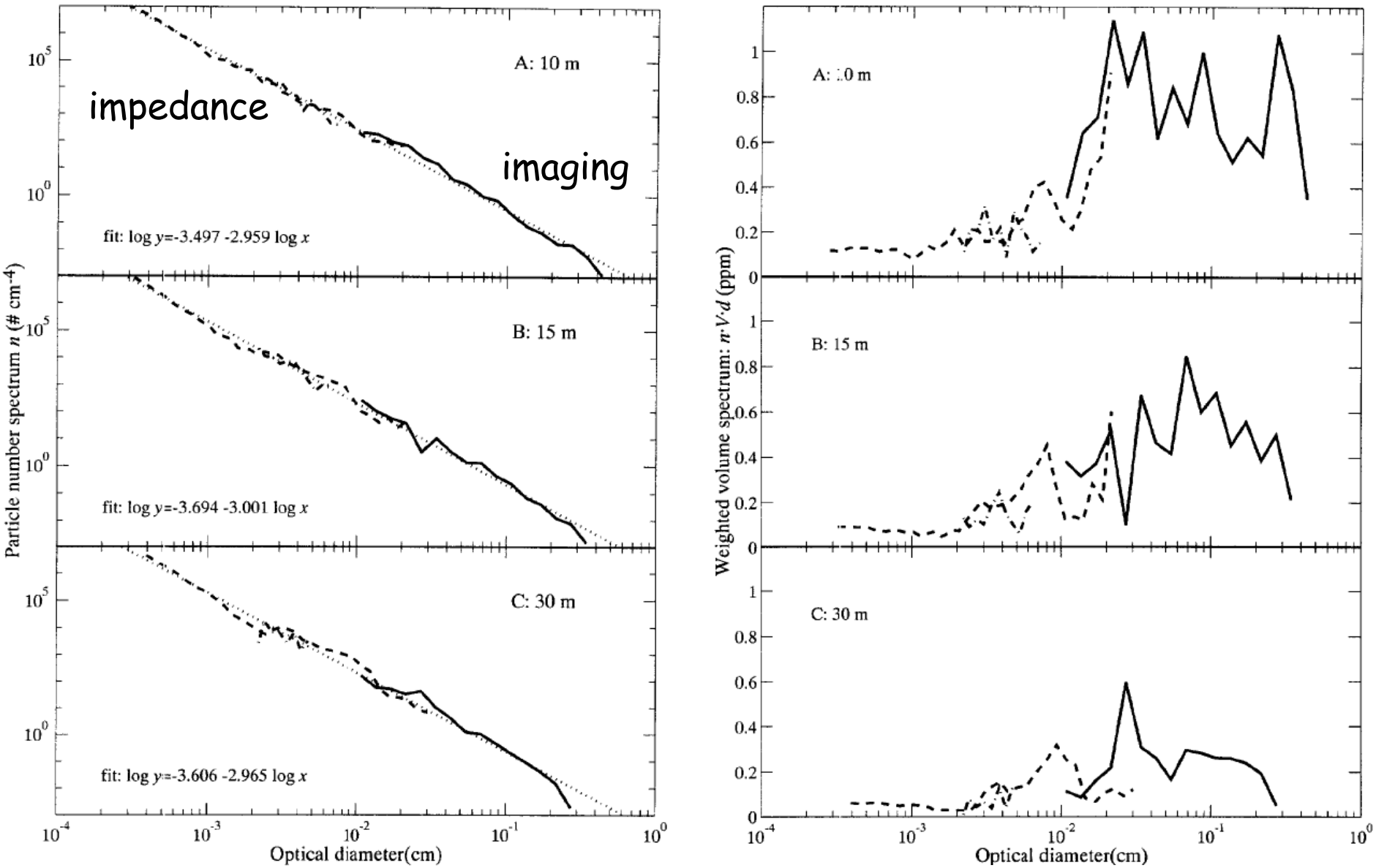
Coulter counter, nets, published values.

Consistent with $n(D) \sim D^{-4}$

Minimum detectable particle size. All particle sizing techniques suffer from weak signals from small particles.

Number distribution

Volume distribution (fractal effect treated)



Common models of PSDs

Power-law size distribution:

$$f(D) = \begin{cases} 0, & \text{if } D < D_{\min} \text{ or } D > D_{\max}; \\ n_0 \left[\frac{D}{D_0} \right]^{-\xi}, & \text{if } D_{\min} \le D \le D_{\max} \end{cases} \quad [\# \, \mathrm{m}^{-3} \mu\mathrm{m}^{-1}],$$

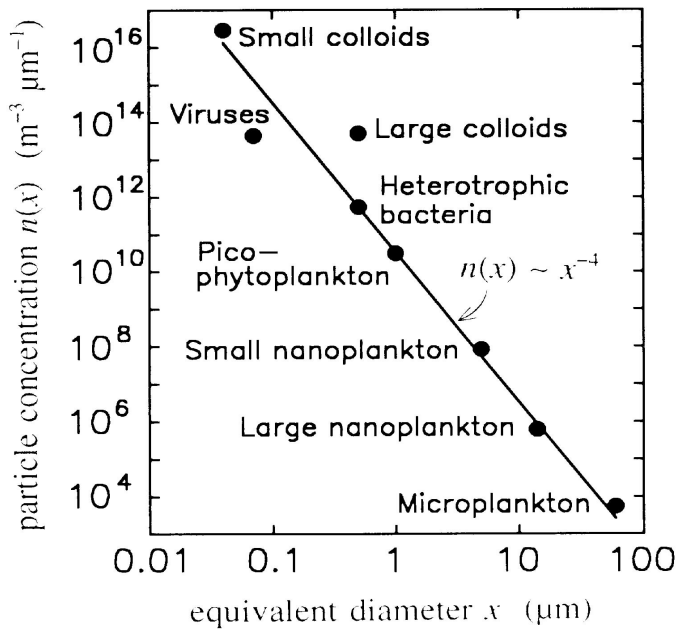


Fig. 3.2. Number size distribution typical of biological particles in the open ocean. [figure courtesy of D. Stramski]

Gamma:

$$n(r) = \begin{cases} 0 & r < 0 \\ Cr^{\mu}e^{-br} & r \geq 0;\ \mu > -1;\ b > 0, \end{cases}$$

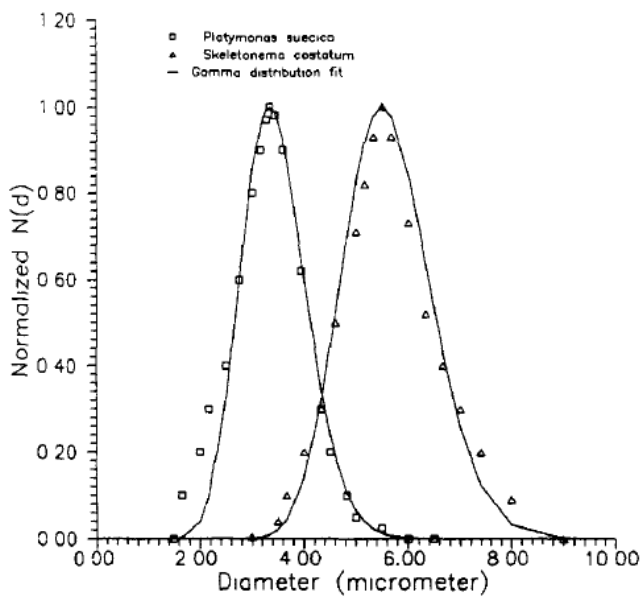
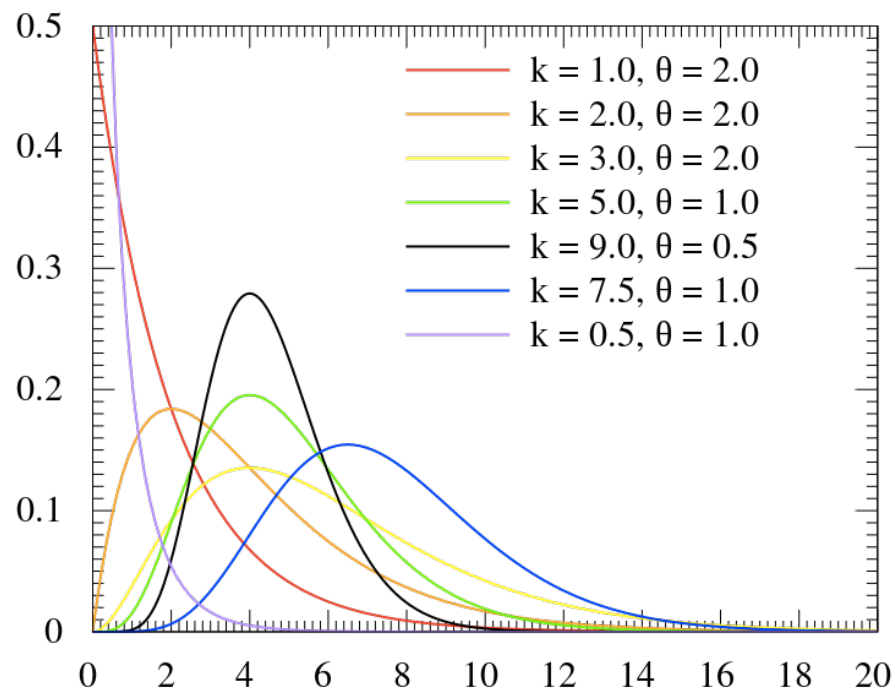


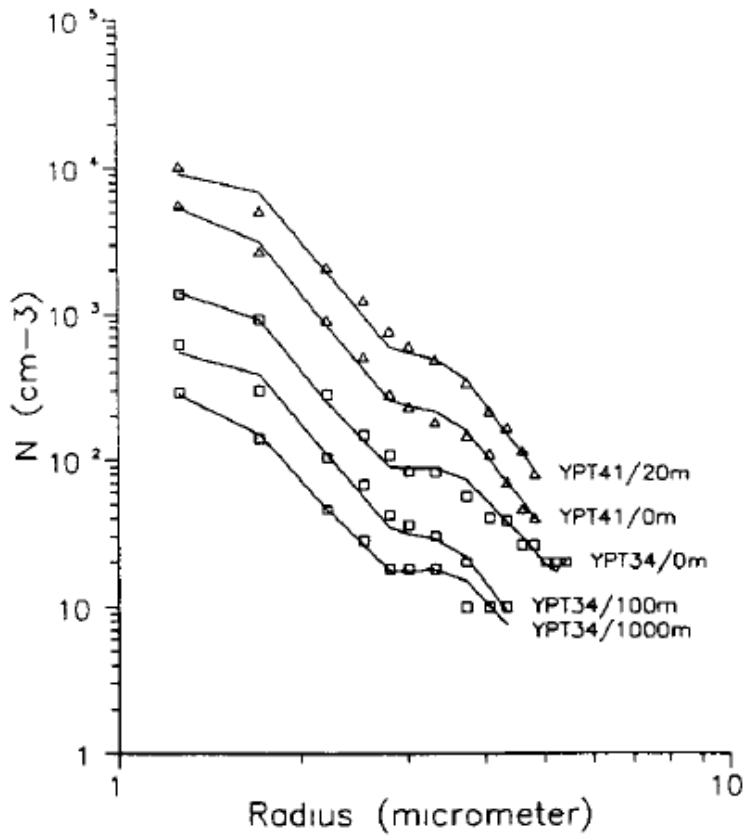
Fig 1 Normalized size distribution of phytoplankton species *Platymonas suecica* and *Skeletonema costatum* (Bricaud and Morel, 1986) and corresponding gamma distributions fit. Parameters of the respective distributions are $\mu = 20$, $b = 5.71$ and $\mu = 40$, $b = 7.279$



PDF= $\frac{1}{\Gamma(k)\theta^k} x^{k-1} e^{-\frac{x}{\theta}}$

Risovic (1993):

$$f(D)=\begin{cases}0, & \text{if } D<D_{\min} \text{ or } D>D_{\max};\\ n_S\left[\dfrac{D}{D_0}\right]^{\mu_S}\exp(-\tau_S D^{\nu_S})+n_L\left[\dfrac{D}{D_0}\right]^{\mu_L}\exp(-\tau_L D^{\nu_L}), & \text{if } D_{\min}\le D\le D_{\max}\end{cases}\qquad [\#\,\mathrm{m}^{-3}\mu\mathrm{m}^{-1}],$$



Summary

- Size matters, but it needs to be defined.
- All data looks great on a log-log plot.
- Simple calculus but details are important.
- Simple models are useful but need to be tested.
- Beware of handling.