GOING DEEPER 1.1

A Glimpse into the Variation Problem: How Do We Know That One Estimate Differs from Another?

A crucial part of the scientific method is the formulation of our ideas as testable hypotheses. The simplest and most testable of hypotheses is the **null hypothesis**, which states that there is no difference between two treatments that you have chosen to study experimentally or by comparative observation. We assume that a given measure is taken from each of several situations that can be classified as belonging to one of the two treatments. But how do we know that our outcome does or does not refute the null hypothesis? This requires some measure that characterizes a consideration of variation of observations. For any experiment, we must perform a series of replicates for each experimental treatment. To judge whether the results differ significantly we must compare the variation between treatments as contrasted to the variability found within treatments.

Imagine the following two cases (**Box Figure 1.1**): a caging experiment is set out on a rocky shore, with 10 replicates each for caged and uncaged areas. After a time, barnacles are counted in each replicate. **Box Figure 1.1a** provides convincing support for the idea that barnacles were more abundant in the caged treatment. The mean (average) numbers between treatments are quite different, but the variation for replicates within a treatment is rather small. We could intuitively conclude that the difference is *significant*. In other words, the variation between treatments is much greater than the variation observed within treatments.

On the other hand, the outcome depicted in **Box Figure 1.1b** is not so clear. The mean differs, but there is a great deal of variation among replicates within a treatment. The difference in mean barnacle density may not be significant, but how would we know?

Analyzing variation to detect differences is the natural objective of **statistics**. We might at first calculate the mean, which is the sum of the numbers in all replicates for a given treatment (caged or uncaged) divided by the number of replicates.

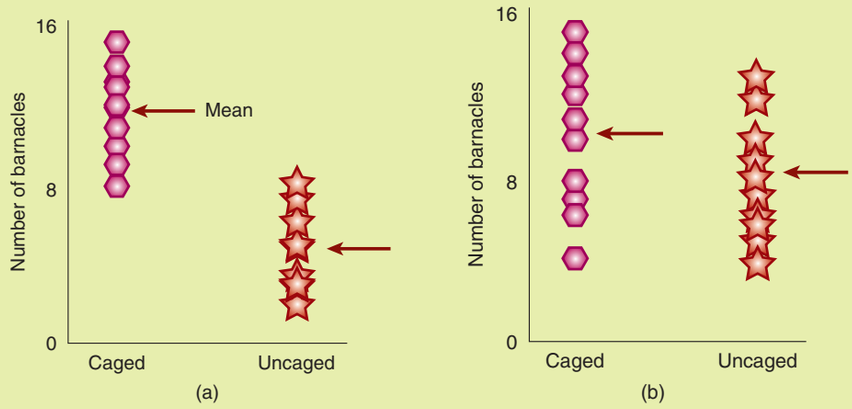
Mean abundances of replicates (N = 10) for each treatment; the experiment was performed twice.

	RESULTS	
TREATMENT	BOX FIGURE 1.1A	BOX FIGURE 1.1B
Caged	11.7	10.1
Uncaged	4.7	8.2

We use a statistical test known as a t test to test the null hypothesis that the mean number of barnacles does not differ between the caged and uncaged treatments. Given the variation seen in the experiments, a value, known as t, can be calculated. If you have had a course in statistics, the following will make sense and will be familiar:

$$t = \frac{\text{sample mean for caged} - \text{sample mean for uncaged}}{\sqrt{(\text{variance of caged} + \text{variance of uncaged})/10}}$$

The variance is a measure of dispersion of points about the mean. This is saying that the higher the variance of data from



BOX FIG. 1.1 **The use of variation to test hypotheses. The null hypothesis to be tested is that there is no difference in barnacle density in caged versus uncaged experimental treatments. (a) In this case it is clear that the differences of means (indicated by arrows) and range of numbers from a group of replicates for each experimental condition support the hypothesis of difference. (b) This set of results suggests that, while the mean number of barnacles does differ between treatments, the variation is too great to justify a firm conclusion that the different treatments cause different barnacle densities.**

GOING DEEPER 1.1 CONT

the two treatments, the lower the value of t. Also, the smaller the difference between sample means, the lower the value of t. As t increases, there is a greater possibility that the null hypothesis of no difference in means is unlikely to be true.

Skipping over the details, it is possible to calculate critical values of t. If the sample t is greater than the critical value, then we can conclude that the null hypothesis is refuted. The threshold value of t is calculated at a probability level. If the probability level is 0.05 (probability is only 5 percent chance that the treatments are equal in effect), the common value used by ecologists and statisticians, and if the sample t is greater than the threshold value, then we may conclude that there is less than 1 chance in 20 that the null hypothesis of no difference in means is true. I am sparing you a number of assumptions behind this.

Now let's turn to our caging data. For the left-hand graph (**Box Figure 1.1a**), it turns out that the probability that the means are the same is 0.0002. This fits with our intuition. For the right-hand graph (**Box Figure 1.1b**), however, the probability is 0.10 that the means are equal. Since we have chosen a threshold probability of 0.05 for our measure of significant differences, we conclude that the differences between caged and uncaged in **Box Figure 1.1b** are not significant. In turn, that means a further conclusion based on **Box Figure 1.1b**—namely, that the mean density in the caged is greater than that of the uncaged treatment—is pretty weak. The calculated mean is greater, but the variation is too great to sustain a refutation of the null hypothesis. ■

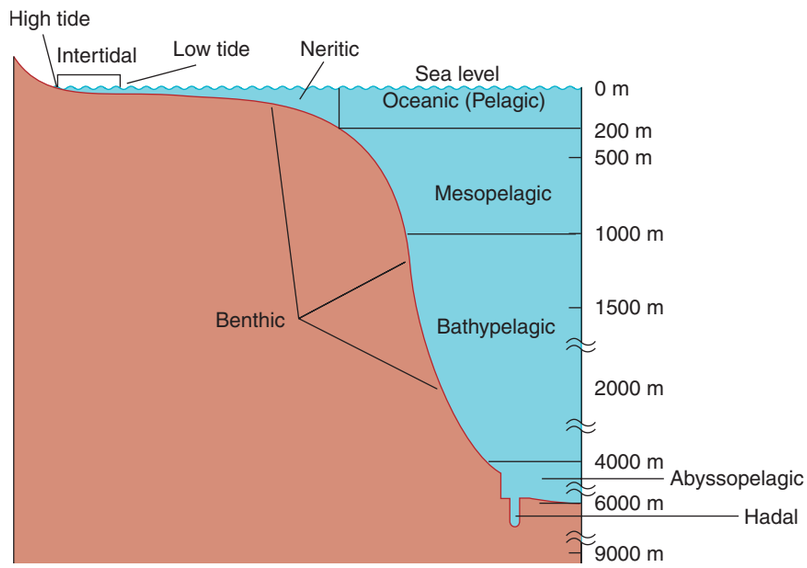


FIG. 1.13 **A cross section of the ocean from the shoreline to the deep sea, showing the location of major marine habitats.**

surface or are **epifaunal**. Most clams are infaunal, whereas oysters and barnacles are epifaunal. Mobile organisms associated with the seabed that can swim (e.g., bottom fish) are said to be **demersal**.

Figure 1.13 gives a general classification for marine habitats based upon water depth. The **intertidal zone** is the range of depths between the highest and lowest extent of the tides. In some parts of the world there is little or no tide, and wind mainly determines the vertical range of this fringing environment (see Chapters 2 and 14). The **subtidal** zone is the entire remainder of the sea, from the low-water tidemark to the greatest depth of the ocean. **Continental shelf** (or neritic) habitats include all seafloor and open-water habitats between the high-water mark and the edge of the continental shelf. Seaward of the shelf is a series of oceanic or pelagic habitats: the **epipelagic** zone includes the upper 200 m of water, the **mesopelagic** zone ranges from 200 to 1,000 m depth, the **bathypelagic zone** ranges from 1,000 to 4,000 m depth, and the **abyssopelagic** zone ranges from 4,000 to 6,000 m depth; **bathyal** benthic bottoms range from 1,000 to 4,000 m depth, and **abyssobenthic** bottoms range from 4,000 to 6,000 m depth. **Hadal** environments include those in the seabed and the waters at the bottoms of the trenches, often far deeper than 6,000 m depth. For example, the Marianas Trench reaches about 11,000 m depth.