METHODS OF MEASURING WADER ABUNDANCE

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In early August, the population of migrating Semipalmated Sandpipers *Calidris pusilla* reaches a maximum in the upper Bay of Fundy in eastern Canada with over one million birds present (Hicklin 1987). At this important stop-over area, Semipalmated Sandpipers feed almost entirely on the abundant amphipod crustacean *Corophium volutator*. Between August 6 and 12, 1986, I conducted daily censuses of Semipalmated Sandpipers on a Bay of Fundy mudflat along an intertidal gradient of *Corophium* abundance. In this paper, I will compare the precision of three techniques used to measure wader abundance.

The most precise measurement of wader abundance in a given area can be achieved by continuous observation. All departures and arrivals of waders in the study area are noted along with the time of each observation. The data can be plotted as wader abundance versus time (minutes in this case). Integration of the area under the curve yields a measure of wader-minutes, precisely describing wader abundance over the time interval of study. I refer to this technique as the integrative method.

An alternative and commonly used measure of wader abundance involves averaging repeated counts of waders in a given area (*e.g.* Bengston and Svensson 1969; Goss-Custard 1977). Counts are taken either at fixed intervals (*e.g.* every 20 minutes) or when there is an obvious change in wader abundance. The precision of these measurements can be improved by minimizing the interval between successive counts. I refer to this technique as the averaging method.

A third measure of wader abundance can be obtained by counting the number of wader footprints in standard quadrants (*e.g.* 0.25 m^2). In most soft-sediment habitats, footprints left by foraging waders at low tide are "erased" by tidal currents as the tide rises to cover the flat. Wader footprints on an intertidal flat provide a record of wader abundance during the most recent exposure of the flat. Although it is difficult to translate footprint densities to wader densities, counts of footprints in different intertidal areas are potentially useful in comparing relative abundances between sites. The technique is attractive in that many different areas can be quickly sampled by either photographing or counting the number of footprints in a standard quadrant just before tidal immersion of the site. I refer to this technique as the footprint method.

Figure 1 presents a comparison of these techniques. In Figure 1a, the number of Semipalmated Sandpipers in a 0.1 ha area are plotted against time for the entire period of subaerial exposure of the intertidal site. Typically, a count was made every five minutes with more frequent counts when wader movements into and out of the marked area were high. The area under the curve was digitized with a graphics tablet to yield a measure of 491.5 wader-minutes. The averaging method can be applied to the same data set. The mean of the 50 observations is 17.5 Semipalmated Sandpipers.

The imprecision of the averaging method in comparison to the integrative method is evident from Figures 1b and 1c. The time-series shown in Figure 1a was scrambled by randomly assigning one of the 50 counts to each of the 50 times of observation. This randomizing procedure yields a curve (Figure 1b) that is clearly different from the original curve (Figure 1a). The area under Figure 1b is 469.1 wader-minutes, a value 4.5% below that of the original curve. However, application of the averaging method to the new time-series yields the same mean abundance as before (17.5) because only the order, not the values, of the 50 counts was changed. The integrative method is more precise because it is more sensitive to the magnitudes of the changes between sequential censuses. For these data, there is nevertheless remarkable concordance between the two methods (Figure 1c). For all 14 censuses made during my study, wader-minutes and mean number of waders are highly correlated ($r = 0.89$, $p < 0.01$); only 21% of the variance of one variable is unexplained by the other variable.

The footprint method provides an even less precise measure of wader use. In this study, photographs of nine randomly chosen 0.25 m^2 quadrants were taken each day within each marked 0.1 ha census area just before tidal immersion of the site. In Figure 1d the mean number of footprints per quadrant is plotted against the number of wader-minutes for the 14 censuses of the study. The two variables are not significantly correlated ($r = 0.25$, $p > 0.05$). The failure of the footprint method to provide precise estimates of wader use (relative abundance) can be largely explained by the heterogenous physical properties of the mudflat. Even within a 0.1 ha area, slight topographic features (pools and ridges) retain different quantities of water at low tide. Relatively moist areas will retain footprints better than relatively dry areas. The formation of footprint impressions may also be influenced by differences in sediment porosity and in the distribution of sediment grain sizes along the intertidal gradient. Finally, variation in wader activity on the mudflats will result in variation in the number of footprints made. A resting wader will make few footprints in a given period of time while an actively foraging wader will produce many. Differences in weather from day to day (strong winds, rain) may present difficulties when attempting to compare footprint abundances over time.

Comparison of three methods of assessing wader abundance reveals that both the integrative method and the averaging method are satisfactory. The precision of both methods can be improved by reducing the interval between observations. The integrative method provides a more precise measure because differences in magnitude between successive counts are accommodated. However, the high correlation between integrated counts and averaged counts (Figure 1c) indicates that loss of precision with the averaging method is slight. Although the footprint method is appealing because samples may be obtained in a matter of minutes rather than hours, the precision of the method is poor (Figure 1d). Problems stem from differential retention of footprints in different sediments and variation in the rate of footprint formation.

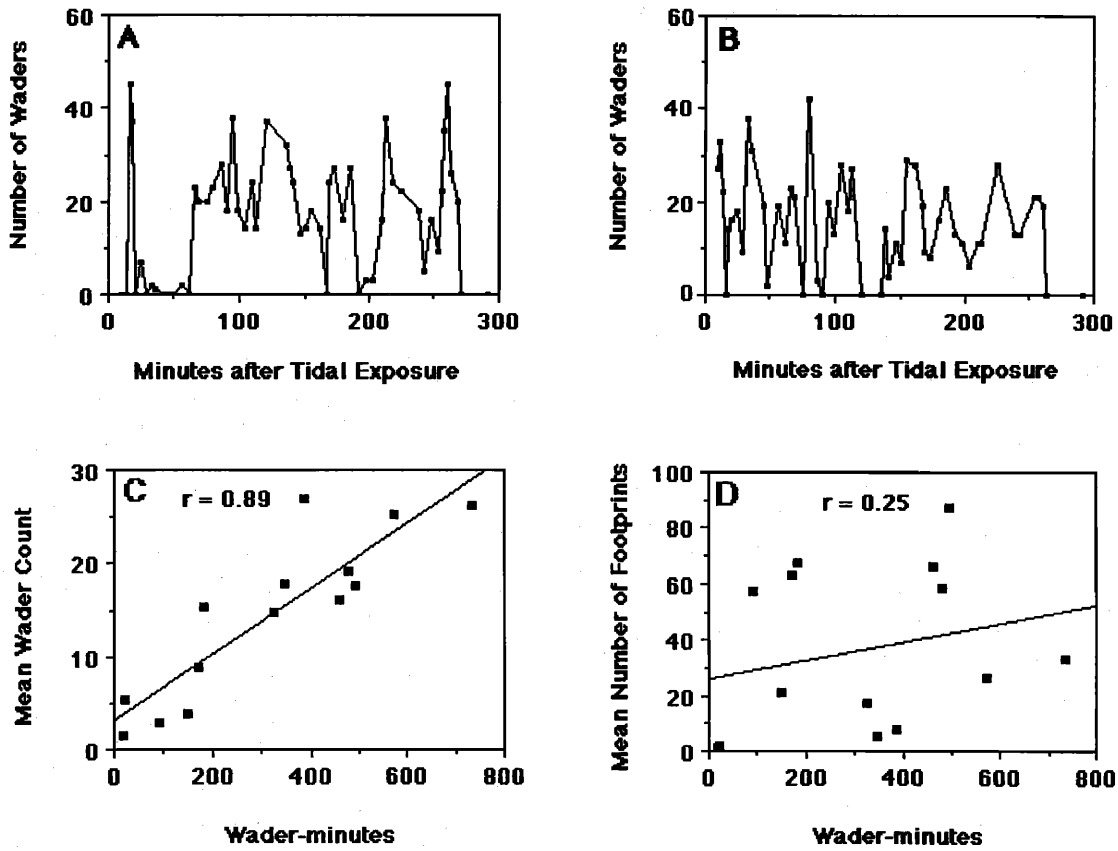

Figure 1. Comparison of methods of determining wader abundance. A. Integrative method for determination of wader-minutes for one low tide period; B. Integrative method using randomly rearranged data from A; C. Comparison of integrative method and averaging method; and D. Comparison of integrative method and footprint method.

REFERENCES

Bengston, S.-A. and Svensson, B. 1968. Feeding habits of *Calidris alpina* and *Calidris minuta* in relation to the distribution of marine shore invertebrates. *Oikos* 19: 152-157.

Goss-Custard, J.D. 1977. Predator responses and prey mortality in Redshank, *Tringa totanus* (L.), and a preferred prey, *Corophium volutator* (Pallas). *J. Anim. Ecol.* 46: 21-35.

Hickling, P.W. 1987. The migration of shorebirds in the Bay of Fundy. *Wilson Bull.* 99: 540-570.

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