Appendix 1.3

The following material is Appendix 1.3 for Chapter 1 of: Fowler, C.W. 2009. Systemic Management: Sustainable Human Interactions with Ecosystems and the Biosphere. Oxford University Press

1 Sample patterns for the eastern Bering Sea (construction of Figs 1.6 through 1.8)

This appendix provides details and references involved in producing Figures 1.6–1.8. It also exemplifies the general process of constructing species frequency distributions (described in detail in Fowler and Perez 1999, with further examples in Chapter 2).

The data used in constructing Figure 1.6 and the bottom row of Figure 1.7 are shown in Appendix Table 1.3.1. The original data sources, specific research, and procedures used to produce these data are contained in the references provided by Perez and McAlister (1993) and Fowler and Perez (1999). Data for the top row of Figure 1.7 are from Livingston 1993 and data for the middle row are from Fowler and Perez (1999).

An important point: there are an immense amount of work and analyses behind the compilation of the data used in constructing these figures. Estimating population is a very difficult task and subject to measurement error, one source of the variation demonstrated in these figures. The populations themselves fluctuate over time, another source of variation. The first step in constructing patterns like those shown in Figure 1.7 is to accumulate the estimates for population size (averaged over seasons to account for times when there are more or fewer individuals within the ecosystem owing to migrations). To calculate estimates of consumption rates, information on body size and size-specific consumption rates must be taken into account. Population numbers are multiplied by mean body size to find biomass; consumption rates are then estimated by multiplying biomass estimates by specific consumption rates, which are estimated from previously established relationships between body size and consumption rates. These quantitative relationships are the end product of even more complicated studies. Information on the composition of the diet allows for breaking down the total consumption of the bottom row of Figure 1.7 to its components as exemplified in the top two rows.

The details of such computations are presented in Perez and McAlister (1993). At all steps, additional sources of variation enter into the picture to contribute to variance in the resulting estimates shown as data in Table 1.3.1.

With data on population size (or consumption rates, or any other measure of a species) figures like Figures 1.6–1.8 can be constructed. For Figure 1.6 and the bottom row of Figure 1.7, the species of Table 1.3.1 ($N = 20$) were subdivided into categories. Each category was chosen as an equal subdivision of population size (Fig. 1.6), biomass consumed (first panel of bottom row of Fig. 1.7), or the log of biomass consumed (second panel of bottom row of Fig. 1.7). The number of species in each category was then divided by 20 to obtain the corresponding portion of species. Thus, the five species with estimated population sizes between 50,000 and 100,000 represented 25% (0.25) of the total as shown in one of the 10 categories for the top panel of Figure 1.6. Each category spans a segment in the range of population size, here in increments of 50,000 animals. Similarly, each category of biomass consumption for the consumption rates within the eastern Bering Sea (lower panel of the left column of Fig. 1.7) represents a 100,000-ton increment across the range shown. In this case, four of the 20 species fell in the second category (100,000–200,000

Appendix Table 1.3.1 List of 20 species of marine mammals found in the eastern Bering Sea, with estimates of population size (averaged over seasons as found in this region) and resource biomass consumed annually (10^3 metric tons (t)) and $\log_{10}$ (10^3 t) for the late 20th century from the same region (from Fowler and Perez 1999, and Perez and McAlister 1993).

Species	Body mass (kg)	Population size	Daily energy requirements (10^3 kcal)	Diet energy value (kcal/g)	Consumption	
					(10^3 t)	$\log_{10}$(10^3 t)
Balaena mysticetus	46,000	148	603.1	1.80	18.1	1.257
Balaenoptera acutorostrata	6,000	1,900	130.9	1.72	52.6	1.721
Balaenoptera physalus	49,000	500	632.3	2.00	57.5	1.760
Berardius bairdii	8,000	209	268.1	1.20	17.0	1.230
Callorhinus ursinus	43	219,750	7.1	1.31	432.4	2.636
Delphinapterus leucas	800	10,750	47.7	1.30	143.5	2.157
Enhydra lutris	20	79,000	4.9	0.90	157.1	2.196
Erignathus barbatus	241	77,500	12.2	1.30	265.1	2.423
Eschrichtius robustus	18,000	2,500	298.4	1.00	271.5	2.434
Eumetopias jubatus	212	32,000	20.7	1.30	185.2	2.268
Megaptera novaeangliae	30,000	63	437.7	1.80	5.5	0.744
Mesoplodon stejnegeri	2,000	200	94.8	1.20	5.8	0.760
Orcinus orca	4,000	500	159.4	1.80	16.1	1.207
Phoca fasciata	46	66,000	3.5	1.20	70.7	1.850
Phoca hispida	34	300,500	2.8	1.20	256.7	2.409
Phoca largha	62	77,000	4.4	1.39	89.1	1.950
Phoca vitulina	49	45,000	3.7	1.40	43.3	1.637
Phocoena phocoena	50	750	6.0	1.63	1.0	−0.001
Phocoenoides dalli	95	64,100	9.6	1.33	169.0	2.228
Physeter macrocephalus	36,000	3,791	828.5	1.20	952.8	2.979

tons of biomass consumed annually which was represented by 20%, or 0.2 of species).

Sobolevsky and Mathisen (1996) present information similar to that of Figure 1.6, for the entire Bering Sea, but as confined to the cetaceans. In this case, there is also information for the late 1940s to be compared to the more recent conditions of the late 1980s or early 1990s. Figure 1.8 presents these data as a frequency distribution (here placing the bars over the midpoints of each category instead of over the upper end of the range represented). The procedures used to construct Figures 1.6–1.8 are straightforward manipulations using common spreadsheet software. In essence, the production of species frequency distributions is a simple matter of "binning" species into categories defined by equivalent subdivisions of the range of any species-level measure. It is parallel to the process used in producing any frequency distribution (e.g., for individual organisms as measured by body size, body temperature, or rate of heart beat) as described in many general statistical texts (Alder and Roessler 1964, Dixon and Massey 1957, Huntsberger 1961, Schmid 1983).

References

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