Sample of Technical Text from *A Niche for Humans*

BEFORE EDITING

SYSTEMIC MANAGEMENT: INTRODUCING AN EXAMPLE

There is a great deal of interest in management involving ecosystems. With this in mind, it is helpful to have a concrete example of the application of systemic management in regulating human influence on ecosystems. To do so we will develop an application for the Bering Sea through the chapters ahead to demonstrate the application of systemic management as an approach that can be used for any ecosystem.

The Bering Sea is a marine system located north of the Aleutian Islands, between Russia on the west and mainland Alaska on the east. For our purposes, a subsection of the entire area, the eastern Bering Sea, is defined as the area east of a line from Attu Island (western Aleutian Islands, in the south) to the center of the Bering Strait to the north (Perez and McAlister 1993). The area and its history are described in various reports such as that of the National Research Council (1996). It is an example of an ecosystem of great value to humans. Recent commercial harvests of fish have taken millions of tons annually from a variety of resource species and this ecosystem has been subject to a great deal of concern regarding the impact of this and other human activities. Several species of marine mammals have been harvested intensively. One species, the Stellar sea cow, went extinct in recorded history. Changes in the system include reductions in marine mammal populations. Several species of marine mammals are subject to legal protection owing to their low numbers. Changes in the composition of the fish species have also caused concern.

Ecosystems can be represented by species frequency distributions (Fowler and Perez 1999) as shown in Figure 1.2 for the eastern Bering Sea (based on Perez and McAlister 1993). This figure demonstrates the characterization of only one of the very many facets of any ecosystem. This first example demonstrates variability among the population sizes of marine mammal species as based on numbers of individuals in thousands (top panel, and $\log_{10}$ raw numbers bottom panel), averaged over seasons. Figure 1.2 also demonstrates limits to the natural variation in population size among species, especially as exhibited in the lower panel.

Figure 1.3 shows a different form of variability, with its own limits. It involves the same set of marine mammal species represented in Figure 1.2 and again for the eastern Bering Sea ecosystem. In this case, we see the biomass consumed annually by the populations of these species (in thousands of metric tons). This graph also shows a spectrum of options for expressing measures of consumption. In this graph, consumption is represented from individual species (pollock, top row), fin fish (a group of species, second row), and the entire eastern Bering Sea (an ecosystem, bottom row). We also see two modes of presentation (raw measures, and log transformed values). We also see measures of human consumption rates (harvests, in the right column) for comparison.

Fowler and Hobbs (2001) argue that one critical part of systemic management is to comply with Tenet 3 of Appendix 1.1. Doing so would mean reducing commercial harvests to move the position of humans to fall within the normal range of natural variation. We begin to see the extent of both problems and needed change; there are orders of magnitude in the differences between human consumption rates and the mean of consumption rates among other species! However, there are other tenets to complicate things. In the chapters ahead, particularly through further development of the Bering Sea example, we will consider implementation of this tenet in combination with the others.

For example, there is the possibility that anthropogenic changes may have made things worse than they appear. The biomass of cetaceans in the entire Bering Sea ecosystem in the 1980s/1990s was estimated to be about 20% of levels found there in the mid 1900s (Sobolevsky and Mathisen 1996, Fig. 1.4). The corresponding declines in population numbers (total for all cetaceans) were estimated to be about 64% of earlier levels in the same study. The most significant changes involve the extinction of the Stellar sea cow and marked reductions in Sei and Blue Whales (the latter assumed to be represented by only minor numbers of individuals in Fig. 1.4). Figure 1.4 exemplifies changes in size (population size) composition, and increases in variation similar to changes observed in other ecosystems. These kinds of changes have to be part of what we take into account if we are going to use other species as empirical examples of sustainability to adhere to Tenet 3 of Appendix 1.1. Data for consumption rates based on data from the 1940s would clearly serve as better frames of reference than those for the ecosystem subjected to the abnormal human influence shown in Figure 1.3.

Management that applies to ecosystems must be based on an approach capable of providing answers to specific questions. How much biomass can sustainably be removed from the Bering Sea by humans? How many species can sustainably be harvested as resources? What is the appropriate allocation of biomass removal over the various trophic levels within the Bering Sea ecosystem (what portion of the harvested biomass would come from each trophic level)? How much biomass (or how many individual organisms) can sustainably be harvested from any particular resource species' population? What fraction of the standing-stock biomass (or numbers) of any particular species can sustainably be harvested? How many humans can live within an ecosystem sustainably?

How do we account for change and the fact that humans have caused change? How do we account for evolutionary impacts of our harvesting on each individual resource species? How do we account for the trophic level, body size or metabolic rate of humans? How does one account for broad temporal and spatial scales without forgetting (discounting or failing to consider) the finer resolution involved in consideration of individuals, molecules, elements, behavior, habitat heterogeneity, and energy dynamics? How do we account for species-level dynamics as involved in extinction and speciation?

Still other questions relate to distinction between human institutions and constructs in the context of the laws of nature. What role will economics play in decision making? How do we resolve difference in management advice stemming from different sciences (e.g., widely different quotas for harvests as suggested on the one hand by consideration of population dynamics and on the other through consideration of behavior, evolution or oceanography)? Does one form of science result in more reliable advice than another? How do we account for all the variety of sciences that might provide information of relevance to management (i.e., how do we avoid ignoring any of the relevant sciences)?

At this point, these questions are posed only as a sampling of questions important in the management process. There are many others. Some are provided with provisional answers in the pages ahead. Answers can be developed for most such questions; the means to develop answers are central to this book. There is then the matter of getting to implementation of what we learn in finding answers.

The species frequency distributions we have seen provide tantalizing insight into how other species serve as examples of sustainability. As will be seen in later chapters, Figure 1.3 relates to the question of what is a sustainable level of biomass removal (whether from an individual species, group of species, or ecosystem). However, before delving into the details, it is first necessary to develop important background. It is important to appreciate the variety among, and within, species frequency distributions and how they represent complexity. We need to understand how they are natural phenomena emergent from and reflective of complexity. Then we can proceed toward understanding how they serve as guidance for systemic management. We need to appreciate the limitations of such guidance given the extent of existing human influence. We can consider ways to deal with such problems. With this understanding we can then explore how species frequency distributions provide answers to questions such as many of those raised above.

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AFTER EDITING

INTRODUCING A METHODOLOGY AND AN EXAMPLE: SPECIES FREQUENCY DISTRIBUTIONS FOR THE BERING SEA

Systemic management as described in this book relies heavily on using empirical evidence from other species as guidance for human self-control. This section introduces the basic methodology of using probability distributions, in this case empirically derived species frequency distributions, drawing on examples from the Bering Sea ecosystem. The Bering Sea example is developed in each subsequent chapter to illustrate the potential for using systemic management to regulate human influence on ecosystems.

Figure 1.2 provides the foundation for systemic management. A probability distribution like the standard "bell shaped curve" shown in Figure 1.2 is a function (f) of all factors (e_i) that contribute to its formation. Therefore it integrates all elements regardless of their importance, including all their interactions and interrelationships. We don't need to know the e_i, or the function "f", to use the probability distribution as information that represents a complete, integrated consideration of all factors, with objective weights already applied by nature to account for their relative importance.

Graphs of species frequency distributions (Fowler and Perez 1999) are empirical probability distributions for various measures of species such as population size, trophic level, and mean adult body size. Species are concentrated in some parts of such distributions more than others. The means, modes, and medians of the distributions indicate central tendencies that characterize the group of species represented; they are characteristics of the group. The spread or dispersal of species across measures of a species-level characteristic reveals the variability among species, and the limits to that natural variation, shown as the tails on either side of the curve, and measured in terms of statistical confidence limits that are also characteristic of the group (Fowler and Hobbs 2002).

ILLUSTRATING THE METHODOLOGY

The species in ecosystems (geographic areas), or any other species assemblage, can be represented by species frequency distributions (Fowler and Perez 1999). The Bering Sea, used here as an example, is a marine ecosystem located north of the Aleutian Islands, between Russia on the west and mainland Alaska on the east. For our purposes, a subsection of the ecosystem, the eastern Bering Sea, is somewhat arbitrarily defined as the area east of a line from Attu Island (western Aleutian Islands) in the south to the center of the Bering Strait in the north (Perez and McAlister 1993, see map in Figure 1.3). The area and its history are described in various reports such as that of the National Research Council (1996).

The Bering Sea ecosystem has great value to humans. Recent commercial harvests of fish have taken millions of tons annually from a variety of resource species, and several species of marine mammals have been harvested intensively. Changes have been observed in the composition of fish species. Marine mammal populations have declined and one species, the Stellar sea cow, went extinct in recorded history. These and other impacts of human activities have generated a great deal of concern. Several species of marine mammals are subject to legal protection owing to their low numbers.

The species frequency distributions shown in Figure 1.4 for the eastern Bering Sea (based on Perez and McAlister 1993) characterize only one of the many facets of any ecosystem. This first example demonstrates variability among the population sizes of marine mammal species based on numbers of individuals in thousands (top panel, and $\log_{10}$ raw numbers bottom panel), averaged over seasons. Figure 1.4 also demonstrates limits to the natural variation in population size among species, especially as exhibited in the lower panel. Limits are illustrated by the lack of observations either side of the main collection of observed values (Fowler and Hobbs 2002).

Figure 1.5 shows a different form of variability, with its own limits. It involves the same set of 20 marine mammal species as represented in Figure 1.4 . In this case, we see the biomass consumed annually by the populations of these species. This graph also shows a spectrum of options for expressing measures of consumption. In this graph, consumption is represented from individual species (pollock, top row), finfish (a group of species, second row), and the entire eastern Bering Sea (an ecosystem, bottom row). It demonstrates two modes of presentation (raw measures, and log transformed values), and gives measures of consumption rates by humans (harvests, in the right column) for comparison.

Fowler and Hobbs (2002) argue that a critical part of systemic management is to comply with Management Tenet 5, to fall within the normal range of natural variation. This is parallel to action taken to ensure that characteristics such as body temperature, blood pressure, food consumption, and heart rate fall within the normal range of natural variation in the practice of medicine in dealing with individuals. Doing so for the harvests of fish would mean reducing takes to within the normal range of natural variation in takes by other species. We begin to see the extent of both problems and needed change: there are orders of magnitude in the differences between consumption rates by humans and the mean of consumption rates among other species. This challenge is further complicated by the need to comply with other management tenets, as illustrated in the chapters ahead.

For example, anthropogenic influence on the non-human species may have resulted in exaggerated measures of human abnormality. There may be less bias in data for systems prior to extreme human influence, and such systems may serve better as a basis for finding a benchmark for "sustainable" levels of yield for a system free of abnormal human impacts. In this example, the biomass of cetaceans in the entire Bering Sea ecosystem in the 1980s/1990s was estimated to be about 20% of levels found there in the mid-1940s (Sobolevsky and Mathisen 1996, Fig. 1.6). The same study determined that corresponding declines in population numbers (total for all cetaceans) resulted in populations in the 1990s that were about 64% of earlier levels. The most significant changes in the Bering Sea involve the extinction of the Stellar sea cow and marked reductions in Sei and Blue Whales (the latter assumed to be represented by only small numbers of individuals in Fig. 1.6). Figure 1.6 exemplifies changes in size (population size) composition, and increases in variation similar to changes observed in other ecosystems. These kinds of changes have to be part of what we take into account if we are going to use other species as empirical examples of sustainability to adhere to Management Tenet 5. Estimates of consumption rates based on data from the 1940s would clearly serve as a better frame of reference for harvests from an undisturbed system than those for the ecosystem subjected to the abnormal human influence shown in Figure 1.5 (which may better reflect what is needed in order for the system to regain its health).

ANSWERING MANAGEMENT QUESTIONS

Management applied to ecosystems requires the ability to answer specific questions. For example, questions of sustainability include:

- How much biomass can sustainably be removed by humans from an ecosystem such as the Bering Sea?
- How many species can sustainably be harvested as resources? What is the appropriate allocation of biomass removal over the various trophic levels within an ecosystem (what portion of the harvested biomass would come from each trophic level)?
- How much biomass (or how many individual organisms) can sustainably be harvested from any particular resource species' population?
- What fraction of the standing-stock biomass (or numbers) of any particular species can be harvested sustainably?
- How many humans can live within an ecosystem sustainably?

Other questions relate to accounting for complexity in different ways.

- How do we account for change and the fact that humans have caused change?
- How do we account for evolutionary impacts of our harvesting on each individual resource species?
- How do we account for the trophic level, body size, or metabolic rate of humans?
- How do we account for broad temporal and spatial scales without forgetting (discounting or failing to consider) the finer resolution involved in consideration of individuals, molecules, elements, behavior, habitat heterogeneity, and energy dynamics?
- How do we account for species-level dynamics like that involved in extinction and speciation?

Still other questions relate to distinguishing between human institutions and constructs in the context of the laws of nature:

- What role does economics play in decision making?
- How do we resolve difference in management advice stemming from different sciences? (For example, widely different quotas for harvests are suggested from the perspectives of population dynamics, behavior, evolution, and oceanography.)
- Does one form of science result in more reliable advice than another?
- How do we avoid ignoring or discounting any of the relevant sciences that might provide information of relevance to management?

These are only a few among many of the questions important in management. Further questions will be posed in subsequent chapters. Within systemic management, most such questions can be answered, and those that can't be answered are clearly identified. Very often the dilemmas they raise can be solved, in applying systemic management. Some questions are answered provisionally in subsequent chapters, and the means to develop clear answers are central to this book. The next step is, of course, implementing what we learn from the answers.

The sample species frequency distributions presented for the Bering Sea provide tantalizing insight into how other species maintain sustainable levels of consumption. As will be seen in later chapters, Figure 1.5 relates to the question of what is a sustainable level of biomass removal, whether from an individual species, group of species, or ecosystem. However, before delving into the details of application, it is first necessary to develop background. It is important to appreciate the variety among, and within, species frequency distributions and how they represent complexity (further consideration of what Figure 1.2 means). We need to understand how they are natural phenomena that emerge from and reflect complexity. Then we can proceed toward understanding how they serve as guidance for systemic management. We need to appreciate the limitations of such guidance, given the extent of existing human influence, and we can consider ways to deal with such problems. With this understanding we can then explore how species frequency distributions provide answers to questions such as many of those raised above, as well as ways to chose appropriate sets of species to be most informative.