QERM 2004 Applied Exam

We Otter Do Well on This Exam

INSTRUCTIONS
QERM Applied Qualifying Exam
Spring Quarter 2004 (June 16 – June 21, 2004)

This packet should contain:

1. This cover sheet
2. Examination
3. Hard copy of dataset. Joanne will also e-mail the dataset to you. Please check and make sure that you receive this dataset and contact her ASAP if you have difficulty opening the dataset.

INSTRUCTIONS:

1. Provide a 1-2 page summary at the very beginning of your examination.
2. Clearly describe in your text the points that diagrams and tables demonstrate.
3. All graphs should be labeled clearly and computer output annotated as need be.
4. Appendices should be numbered so that any references to the Appendix refer to a particular set of pages.
5. Number each page of the exam.
6. A unique identification number is located at the top of this instruction sheet. This identification number must be clearly marked on **EVERY** page of the examination. **DO NOT INCLUDE YOUR NAME on the examination.**
7. If you print any pages in color please provide 4 copies of each colored sheet. If using only back print, 1 copy of the exam is sufficient.
8. Completed examinations must be returned to the QERM office (Loew 304) by 10:00 a.m. on Monday, June 21. If you turn it in early please leave it in Joanne's Loew 304 mailbox.

LIBRARY HOURS:

****REMEMBER**** libraries may be **CLOSED** Saturday and Sunday, June 19-20, so any reference materials you might need should be checked out before then.

QUESTIONS?

Dr. Conquest should be contacted if there are any questions on the statistical portion of the exam. Her office phone is 221-7966, home phone number 206-325-7237. She can be reached by e-mail at conquest@u.washington.edu .

Questions regarding the modeling portion of the exam may be directed to Mark Kot at kot@amath.washington.edu.

Joanne will be in the office on Wednesday, Thursday and Monday from 9:00 a.m. to 2:00 p.m. Feel free to e-mail her at jbesch@u.washington.edu or call her at home, 206-525-2414.

Good luck!

1. Background

In 1960, Hairston, Smith, and Slobodkin (HSS) argued that the world is green because predators control herbivore populations. Predators, in other words, prevent herbivores from overexploiting plant populations. In 1977, Fretwell extended the basic ideas of HSS to food webs that have different numbers of trophic levels: In a two-level web, herbivores are free of predators and can overexploit their food plants. In a three-level web, herbivores are regulated by their predators and cannot overexploit their food plants. In a four-level web, the top predator regulates the predator on the third level that would otherwise limit herbivore populations, and so on.

Sea otters (*Enhydra lutris*), sea urchins, and kelp forests provided early support for the HSS hypothesis. The Pacific maritime fur trade eliminated sea otters from a number of Aleutian islands. Islands with abundant sea otters had few sea urchins and well-developed kelp forests. Islands lacking sea otters had abundant sea urchins and depauperate kelp forests.

During the 1990s, the abundance of sea otters in the west-central Aleutian Islands declined by 80–90%. The declines were apparently the result of increased predation by killer whales. (Killer whales probably switched to sea otters following the collapse of Stellar sea lion and harbor seal populations in western Alaska during the 1970s and 1980s.) Following this decline in sea otters, sea urchin populations increased, leading to the deforestation of many kelp communities.

Question

Assume that kelp grow logistically in the absence of sea urchin. Write down *simple* kelp–urchin and kelp–urchin–otter food-chain models. (I am assuming that these will be systems of differential equations.) Determine the equilibria (or any other attractors) for your two food-chain models. Are the values of your equilibria consistent with the HSS hypothesis ? (You will need to make reasonable inferences about the parameters in your models to answer this question.) How would you expect the length of a food chain to affect the stability of equilibria ? Determine and compare the stability of the equilibria for your two models.

(If time and enthusiasm permit, answer the same questions for a more realistic 3-species food chain, e.g., for one with more realistic functional responses, and/or for a 4-species kelp–urchin–otter–killer whale model. Do not consider doing this, however, until you have done a good job on the rest of the exam.)

2. Background

Bering's 1741 discovery of abundant sea otter (*Enhydra lutris*) populations heralded 170 years of commercial sea otter harvesting. During this period, sea otter populations declined from some 300,000 individuals to 1,000–2,000 individuals. In 1911, sea otters gained legal protection as the result of the Fur Seal Treaty between the United States, Russia, Japan, and Great Britain. At the time of the signing of this treaty, the southern subspecies of the sea otter, the California sea otter (*E. l. nereis*), was thought to be extinct.

In 1914, a small population of 50–100 California sea otters was discovered near Point Sur, just south of Monterey, on the central California coast. The presence of this population did not become general knowledge until 1938. This population slowly increased in number and range up until the mid-1970s. The mid-1970s and early 1980s was a period of decline, due in large part to increased losses in a coastal set net fishery. (During this time, the estimated annual take in gill and trammel nets was 80 sea otters.) After the implementation of protective measures, the population quickly began to grow again. However, since the mid-1990s, the California sea otter population has once again been in (slow) decline. The reasons for this most recent decline are unknown, but may include increased pollution and disease, accidental losses in fishing gear, and food resource limitation. The estimated abundance of California sea otters in 2003 was 2,500.

The California sea otter was listed as "threatened" in 1977 under the Endangered Species Act. It retains this status because of its small population size, limited range, and susceptibility to catastrophic oil spills.

Data

The following table outlines some early data on the spatial spread and population size of California sea otters after their rediscovery. Although the sea otter is a marine mammal, it rarely ventures more than 1 km from shore. So, the spatial spread can be thought of as linear (up and down the coast). The habitat along the California coast is not uniform. It is known, for example, that otters, between 1972 and 1973, reached sandy or soft-bottomed habitat (in both the north and south) that is structurally different from the preferred rocky, subtidal, kelp-forest habitat that lies continuously between the Seaside area in the north to Point Cayucos in the south. Currents may or may not be a factor.

Range Expansion (in km) and Population Size
of the California Sea Otter
(see below for explanation of data)

	Northern Range		Southern Range			
Year	Increase	Length	Increase	Length	Total Range	Population Size
1914	NA	NA	NA	NA	11	50
1938	11	11	21	21	43	310
1947	08	19	23	44	74	530
1950	02	21	13	57	89	660
1955	03	24	16	73	108	800
1957	11	35	06	79	125	880
1959	06	41	06	85	137	1050
1963	05	46	10	95	152	1190
1966	00	46	06	101	158	1260
1969	06	52	13	114	177	1390
1972	00	52	15	129	192	1530
1973	23	75	29	158	244	1720
1974	06	81	05	163	255	1730
1975	08	89	00	163	263	NA
1976	10	99	06	169	279	1789
1977	08	107	06	175	293	NA
1978	00	107	00	175	293	NA
1979	00	107	06	181	299	1443
1980	00	107	13	194	312	NA
1982	00	107	00	194	312	1338
1983	26	133	15	209	353	1226
1984	00	133	00	209	353	1203
1986	NA	NA	NA	NA	NA	1400

The extent of the range is determined by the linear distances along the coastline between the outermost main raft of otters at the population boundaries. Point Sur was used as the location of the division between the northern and southern populations. The total estimated population size was based on aerial and shore counts.

Question A

Use appropriate statistical analysis to investigate the spatial spread of the sea otters for the total range, the northern front, and the southern front. Discuss your results. For example, what can you say about the rate of northern spread vs. that of southern spread? Relate your results to the information given regarding the habitat along the California coast.

Question B

Write down and analyze simple models for the spatial spread of the California sea otter that are consistent with the above data. You might want to write down several models, with the first model being overly simplistic, but easy to analyze and the last model being more realistic, but hard (or impossible) to analyze. Feel free to include whatever factors (population growth, diffusion, advection, etc.) you feel are important.