1-1-2018

Parrots and Palms: Analyzing Data to Determine Best Management Strategies and Sustainable Harvest Levels

James P. Gibbs
State University of New York College of Environmental Science and Forestry

J. Michelle Cawthorn
Georgia Southern University, mcawthor@georgiasouthern.edu

Adriana Bravo
American Museum of Natural History

Ana L. Porzecanski
American University of Natural History, alporze@amnh.org

Recommended Citation

Gibbs, James P., J. Michelle Cawthorn, Adriana Bravo, Ana L. Porzecanski. 2018. "Parrots and Palms: Analyzing Data to Determine Best Management Strategies and Sustainable Harvest Levels." *Lessons in Conservation*, 8 (1): 21-28. source: https://www.amnh.org/our-research/center-for-biodiversity-conservation/resources-and-publications/lessons-in-conservation/lessons-in-conservation-volume-viii
https://digitalcommons.georgiasouthern.edu/biology-facpubs/115

American Museum of Natural History
Center for Biodiversity and Conservation
Network of Conservation Educators & Practitioners

Parrots and Palms: Analyzing Data to Determine Best Management Strategies and Sustainable Harvest Levels

Author(s): James P. Gibbs
Adapted by: Michelle Cawthorn, Adriana Bravo, and Ana L. Porzecanski

Source: *Lessons in Conservation*, Vol. 8, Issue 1, pp. 22–29

Published by: Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History

Stable URL: ncep.amnh.org/linc/

Parrots and Palms: Analyzing Data to Determine Best Management Strategies and Sustainable Harvest Levels

James P. Gibbs[1]
Adapted by Michelle Cawthorn,[2] Adriana Bravo,[3] and Ana L. Porzecanski[3]
[1]State University of New York College of Environmental Science and Forestry, Syracuse, NY, USA; [2]Georgia Southern University, Statesboro, GA, USA; [3]American Museum of Natural History, New York, NY, USA

ABSTRACT
This exercise[1] presents a scenario and raw data on a realistic conflict between parrot conservation and palm tree harvest. It requires that students analyze data very comparable to what would be gathered in the field, to: 1) construct a life tables for the palm and parrot, 2) extract vital statistics about both the palm and parrot population from the life tables, 3) estimate maximum sustainable yield for both species, and 4) make a decision about the sustainability of harvest intensity. It illustrates the importance of data analysis skills for conservation.

1. PART 1. INTRODUCTION

1.1. Objectives

Debates in conservation often focus on population management issues. For example, how do we reverse declines in endangered species, or harvest, in a sustainable way, populations of abundant species? Any population undergoes changes through time that are determined by interactions between age-specific mortality (death) and fecundity (birth) rates and the numbers of individuals of different ages. A first step toward understanding these processes is to use life table analysis to calculate the population's vital statistics. The analysis of demographic data can provide many insights into the population's behavior, and into management options for that population.

This exercise aims to provide you with an introduction to *applied demographic analysis*.[2] We examine a scenario involving parrots and harvesting of the trees they require for nesting. Our objectives are to: 1) evaluate different strategies for sustainable harvesting of parrots for the pet trade, and 2) balance sustained yield for trees and parrots simultaneously. The exercise is intended to provide you with first-hand experience analyzing the type of population data typically gathered by field biologists within a realistic context. That context is one in which conservation biologists are struggling to find a balance between parrot conservation and harvest for the pet trade as well as timber harvest and the incidental loss of nesting trees for the parrots.

1.3. Background

This scenario is contrived but matches closely many details of real parrot populations as well as situations affecting parrot conservation, that is, harvest for the pet trade and loss of vital nest trees due to timber harvest (Figure 1). Consider a hypothetical species of small parrot that *matures at age three and then breeds at a modest level (two or three chicks per year) for approximately three years*. The parrot is much sought after for sale in the pet trade. Adults can be harvested directly through netting outside the nesting season or nestlings can be removed from nest trees and reared by hand. These parrots only nest in holes in a particular species of palm that is sought after by humans as a source of building material and thatch. Parrot nests are fairly inconspicuous and the harvesting of palms is done without knowledge of where the parrots nest. It also occurs during the dry season, which happens to be the nesting season of the parrots. Thus, some of the palms felled incidentally kill young parrots in nests as well as the attending female.

We are concerned with a 10,000 km² community forest.

[1] For advanced student version of this exercise, see *Applied Demography: Parrots and Palms* found at ncep.amnh.org.
[2] For more background reading, refer to *Applied Demography* found at ncep.amnh.org.

*Figure 1. Red-bellied macaws (*Orthopsittaca manilata*) on a dead Buriti palm tree (*Mauritia flexuosa*). Image: Ltoniolo (own work) via Wikimedia Commons, [CC BY-SA 4.0].*

Palm density is 100 per km^2, although under the best of conditions at *carrying capacity* (*K*) they can be twice as abundant. The parrots typically occur at a density of 1 parrot (of all ages) per 10 km^2; again, K is double the typical density (*K = 2 parrots/10 km^2*). During palm harvest, every thousandth palm felled will, on average, destroy a nest and the attending pair of adult parrots.

Based on this scenario, the exercise tackles three questions:

1. How many young can be sustainably removed from the parrot population each year?
2. What is the maximum sustained yield of the palm?
3. Given that some parrot mortality occurs incidentally to palm harvest, is managing palms at their optimal yield level acceptable in terms of maintaining the parrot population?

2. PART 2: DATA

2.1. Observations from the Field

The following data (Tables 1, 2) are collected from an unharvested population of parrots. Table 1 lists longevity data from a cohort of 91 females. The data are only from females because reproductive output in males is difficult to measure. We will assume that life table estimates for females also apply to males. The longevity data are the age at death (in years) of a sample cohort member. For example, #16 at 0.1 years represents individual #16 that died at age 0.1 years (or about 1 month).

In Part 3 of this exercise, you will use these data to determine the number of individuals that survived to each age, starting with age 0.

The next set of data (Table 2) describes the maternity (birth rate/fecundity) rates in the parrot population. The data were collected from a representative sample of females in the population. Biologists climbed nest trees of known-aged females and determined how many young they produced. Each individual is just one sample of the reproductive output of a female of a particular age. You will note from the data that *reproductive maturity is reached at age 3 years and senescence sets in by age 6 years*. The maternity data correspond to the number of female offspring produced by females of a particular age. For example, 3 at 5 years indicates that 3 female offspring were produced by this 5-year-old female. Using these data you will calculate the average maternity rate for females of a given age.

3. PART 3: DATA ANALYSIS

3.1. Construct the Life Table

Now construct a life table (see Table 8) for this population so that you can determine the: 1) survivorship values, 2) survival rates, 3) mortality rates, 4) maternity rates, and 5) population growth rates.

The first step is to determine the number of females alive (*N*) at the beginning of each time interval *x* (*Nx*). N_0 is the total number initially present in the cohort, or 91. For the subsequent time intervals, determine the number of females still alive from the longevity data provided above. The easiest way to do this is to tally the number of individuals that died at each age. Then make a cumulative summation from the oldest age class upward to the youngest. This will provide you with each

Table 1. Longevity data (in years) for individual parrots.

INDIVIDUAL NUMBER	AGE AT DEATH (YEARS)
46	0.1
16	0.1
82	0.1
20	0.1
22	0.1
55	0.1
91	0.1
64	0.1
66	0.1
10	0.2
43	0.2
45	0.2
56	0.2
62	0.2
18	0.3
85	0.3
60	0.3
52	0.4
32	0.4
68	0.7
36	0.7
75	0.7
50	0.7
4	0.9
48	0.9
59	0.9
33	0.9
71	1
9	1
11	1
78	1
13	1
53	1
89	1
57	1
70	1.2
14	1.2
23	1.2
25	1.2
31	1.2
8	1.4
28	1.6
27	1.9
44	2
19	2
40	2.2
12	2.2
81	2.2
54	2.2
87	2.2
65	2.2
5	2.3
41	2.4
63	2.4
39	2.7
37	2.9
24	3
58	3
7	3.2
76	3.2
90	3.2
34	3.3
74	3.3
49	3.3
6	3.7
73	3.9
72	4
42	4
17	4.1
1	4.2
88	4.4
61	4.7
2	5
35	5
3	5
47	5
80	5
26	5
51	5.2
86	5.7
29	5.7
15	6
79	6.2
21	6.4
30	6.8
84	6.9
83	7
38	7.3
77	7.4
69	7.6
67	8.8

of the *Nx* values, with N_0 = 91 as noted earlier. So, if the last individual died at age 8, then N_8 = or number of females alive at age 8 = 1, if 4 others died at age 7, then N_7 = 4 + 1 = 5, if 5 others died at age 6, then N_6 = 5 + 4 + 1 = 10, etc. (See Table 3).

Survivorship values are denoted by the symbol l_x and are the proportion of individuals born who survive to an age *x*. The zeroth survivorship l_0 is defined to be 1 (all individuals born are alive). Thereafter the survivorship values get smaller until they reach zero at the maximum age. So, survivorship at any age *x* is simply the proportion of the 91 individuals born that are still alive at that age. So, given the example N_x values above, l_8 = N_8/N_0 =

Table 2. Number of female offspring produced by females of a particular age (in years), from a sample of 25 females.

OFFSPRING	AGE (YEARS)
2	3
0	4
1	5
1	3
1	4
2	3
3	3
4	4
4	4
3	5
3	3
3	4
6	4
0	5
0	3
1	4
2	3
2	3
3	3
3	5
3	4
4	5
4	4
3	3
3	5

1/91 = 0.011, $l_7 = N_7/N_0$ = 5/91 = 0.055, etc. Calculate survivorship values using your data from Table 3 and fill out Table 4. When you are finished, transfer your answers to the corresponding column in Table 8.

Organisms that survive until later in life and then succumb to age-related mortality have a *Type I survivorship curve*. For example, larger mammals, such as whales, bears, and elephants, have Type I survivorship curves. Some organisms have relatively constant survivorship throughout their life. Most reptiles, for example, fall in this category. This steady decline typifies

Table 3. Calculate the number of females alive at each time interval by using the data given above to fill in the blanks. Transfer your answers to the corresponding column in Table 8.

TIME INTERVAL	NUMBER OF INDIVIDUALS DYING IN EACH TIME INTERVAL	N_x
N_0		91
N_1		
N_2		
N_3		
N_4		
N_5		
N_6	5 + 4 + 1	
N_7	4 + 1	5
N_8	1	1

a *Type II survivorship curve*. On the other extreme are organisms such as insects and many fish with little or no parental care and vulnerable young. In these organisms, a *Type III survivorship curve* declines quickly with age owing to high mortality in the younger age classes and lower mortality in older animals (Gotelli 2008). These survivorship curves are illustrated in Figure 2. In the case of this figure, for example, 50 percent of the organism born into a population with a *Type II survivorship curve* lived to year 10.

3.2. Constructing a Survivorship Curve for Parrots

Now, using the values you calculated in Table 4, create a graph that depicts survivorship. The y-axis values are l_x and are presented on a logarithmic scale.

1. What variable will go on the x-axis?
2. Draw your graph, label axes x and y, and add a caption in the space provided in Figure 3.
3. Does the shape of the curve most approximate a Type I, Type II, or Type III survivorship curve, and why?

Survival rates, s_x, are the proportion of individuals alive at age *x* that will survive to age *x* + 1. The survival rate of age *x* is equal to the quotient of $l_x + 1/l_x$. Because survivorship values decrease with age, survival rates will always range from 0 to 1. So, given the sample l_x values above, s_7 = 0.011/0.055 = 0.2, etc. Calculate survival

Figure 2. Types I, II, and III of survivorship curves within a population. Survivorship is the fraction of newborns living to a particular time.

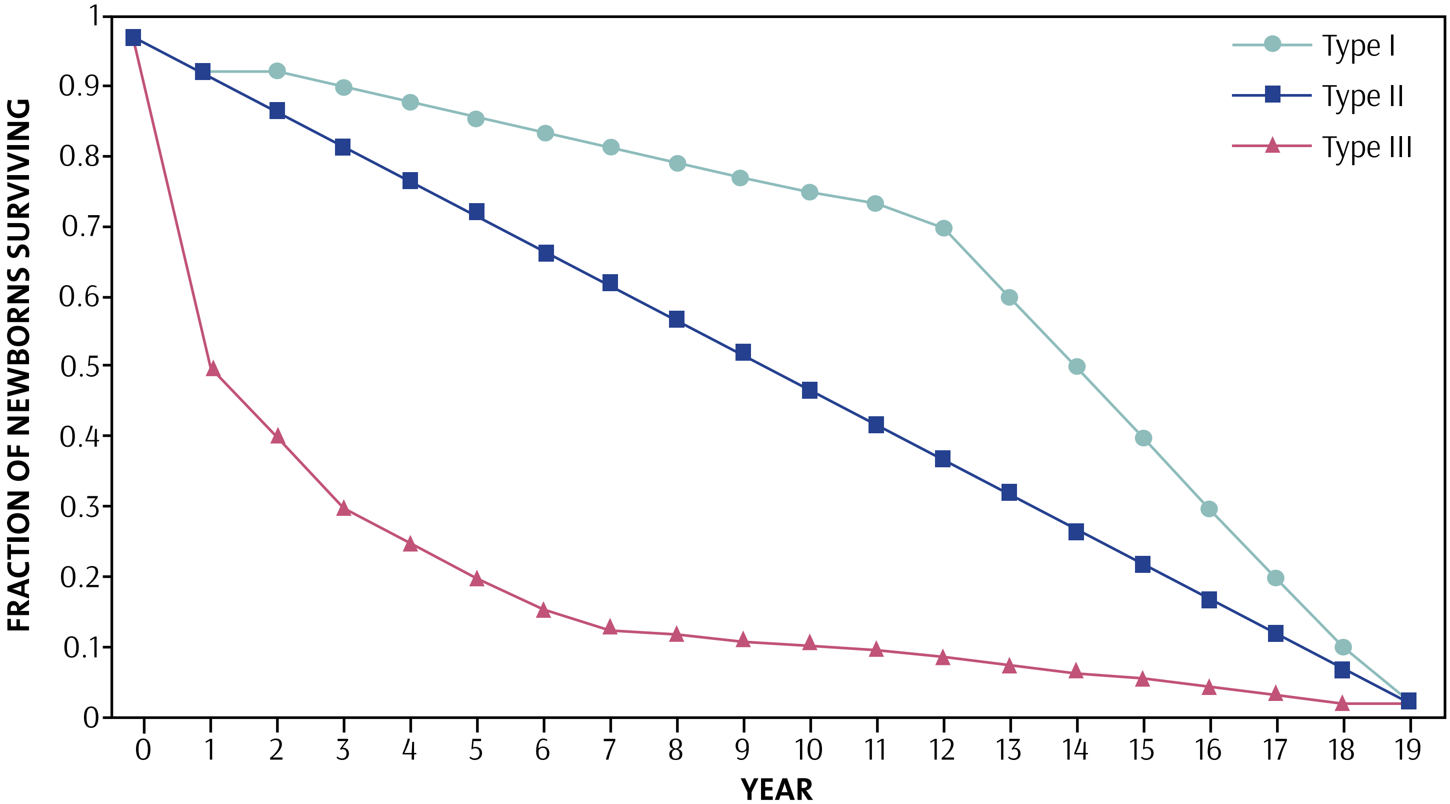
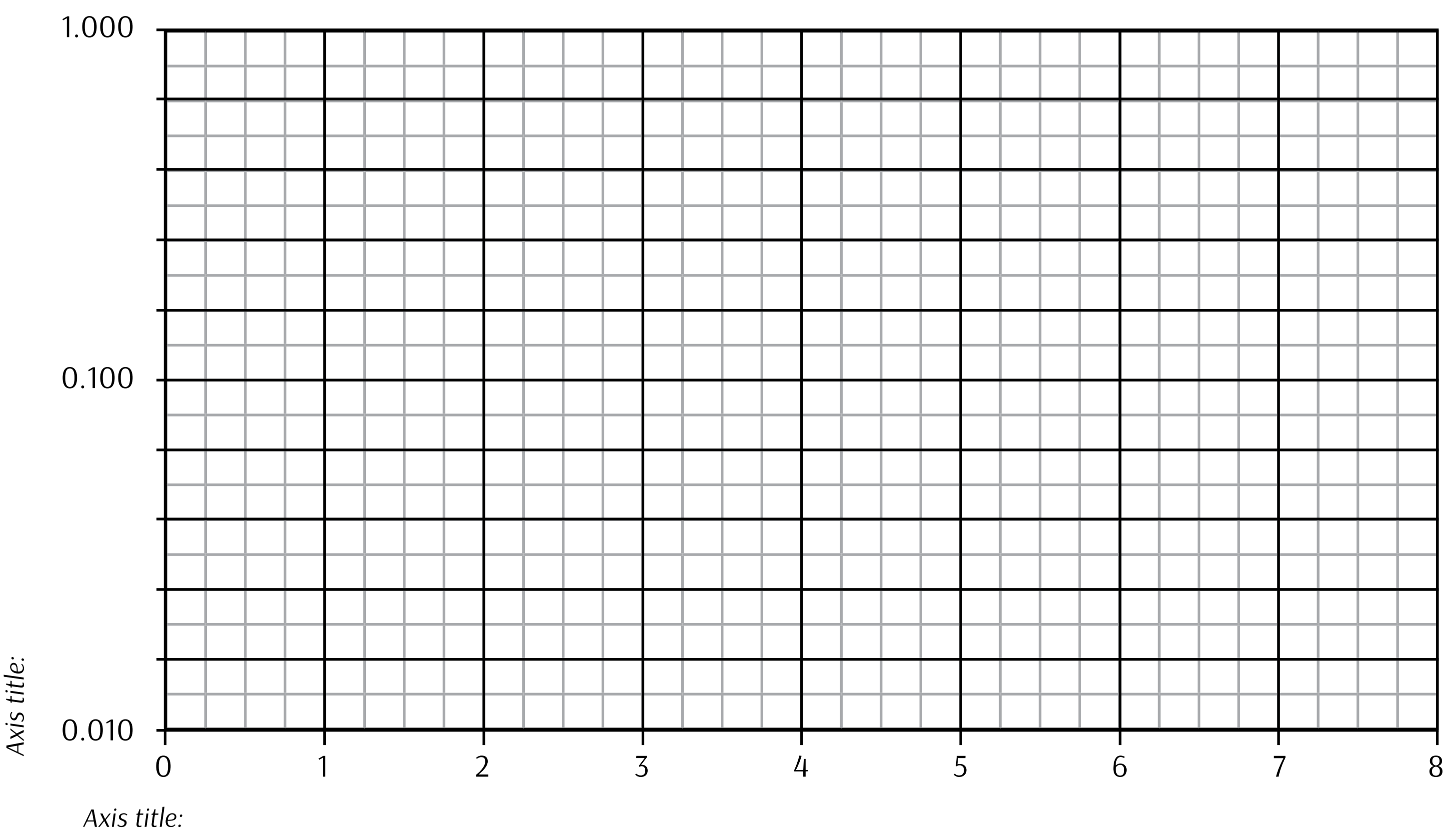


Figure 3. Caption:



rates using your data from Table 4 and fill out Table 5. When you are finished, transfer your answers to the corresponding column in Table 8.

Mortality rates, d_x, are the proportion of individuals alive at age x that will die before age $x + 1$. These are the reverse of survival rate values, so for any age x, $d_x = 1 - s_x$. Calculate mortality rates using your data from Table 5. and fill out Table 6. When you are finished, transfer your answers to the corresponding column in Table 8.

The *maternity rate*, m_x, is the number of individuals produced per unit time per individual of a given age. It is usually calculated for females only in a female-based life table such as this, that is, as daughters per mother. For age class 5, 6 individuals had 14 female offspring, so 14/6 = 2.33. Calculate maternity rates using the data provided in Table 2 and fill out Table 7. When you are finished, transfer your answers to the corresponding column in Table 8.

4. Why are there no data for age classes 1 and 2, or 6, 7 and 8 (in Table 7)?

Table 4. Calculate survivorship values using your data from Table 3. When you are finished, transfer your answers to the corresponding column in Table 8.

SURVIVORSHIP VALUES	$l_x = N_x / N_0$	l_x
l_0	91 / 91	
l_1		
l_2		
l_3		
l_4		
l_5		
l_6	10/91	
l_7	5/91	
l_8	1/91	0.011

Table 5. Calculate survival rates using your data from Table 4. When you are finished, transfer your answers to the corresponding column in Table 8.

SURVIVAL RATES	$s_x = l_{x+1} / l_x$	s_x
s_0		
s_1		
s_2		
s_3		
s_4		
s_5		
s_6	0.055/	
s_7	0.011/0.055	0.2

Table 6. Calculate mortality rates using your data from Table 5. When you are finished, transfer your answers to the corresponding column in Table 8.

MORTALITY RATES	$d_x = 1 - s_x$	d_x
d_0		
d_1		
d_2		
d_3		
d_4		
d_5		
d_6		
d_7	1 - 0.2	
d_8	1 - 0	1

Table 7. Calculate maternity rates using the data provided in Table 2. When you are finished, transfer your answers to the corresponding column in Table 8.

MATERNITY RATES	m_x PER INDIVIDUAL	m_x AVERAGE PER AGE CLASS
m_0		
m_1		
m_2		
m_3		
m_4		
m_5	(1+3+0+3+4+3)/6	2.333
m_6		
m_7		
m_8		

Table 8. Life table for parrots using data provided in Tables 1 and 2. The last two columns will be useful for the calculations in the rest of the exercise (see below).

x	N_x	l_x	s_x	d_x	m_x	l_xm_x	xl_xm_x
0	91						
1							
2							
3							
4							4 x 0.794 =
5			0.526	0.474	2.333	0.209 x 2.333 =	
6							
7	5						
8	1	0.011	0	1			

3.3. Calculate Vital Statistics for the Population

From the life table you have constructed (Table 8), one can calculate some useful statistics for the population. The first such statistic is the net reproductive rate, which is a measure of the productivity of a population:

R_0 Net reproductive rate = average number of female offspring that will be produced per female during her lifespan

$= \sum l_x m_x / l_0$, or $\sum l_x m_x$ when $l_0 = 1$

This is calculated by summing the products of the age-specific survivorship and maternity values in the life table. Simply multiply the values of l_x and m_x across the age classes (rows of the life table) and then sum these products over the various age classes. The sum will equal the net reproductive rate for the population.

5. What is the net reproductive rate of this parrot population? Show your calculations.

A second useful statistic is the generation time. Generation time is the time elapsed between the birth of an individual and the birth of its offspring.

G Mean generation time = average time between the birth of females and the birth of their female offspring

$= (\sum x l_x m_x)/R_0$

6. What is the mean generation time of this parrot population? Show your calculations.

A third useful statistic is the intrinsic rate of increase. An approximation of this rate is:

$r_{estimate}$ the intrinsic rate of increase, which is in essence the natural log of the net reproductive rate adjusted for generation length to provide a measure of population growth per unit of time

$= \ln(R_0)/G$.

7. What is the estimate of r? Show your calculations.
8. Does the population appear to be increasing or decreasing? How do you know?

4. PART 4: EVALUATING A HARVEST STRATEGY FOR PARROTS AND PALMS

4.1. Parrots

Now you can calculate the *maximum sustained yield (MSY)* for this parrot population using the following equation:

MSY the highest harvesting rate of individuals from a population that will not reduce its population size

$= r_{est}(K/4)$

K is the size of the population when it is unharvested, that is, at *carrying capacity*, and r_{est} is the intrinsic rate of increase.

Recall that the life table was for females but that there are males also in the population so *multiply your resulting maximum sustained yield figure by 2* (assuming equal sex ratios).

9. What is the maximum sustainable number of parrots that can be harvested each year from the entire forest? Show your calculations.

4.2. Palms

Compared to parrots, palms take longer to mature and have vastly higher maternity rates. Palms are monoecious (pollen and ovules produced on the same plant); like many tropical plants, their seeds are heavily predated once they fall to the ground and hence have very low germination rates. However, if seeds do germinate, the seedlings enjoy fairly high survival rates and most become reproductively mature by 15 years of age. Each palm produces approximately 1,000 flowers per year, most of which will develop into a one-seeded fruit. After approximately 10 reproductive years, the palms will succumb to trunk rot and die.

10. If R_0 = 47.3 and G = 19.30, what is r_{est} for this species?
11. What is the maximum sustainable number of palms that can be harvested each year from the entire forest? Show your calculations.

4.3. Balancing Palm Harvest Versus the Incidental Killing of Parrots

Now let's first evaluate whether harvesting palms at their optimal level can be tolerated by the parrot population, which is incidentally affected when palms felled inadvertently enclose nesting parrots. If the palm populations can be harvested in a sustainable manner at the same rate at which they can potentially grow, then what was the estimated maximum sustainable annual harvest rate for the palms? What was it for the parrots? Based on data originally given in the scenario, recall that the area is 10,000 km^2, that 10 km^2 hosts one parrot (of any age) and 1,000 palms, that felling every thousandth palm kills a nesting pair of parrots, and that carrying capacities for each species are twice their current densities. You now have all the information you need to address the questions at hand:

12. If the palm population is harvested at its maximum sustainable limit, will the parrot population be at risk? Please explain how you arrived at your conclusion and show any calculations used.
13. What annual harvest of palms would you recommend to maintain a healthy parrot population, and why?
14. Describe an alternative scenario that would change your answer for question 12 above. Explain.

REFERENCES

Gibbs, J. 2006. Applied Demography. Synthesis. Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History, New York, NY, USA. Available from http://ncep.amnh.org.

Gotelli, N.J. 2008. A Primer of Ecology. 4th edition. Sinauer Associates, Sunderland, MA, USA.