

**I. (20 pts) mathbioLibrary/setABioc2Labs/Lab122\_A3\_seagull.pg**

Because of the accuracy of WebWork, you should use 5 or 6 significant figures on this problem.

The class lecture notes examined the idea of optimal foraging by Northwestern crows (*Corvus caurinus*) on whelks (*Thais lamellosa*). A similar behavior of dropping butter clams (*Sacdonus giganteus*) for food is observed with the Glaucous-winged gull (*Larus glaucescens*) on the San Juan Islands [1]. As with the crows, the seagulls select clams from the intertidal zone, then fly back to an area with rocks, cement, or wood before dropping the clams to access the soft body parts. (Some gulls break the clams on the rocks while standing, but this foraging behavior is not explored in this problem.) The clams break open more readily than whelks from the data reported in the article [1]. In this question, you will reproduce some of the results in the notes to determine the optimal foraging strategy for Glaucous gulls.

a. Below is a table that simulates an experiment of dropping clams from different heights to determine how many drops are required to break open the clam. (The table was created on an interpretation of numbers cited in the article and does not reflect an actual experiment.) The average number of drops,  $N(H)$ , to open a clam as a function of the drop height,  $H$ , in meters is shown below.

$H(m)$	$N(H)$	$H(m)$	$N(H)$
0.5	13.37	4	1.64
1	3.81	5	1.43
1.5	2.59	6	1.28
2	2.15	10	1.2
3	1.91	15	1.08

As in the lecture notes, the proposed function to fit these data has the form

$$N(H) = 1 + \frac{a}{H-b}.$$

Use Excel's solver to find the least squares best fit the parameters  $a$  and  $b$  to these data. Give the value of the sum of squares error. Write the function  $N(H)$  with these parameters.

$a =$  \_\_\_\_\_

$b =$  \_\_\_\_\_

$SSE =$  \_\_\_\_\_

$N(H) =$  \_\_\_\_\_

Vertical Asymptote at  $H =$  \_\_\_\_\_

This function is (Increasing, Decreasing, or Neither) \_\_\_\_\_

Find the number of drops predicted by the model at  $H = 4$ .

$N(4) =$  \_\_\_\_\_

What is the percent error between this model and the experimental finding?

Percent Error = \_\_\_\_\_

b. In your Lab report, create a graph with both the data and  $N(H)$ . Create a dotted or dashed line to indicate any asymptotes (vertical and horizontal). Briefly describe the graph. State the significance of the vertical and horizontal asymptotes with regards to breaking open butter clams. State if this function is monotonic and what that implies about its derivative. Find the derivative (including a general  $a$  and  $b$ ) and determine the sign of the derivative for  $H \neq b$ . Can you explain why this particular functional form was chosen by the authors or could you suggest a better function?

c. The energy expended by a gull to open a clam is dependent on how high the bird flies times the number of drops that it takes to open the clam. Thus, the energy function has the form

$$E(H) = kH \left( 1 + \frac{a}{H-b} \right),$$

where  $k = 1$ .

Are there any horizontal asymptotes? (YES or NO) \_\_\_\_\_

If there is a horizontal asymptote, then what value of  $E$  is the asymptote?

$E =$  \_\_\_\_\_ (Write DOES NOT APPLY, if there isn't one.)

Are there any vertical asymptotes? (YES or NO) \_\_\_\_\_

If there is a vertical asymptote, then what value of  $H$  is the asymptote?

$H =$  \_\_\_\_\_ (Write DOES NOT APPLY, if there isn't one.)

Find the derivative of this function.

$E'(H) =$  \_\_\_\_\_

Determine the height which produces the minimum expenditure of energy.

$H_c =$  \_\_\_\_\_

If  $k = 1$ , then determine the value of  $E$  at the minimum energy.

$E(H_c) =$  \_\_\_\_\_

d. In your Lab Report, graph the energy function with your values of  $a$  and  $b$ , and  $k = 1$  letting  $H$  vary to a maximum of 5 m. Show clearly any asymptotes on your graph (using dotted or dashed lines). Also, add a point on your graph at the minimum and label that point. Write a brief description of the shape of this curve and discuss the optimal solution for a solitary bird.

Write a brief paragraph on *kleptoparasitism* and discuss how this concept relates to this problem. Include some attributes about gull behavior, especially how they feed in a group. The authors of the gull study [1] noted that the gulls usually flew about 4-7 m before dropping the clams, which you will notice is higher than the value you obtained in Part b. Thus, for some reason, the gulls choose to spend more energy flying higher to guarantee that the clams are more likely to break open on the

first drop. Write a brief explanation for why the birds might choose this strategy. Comment on how kleptoparasitism might affect the energy function that should be used in determining calories gained from a broken clam. (The gull only benefits from the energy spent dropping the clam if it eats the clam.) You should also reason why the gulls might not go even higher to better guarantee that the clam dropped opens.

1;

[1] D. P. Barash, P. Donovan, and R. Myrick, Clam dropping of the Glaucous-winged gull (*Larus glaucescens*) (1975), *Wilson Bull.* (87) p.60-64.