DEPARTMENT:

Mathematics

FACULTY SPONSOR:

Dr. Philip Gustafson

STUDENT(S):

Lew Griffith

PROJECT TITLE:

Modeling Hunting Energy Expenditure

Modeling Hunting Energy Expenditure

By Lew Griffith

Mentor: Phil Gustafson, PhD

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Introduction

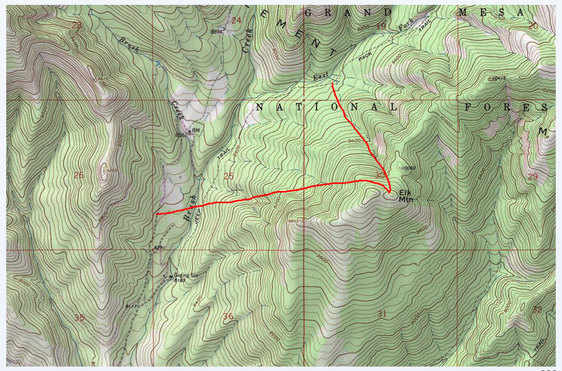
Having the energy and supplies to get from one point and back is important to hikers and hunters alike. How far can they hike so that they can still get back to their base camp with their bagged animal? In this project, we will seek to find the answer in order to help hunters know their limits and maximize the enjoyment of their exertions.

Objective

Model energy expenditure and hiking speed for a hunt on Elk Mountain, which is north of Collbran, CO. The models reflect a hunter whose weight with their gear is 260 lbs. Models were also needed to expand the hiking data from the Pikes Peak Project of CMU's Mathematical Modeling class.

Hunting Route

The proposed hiking route for the hunt will be from Brush Creek Rd. up to the top of Elk Mountain, then downhill to the jeep trail located on the north side of the mountain.



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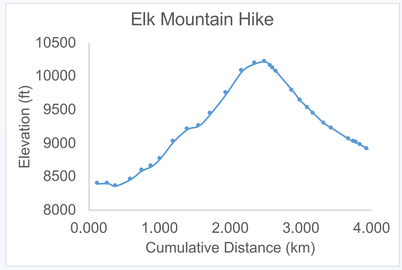
Note that this does not consider the thickness of the vegetation or the presence of game trails. Once an animal is killed, it is then time to hike down the mountain with the meat/animal.

Data: Elevation, Energy and Speed

Elevation data obtained from CMU Geology TOPO! Program [2]. Thirty waypoints divide the 3.943 km hike into trail segments.



Pike's Peak Project [1] gives kcal/km and km/hr data for hikers of different weights.

Table 1: Table of kcal/km by different weights of subject and angles of inclination

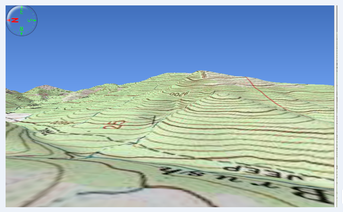
	0	3	6	9	12	15	18	21	24	27	30
100 lbs	52.08	76.92	108.53	144.63	183.70	225.01	268.34	313.73	361.36	411.54	464.69
120 lbs	56.78	86.69	125.06	168.72	215.73	265.26	317.09	371.28	428.09	487.91	551.22
140 lbs	61.65	97.40	143.55	195.82	251.84	310.68	372.11	436.26	503.44	574.13	648.91
160 lbs	66.74	109.18	164.27	226.37	292.61	361.98	434.29	509.68	588.59	671.57	759.31
180 lbs	72.07	122.26	187.66	260.98	338.86	420.21	504.86	593.04	685.26	782.19	884.65
200 lbs	77.73	136.90	214.25	300.48	391.69	486.74	585.50	688.30	795.74	908.62	1027.91
220 lbs	83.77	153.48	244.78	345.95	452.56	563.41	678.45	798.09	923.08	1054.34	1193.02

Table 2: Table of km/hr by different weights of subject and angles of inclination

	0	3	6	9	12	15	18	21	24	27	30
100 lbs	5.50	3.73	2.64	1.98	1.56	1.27	1.07	0.91	0.79	0.70	0.62
120 lbs	5.05	3.31	2.29	1.70	1.33	1.08	0.90	0.77	0.67	0.59	0.52
140 lbs	4.65	2.94	2.00	1.46	1.14	0.92	0.77	0.66	0.57	0.50	0.44
160 lbs	4.30	2.63	1.75	1.27	0.98	0.79	0.66	0.56	0.49	0.43	0.38
180 lbs	3.98	2.34	1.53	1.10	0.85	0.68	0.57	0.48	0.42	0.37	0.32
200 lbs	3.69	2.09	1.34	0.95	0.73	0.59	0.49	0.42	0.36	0.32	0.28
220 lbs	3.42	1.87	1.17	0.83	0.63	0.51	0.42	0.36	0.31	0.27	0.24

Assumptions

- Uphill hiking speed approximately equal to downhill hiking speed.
- Hunter is well-fed and hydrated before hunt in order to reduce supplies needed.
- Hunter has truck parked by jeep trail at end of route to help haul animal to camp.
- All data and models reliable to use with average person at the proposed weight.
- The hunter will pack out 100 lbs. of meat downhill on their person to truck.
- Hunter will stay on route.



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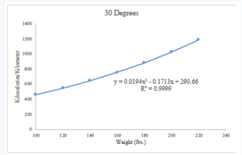
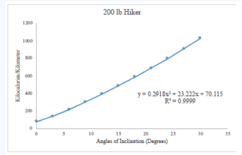
Expanded Data Models

The original data from the Pikes Peak Project was only for weights 100-220 lbs. and 0-30 degrees of inclination. To expand the data, a model for each angle and each weight was created using Microsoft Excel. For example, the trendlines on the graphs below can be used to predict kcal/km data outside of the data set.

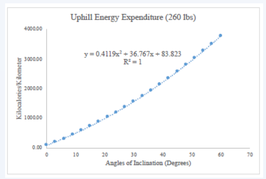


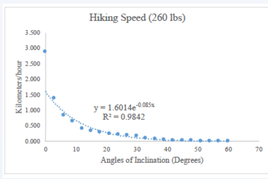


Hiking Speed and Energy Expenditure Models

Below are the models to predict the 260 lbs hunter's hiking speed S (km/hr), kcal/km burned hiking uphill K_u, and W/kg burned hiking downhill K_d for a given angle a, rate of change (multiplied by 100) G, and hiking speed s (m/sec).

- $S = 1.6014e^{-0.085a}$
- $K_u = 0.4119a^2 + 36.767a + 83.823$
- $K_d = 1.44 + 1.94s^{0.43} + 0.24s^4 + 0.34sG(1 - 1.05^{1-1.1^{G+32}})$ [3]



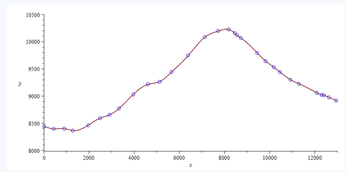


S model was chosen because of the shape of the kcal/km data and R^2=1. The hiking speed data shows the pattern of exponential decay, although K_u underestimates at low angles. Both K_u and S were constructed using Microsoft Excel. K_d model can be used for both uphill and downhill energy expenditures. Note the methods below:

- $1\frac{W}{kg} \cdot 1\ lb \cdot \frac{1\ kg}{2.2046\ lbs} \cdot \frac{3600\ sec}{1\ hr} \cdot 1\ hr \cdot 1\frac{\frac{Joule}{sec}}{1\ W} \cdot \frac{1\ kcal}{4184\ Joules}$ is approximately 0.3903 kcal
- $\tan^{-1}(slope) = angle$
- $1\frac{kcal}{km} \cdot 1\ km = 1\ kcal\ and\ time = \frac{distance\ traveled}{speed}$

Conclusion

- Each model predicts that the hunt would take approximately 9.5 hours
- Using cubic spline derivatives, TOPO! data, and the three models, it is predicted that a hunter would burn 2400-2700 kilocalories on this route
- This may change depending on how many trips are needed to retrieve the animal.



Future Study

Possibilities include:

- Looking at weights other than 260 pounds
- Gathering new data on downhill hiking speed and energy expenditure
- Calculating the energy expenditure for other routes and locations
- Testing the accuracy of models with new data
- Making a new cubic spline with more data to differentiate the resulting functions to find more accurate instantaneous rates of change

Acknowledgments

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- Dr. Tracii Friedman for always believing in me

References

1) Dr. Phil Gustafson's Pikes Peak Project data
2) Topo National Geographic topological data and maps
3) "Estimating Energy Expenditure During Level, Uphill, and Downhill Walking" by David P. Looney, William R. Santee, Eric O. Hansen, Peter J. Bonventre, Christopher R. Chalmers, and Adam W. Potter
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9) Terry Griffith's photo