MEMORANDUM

To: Santa Barbara Government
From: Sara Orofino and Jeremy Knox, Master of Environmental Science and Management Students
Date: May 22, 2019
Subject: **Economics of a Vessel Speed Reduction Program in Santa Barbara Channel**

BACKGROUND

The coast of California is home to a diverse marine ecosystem. Among the most important components are whales. Every year, over 20 whales are struck by container ships along the West Coast of the United States.[1] The Santa Barbara Channel, off the coast of Calfiornia stretching from Point Conception to Point Mugu, is frequently visited by three endangered whale species: blue, fin and humpback. This is due to the unique location of the SB Channel where cold water from the north combines with warmer water from the south. Unfortunately, this channel is also a key shipping area for container ships. These ships transport 90% of the world's goods and travel through SB Channel more than 2,700 times every year[2]. One proposed soltuion to reduce the frequency of whale strikes is a vessel speed reduction (VSR) program. Reducing the speed of ships through this channel would result in a 60% decrease in risk of whale strikes. The following analysis demonstrates that VSR program benefits outweigh costs by a couple orders of magnitude and concludes that the prgram should be adopted.

METHODS

Data: A contingent valuation survey to 500 Santa Barbara County residents was given to determine the local demand for a VSR program. Variables measured: (1) *risk*: level of risk reduction, (2) *bid*: annual payment for the household, (3) *vote*: 1 is yes, 0 is no, (4) *NEP* : measure of environmental concern, (5) *age*: categorical, (6) *income*: categorical.[3] **Model**: Linear regression model of *vote* on *age*, *income*, *NEP*, *bid* and *risk*.[4]

ANALYSIS

To analyze Santa Barbara respondents probability of voting yes on a VSR program we use a linear regression model. Given that reducing the risk of whales strikes by 20% saves five whales, our model suggests the willingness to pay for saving one whale is $2.78, on average ceteris paribus.[5] Furthermore, implementing a 60% reduction VSR program would result in an average willingness to pay of $71.48.[6] Reducing the risk by this much would save 15 whales. Santa Barbara residents will recieve these benefits but the cost will be spread across the country (from a price increase on goods transported by these ships).The cost to implement a 60% VSR is $7 million. Santa Barbara residents would recieve a benefit of over $10 billion giving a surplus of over $3.7 million.[7]

Ships that reduce their speed not only reduce the risk of colliding with whales but also emit less carbon. An alternative to the price increase on products aboard these ships is a carbon credit program. There are carbon trading markets that could potentially offset the cost of implmenting a 60% VSR program. Our analysis shows that a carbon market that prices carbon at $50 per ton would offset the cost of reducing speed thereby incentivising ships to reduce their speed.[8] In this scenario, the benefit of 15 whales being saved to Santa Barbara Residents would be over $10 billion while the cost would go to all tax payers and stakeholders who fund the carbon offeset program.

CONCLUSION

Reducing the speed of ships through the Santa Barbara Channel would result in a 60% decrease in risk of whale strikes, ultimatley saving 15 whales. The cost would fall on consumers of the products among these ships or citizens who's tax dollars go to carbon credit program. Given that benefits far outweigh cost, Santa Barbara Government should implment the VSR program.

[1] Redfern et al., 2013 cited from WhaleStrikes Group Porject
[2] Hakim, 2014 cited from WhaleStrikes Group Porject
[3] WhaleStrikes Group Porject
[4] See Technical Appendix: (1) Linear model is used, instead of logistic, because the ease of interpretation. Significance of variables was not analyzed and averages/medians were used for calculations.
[5] See Technical Appendix: (2)
[6] See Technical Appendix: (4)
[7] See Technical Appendix: (5) & (6)
[8] See Technical Appendix: (7)

Technical Appendix

1. Linear Probability Model

Create a linear probility model that predicts a respondent's probability of voting "yes" on the ballot based on their age, income, NEP score, the program's risk reduction, and cost of the program to that respondent.

Regression Model:

$Probability(Voting\ Yes) = 0.1197 + 0.0204(Age\ to\ 30) - 0.0201(Age\ to\ 40) + 0.01(Age\ to\ 50) - 0.0162(Age\ to\ 60) + 0.0088(Income\ One\ Percent) + 0.0027(Income\ Poor) + 0.0075(Income\ Rich) + 0.0468(Income\ Very\ Rich) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(Risk\ Reduction)$

Coefficient Interpretation:

Age: Reference Level Over 65

- to 30: All else being equal, a person in the age bracket of to 30 would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0204 higher than a person in the age bracket over 65.
- to 40: All else being equal, a person in the age bracket of to 40 would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0201 lower than a person in the age bracket over 65.
- to 50: All else being equal, a person in the age bracket of to 50 would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.01 higher than a person in the age bracket over 65.
- to 60: All else being equal, a person in the age bracket of to 60 would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0162 lower than a person in the age bracket over 65.

Income: Reference Level Middle

- Poor: All else being equal, a person with an income level of one percent would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0027 higher than a person with a medium income level.
- Rich: All else being equal, a person with an income level of one percent would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0075 higher than a person with a medium income level.
- Very Rich: All else being equal, a person with an income level of one percent would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0468 higher than a person with a medium income level.
- One Percent: All else being equal, a person with an income level of one percent would be expected to have a probability of voting yes on a vessel speed reduction program that is, on average, 0.0088 higher than a person with a medium income level.

NEP: For every 1 unit increase in environmental concern, we would expect the probability of voting yes on a vessel speed reduction program to increase by 0.0159, if all other variables are equal.

Bid: For every 1 dollar increase in annual household payment, we expect the probability of voting yes on a vessel speed reduction program to decrease by 0.0011, if all other variables are equal.

Risk: For every 1 unit increase in risk reduction, we would expect the probability of voting yes on a vessel speed reduction program to increase by 7×10^{-4}, if all other variables are equal.

2. Value of Prevented Whale Deaths

Reducing the risk of whale strikes by 20% saves five whales every year. Based on this, the vessel speed reduction by 4% saves a single whale every year. To find the value of each individual whale saved find the willingess to pay for vessel speed reduction programs of 0% and compare to the willingess to pay for vessel speed reduction of 4%.

Risk Reduction 0%

Assume the probability of voting yes is the average of the votes ($p = 0.714$), assume an age to 30, income rich, and the average NEP (38.366), solve for the willingness to pay for the program using:

$$0.714 = 0.1197 + 0.0204(Age\,to\,30) + 0.0075(Income\ Rich) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(0)$$

$$Willingness\,to\,Pay = 39.5$$

Risk Reduction 4%

Again, assume the probability of voting yes is the average of the votes ($p = 0.714$), assume an age to 30, income rich, and the average NEP (38.366), solve for the willingness to pay for the program using:

$0.714 = 0.1197 + 0.0204(Age\,to\,30) + 0.0075(Income\ Rich) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(4)$

$Willingness\ to\ Pay = 42.28$

The value of a single whale is the difference between the willingness to pay for a vessel speed reduction program at 4% and at 0%.

$Individual\ Whale\ Value = 2.78$

3. Estimated Willingness to Pay for a Vessel Speed Reduction Program

a. Choose three participants at random

Using a random number generator select three participants:
- 38 NEP:32 Income:Rich Age:to30
- 44 NEP:51 Income:Poor Age:to40
- 102 NEP:51 Income:Middle Age:to60

b. Predict willingness to pay for 60% VSR program

Assume the probability of voting yes the average of all the yes votes ($p = 0.714$), calculate the willingness to pay using the following equations:

Individual 38:
$0.714 = 0.1197 + 0.0204(Age\,to\,30) + 0.0075(Income\ Rich) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(60)$

Individual 44:
$0.714 = 0.1197 - 0.0201(Age\,to\,40) + 0.0027(Income\ Poor) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(60)$

Individual 122:
$0.714 = 0.1197 - 0.0162(Age\,to\,60) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(60)$

Individual 38:
$Willingness\ to\ Pay = 13.14$

Individual 44:
$Willingness\ to\ Pay = 263.84$

Individual 122:
$Willingness\ to\ Pay = 257.64$

4. Santa Barbara Estimated Willingness to Pay for VSR Program

Again assume the probability of voting yes the average of voting yes ($p = 0.714$). Use the median income bracket (rich), the median age bracket (to 50), and average NEP (38.366) to calculate willingness to pay using:

$0.714 = 0.1197 + 0.0075(Income\ Rich) + 0.01(Age\,to\,50) + 0.0159(NEP) - 0.0011(Bid) + 7 \times 10^{-4}(60)$

$Average\ Santa\ Barbara\ County\ Household\ Willingness\ to\ Pay = 71.48$

5. Total benefits to Santa Barbara residents (population = 150,000).

Risk = 60%
Cost = 7 million

Calculate Total Benefits using the following equation:
Total Benefits = $71.48\ per\ household * 150,000\ households$

Total Benefits = 1.0721383×10^7

6. Do Benefits Outweight Costs

Yes, based only on these benefits the benefits do outweight the costs.

Cost = 7 million
Benefits = 1.0721383×10^7

$Surplus = 1.0721383 \times 10^7 - 7000000 = 3.7213828 \times 10^6$

7. Price of Carbon Credits

Assume that for any ship transiting the Santa Barbara Channel the speed reduction tha results in a 60% risk reduction costs the shipper 1000 but will result in 20 fewer tons of carbon dioxide per transit.

Shipping companies will adopt the VSR for self interested reasons if the value of the carbon credits is equal to the cost.

$20 * Z = 1000$
$Z = 50/ton$

8. Whales Saved by Carbon Credits

Assume the value of the carbon credit is 50/ton and all ships reduce speed to achieve the 60% risk reduction.

Number of Whales Saved:
20% Reduction = 5 Whales saved
$Whales\ Saved = 5 * 3 = 15$

The social value of the whale reduction program is the total benefit of that program minus the cost. Since the carbon credits would avoid the 7 million cost of the program, the social value is just the total benefit of the program.

$Social\ Value = 1.0721383 \times 10^7$