Agenda Item E.6
Attachment 1
September 2017

Predictors of Halibut Viability for Electronic Monitoring in the West Coast Trawl IFQ Fishery

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Study Objective:

Electronic monitoring systems are increasingly used in the West Coast trawl IFQ fishery as an alternative to an on-board observer; however, the method used by observers to assess halibut viability is not feasible with a video monitoring system. This study evaluates whether halibut viability can be predicted from an alternative set of condition variables that could be collected with an electronic monitoring system for the West Coast IFQ bottom trawl fishery.

Background:

Pacific halibut captured in the U.S. West Coast trawl IFQ fisheries are a prohibited species and therefore discarded at sea. Observers use a gear-specific key developed by the International Pacific Halibut Commission (IPHC) to evaluate halibut viability (i.e., halibut condition). Halibut viability is assessed categorically to be excellent, poor, or dead. These categories are then converted to a specific mortality rate determined by the IPHC: excellent = 0.20, poor = 0.55, dead = 0.90.

Electronic monitoring systems have been used as an alternative to an on-board observer for monitoring purposes under exempted fishing permits (EFPs) since 2015. Halibut viability cannot be determined from video using the existing gear-specific key as it requires hands-on evaluation of the halibut; however, alternative factors relating to halibut condition are potentially available. Previous research has found that halibut viability can be predicted by factors such as the length of the halibut, the time on deck, and the tow size and duration (Richards et al. 1994).

In this study, we evaluated the relationship between halibut viability as recorded by observers and alternative predictors of halibut condition that could be collected with electronic monitoring systems. The study included halibut caught on West Coast bottom trawl vessels in the IFQ fishery. The predictors included factors presently collected in the electronic monitoring program for the West Coast IFQ fishery, as well as factors that might feasibly be collected in the future:

- Predictors available with current electronic monitoring data
  - Fish length
  - Time on deck
  - Duration of tow
  - Depth of tow (from captain's logbook)
  - Weight of tow
  - Composition of tow (ratio of spiny fish)
- Predictors that could potentially be collected
  - Sea Surface Temperature
  - Air Temperature

Methods:

Halibut Data

Observers on West Coast bottom trawlers in the IFQ fishery assessed the viability of all halibut before they were discarded. When possible, viability was assessed for each individual; otherwise viability was assessed for a sub-sample of the halibut.

In addition to viability, observers measured the time each halibut was on deck (time from when the codend came on deck to when viability was assessed) using a hand-held stopwatch. Additional covariates, including fork length, haul depth, haul duration, weight of haul, composition of haul (from which proportion of rockfish was determined), location, date and time, were all collected according to standard WCGOP observer protocols.

Observers also tried to record the sea surface temperature and air temperature from vessel equipment, but in many cases the information was not available thus reducing the sample size substantially. Of greater concern, the data appeared suspect (e.g. higher temperatures were observed at more northern latitudes and during winter months). Furthermore, equipment was not standardized. Given that these data may not be reliable, temperature variables were not included in subsequent analysis.

Data Analysis

Analysis of study data was exploratory in approach. Distributions of predictor variables were examined and log transformations were used when appropriate. Correlation among several of the predictor variables was expected. All potential correlations were assessed with Pearson correlation tests and examination of the data.

Relationships between halibut viability and predictor variables were plotted in histograms. Relationships were modeled using generalized ordered logistic regression models (using vglm with the cumulative family and non-proportional odds from the VGAM library in R). These models are an extension of logistic regression designed for ordinal categorical response data. The relative importance of predictor variables was compared using AIC. For an initial analysis using the 2015 data, only single variable models were included. Based on these results, multi-variable models were selected and tested with the 2016 data. Fitted model values were used to create probability distributions for each individual predictor using the complete data set (both 2015 and 2016 data).

A classification tree was used to further evaluate the importance of different predictor variables (both years of data; built using the rpartScore library in R, a classification tree for ordinal response).

Results:

Halibut viability and related predictors were recorded for 12,729 individual halibut. These halibut were collected from 3,566 hauls on 55 vessels. Individual hauls contained between 1 and 92 halibut (median = 3); individual vessels caught between 1 and 584 halibut (median = 73). In total, halibut viability was rated "Excellent" for 5,563 fish, "Poor" for 1,922 fish, and "Dead" for 5,244 fish.

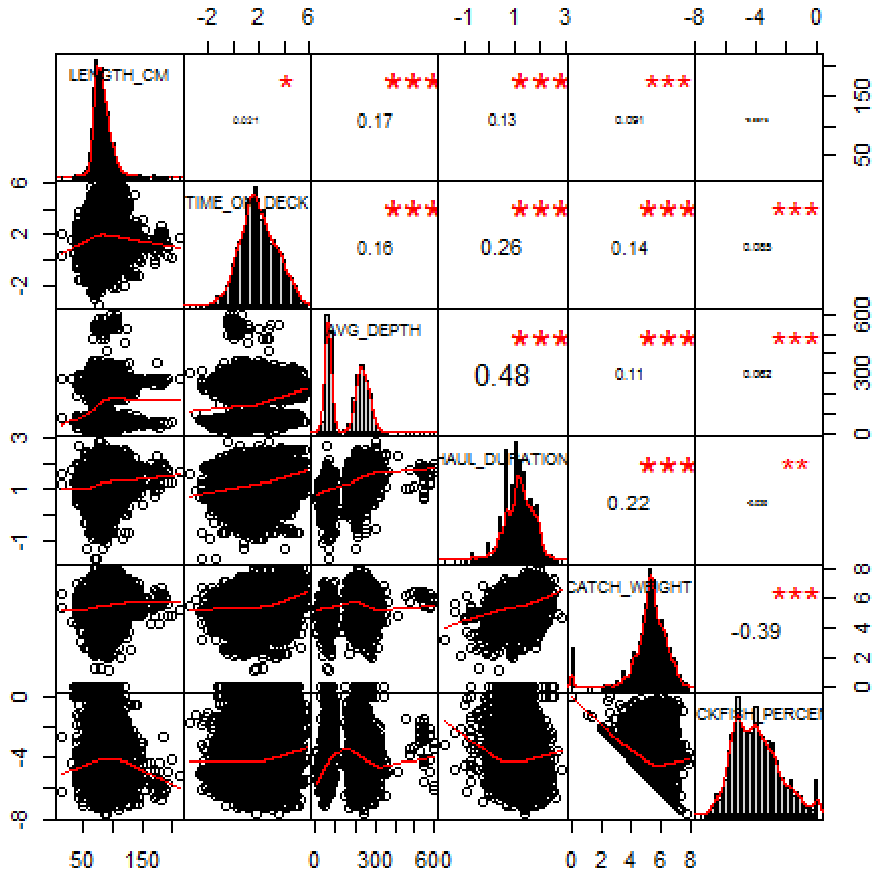
Bottom trawl vessels included in this study used three types of trawl gear: Groundfish trawl, large footrope; groundfish trawl, small footrope; and Oregon set-back flatfish net. Hauls that used 'Groundfish trawl, long footrope' had deeper average depths than the other gear types; correspondingly, hauls were longer, catch weight was higher, and time on deck for halibut was often longer. Some vessels used more than one gear type. Summary data, including mean (±SD) for each predictor by gear type, are presented below.

Gear	Vessel Count	Haul Count	Total Halibut	Excellent	Poor	Dead
Groundfish trawl, large footrope	50	1746	6925	36 %	15 %	48 %
Groundfish trawl, small footrope	20	477	1766	46 %	19 %	35 %
Oregon set-back flatfish net	20	1343	4038	55 %	13 %	32 %

Gear	Fork Length (cm)	Time On Deck (min)	Tow Duration (hrs)	Tow Depth (m)	Catch Weight (lbs)	Proportion Rockfish
Groundfish trawl, large footrope	84 ± 15	24 ± 39	5 ± 2	232 ± 58	409 ± 404	0.06 ± 0.14
Groundfish trawl, small footrope	79 ± 16	14 ± 21	3 ± 1	66 ± 24	219 ± 169	0.09 ± 0.22
Oregon set-back flatfish net	80 ± 14	11 ± 18	3 ± 1	66 ± 36	243 ± 146	0.06 ± 0.17

Correlations among predictor variables

Correlations among predictor variables were significant in many cases, although these correlations were often weak and may be artefacts of the large sample size (see lines of best fit on the correlation chart below). Strongest correlations were between haul duration and depth (+); catch weight and percent rockfish (-); and haul duration and time on deck (+).



Predictor variable models

Halibut viability rankings were significantly related to each of the individual predictors in 2015 except the percent of rockfish; however, the odds ratios indicated a weak relationship in most cases. Time on deck was the best individual predictor of halibut viability.

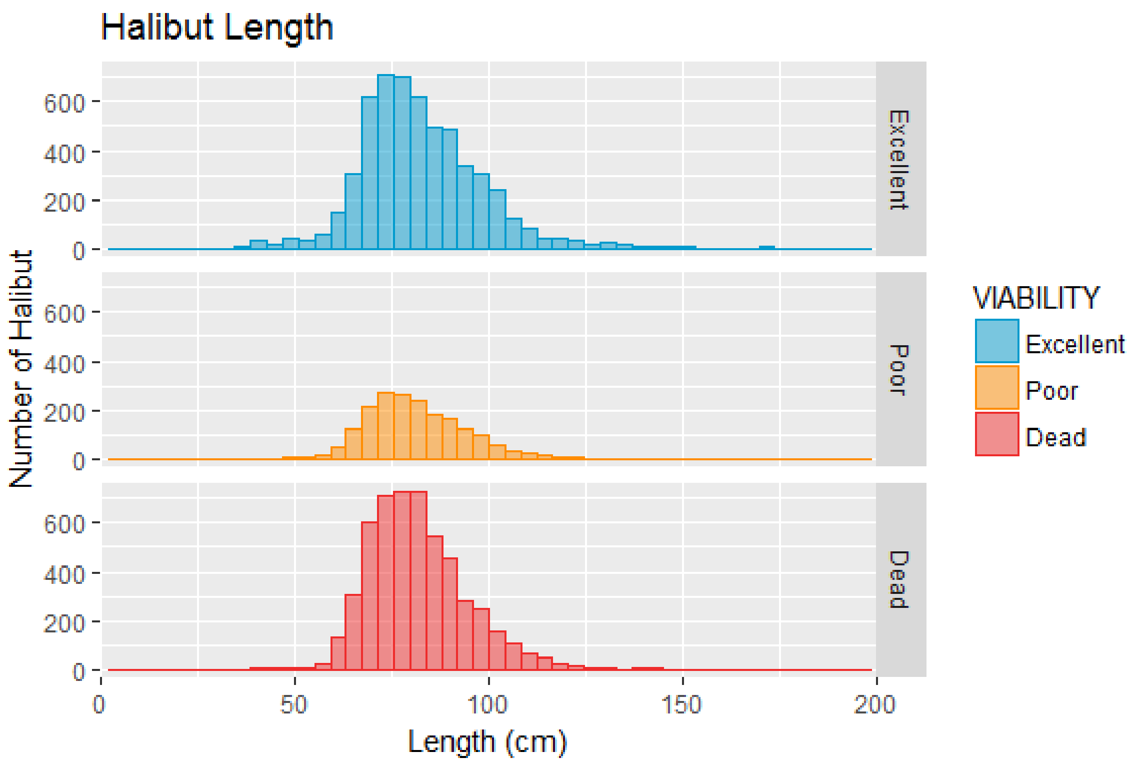
Because there are three possible outcomes, an odds ratio is calculated for the odds of excellent versus poor/dead (E|PD) and for excellent/poor versus dead (EP|D). Odds ratios are the odds of the first outcome versus the second per unit increase in the predictor variable (or for log transformed values, the percent increase; with the natural log this is the odds - roughly - per doubling of the predictor variable). Odds ratios close to 1 generally indicate weaker effects. Odds ratios above 1 indicate better viability rankings as the predictor variable increases and odds ratios less than 1 indicate better viability rankings as the predictor decreases.

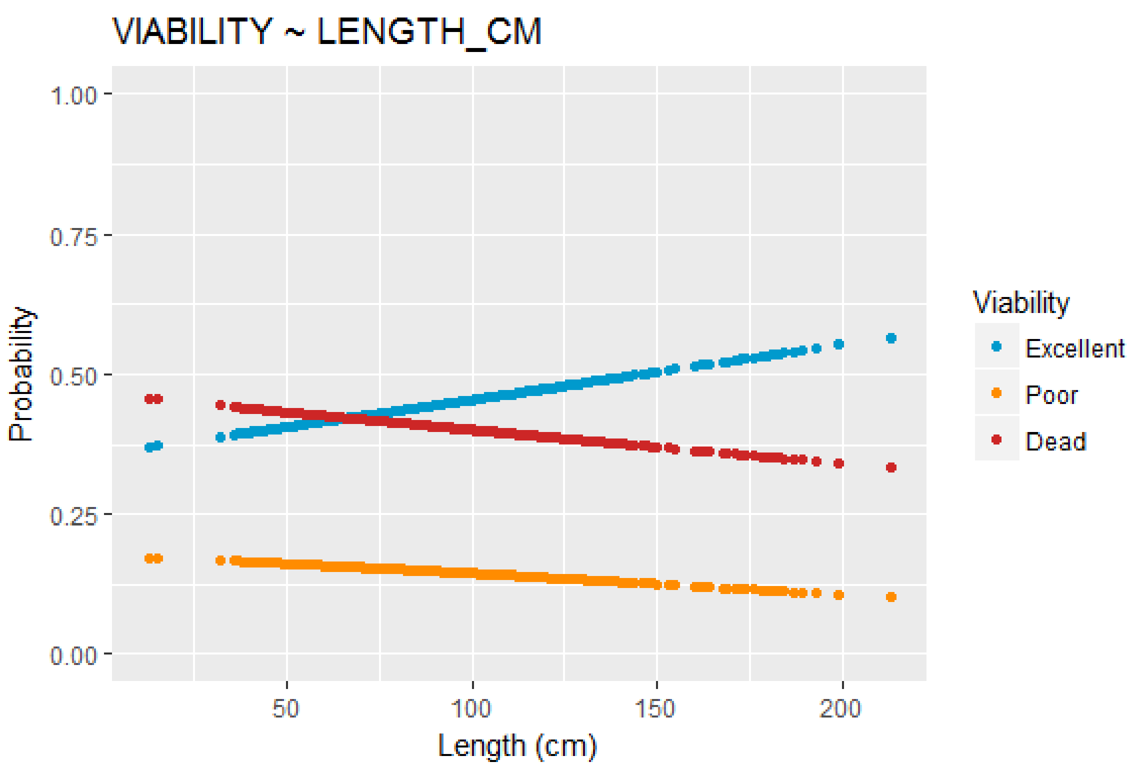
Model	Odds E|PD	Odds EP|D	AIC	logLikelihood	deltaAIC
VIABILITY ~ log(TIME_ON_DECK)	0.333 *	0.364 *	10275.51	-5133.756	0.000
VIABILITY ~ log(HAUL_DURATION)	0.287 *	0.275 *	11965.67	-5978.836	1690.162
VIABILITY ~ AVG_DEPTH	0.996 *	0.996 *	12411.04	-6201.52	2135.530
VIABILITY ~ log(CATCH_WEIGHT)	0.817 *	0.779 *	12524.32	-6258.162	2248.813
VIABILITY ~ LENGTH_CM	1.006 *	1.005 *	12633.88	-6312.938	2358.365
VIABILITY ~ log(ROCKFISH_PERCENT)	0.982	0.966	12642.32	-6317.161	2366.812

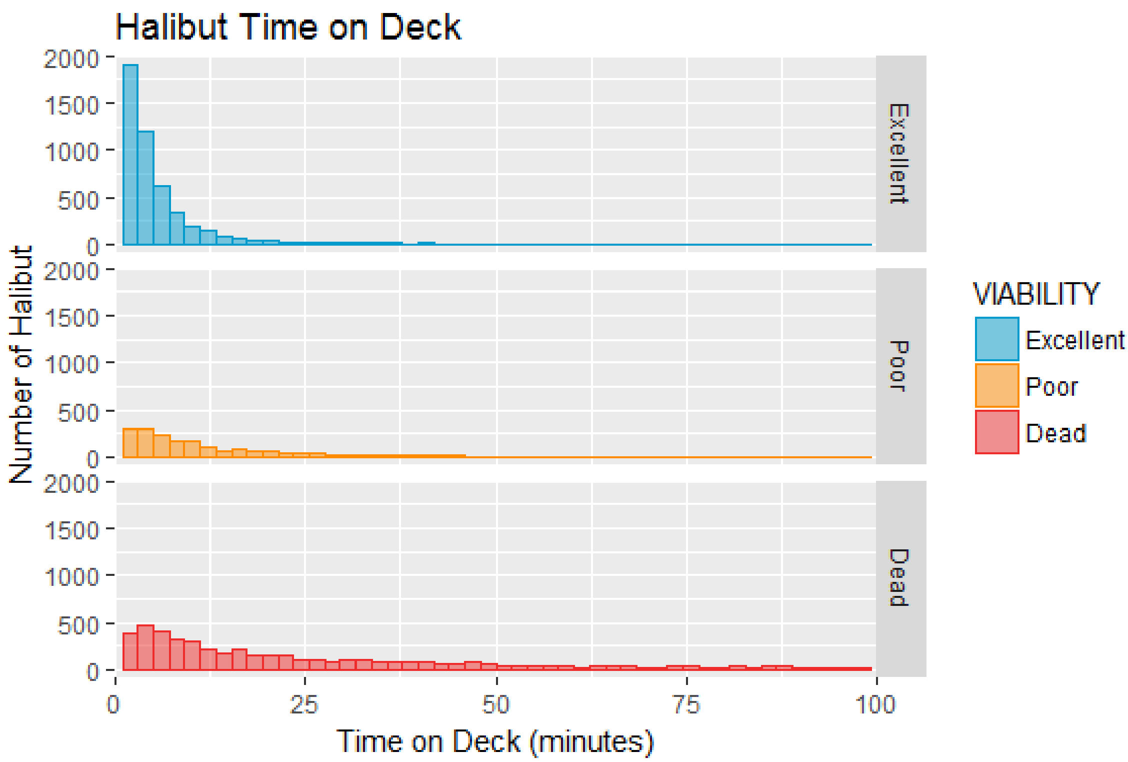
Multi-variable models were selected based on the results of the exploratory results from 2015. Time on deck was included in all models, and haul duration in all but one given their performance in the 2015 models. Two predictors were dropped: percent rockfish (which was not significant a single predictor) and haul depth (which is significantly correlated with haul duration; furthermore haul depth is recorded in captains logbooks whereas haul duration can be measured independently in the EM system). Five models were included in the analysis.

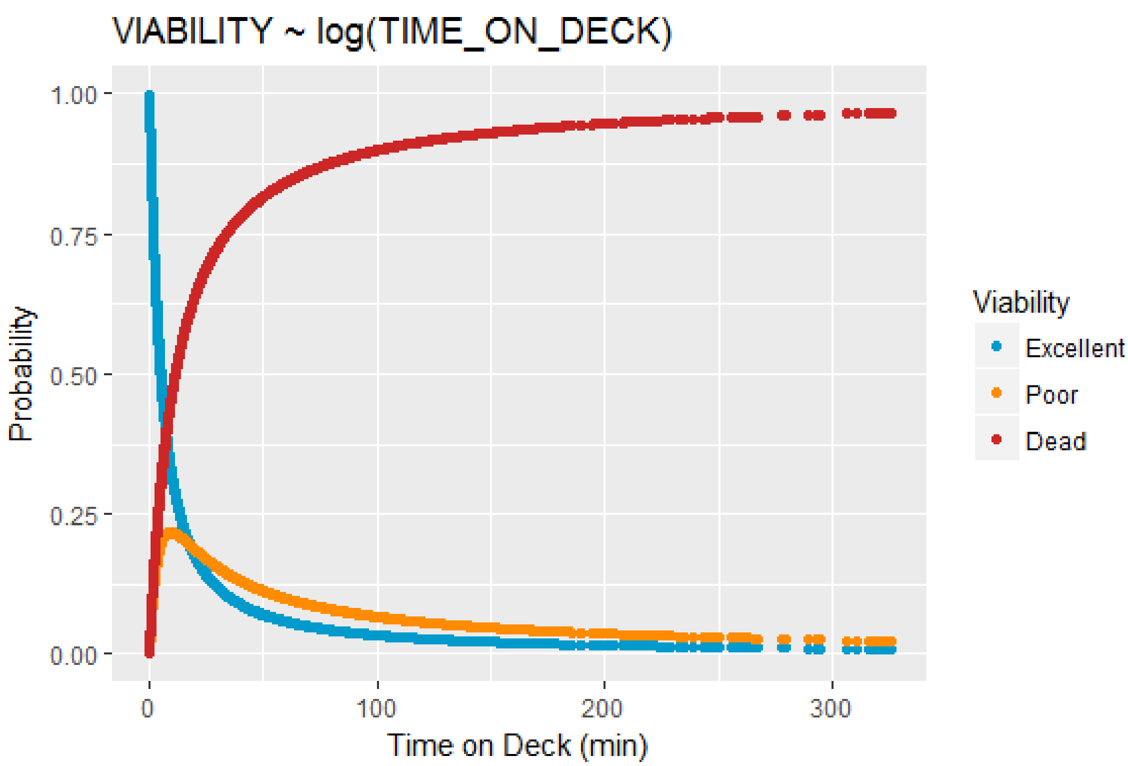
Models including haul duration had notably lower AIC scores than time on deck alone. The addition of halibut length also led to a modest decrease in score, while catch weight only added very slight improvement to the models.

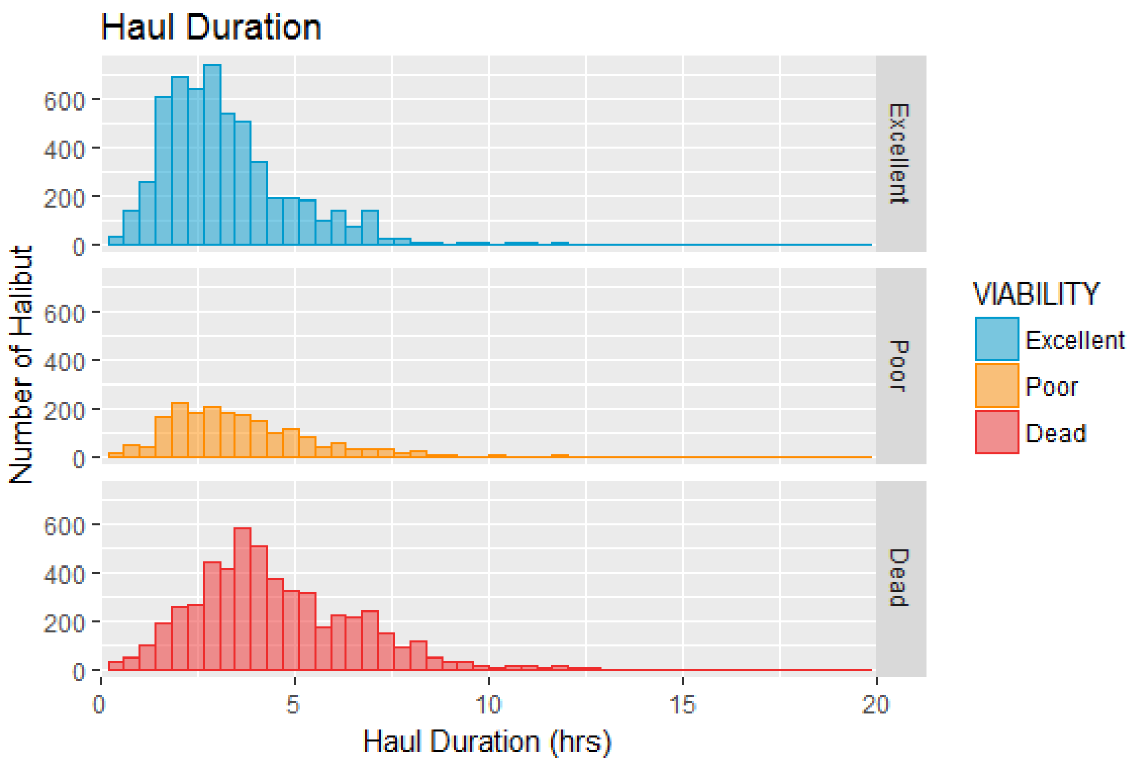
Model	Odds E|PD	Odds EP|D	AIC	logLikelihood	deltaAIC
VIABILITY ~ log(TIME_ON_DECK) + log(HAUL_DURATION) + LENGTH_CM + log(CATCH_WEIGHT)	0.332 *	0.377 *	10198.99	-5089.496	0.000
VIABILITY ~ log(TIME_ON_DECK) + log(HAUL_DURATION) + LENGTH_CM	0.333 *	0.379 *	10199.13	-5091.563	0.134
VIABILITY ~ log(TIME_ON_DECK) + log(HAUL_DURATION) + log(CATCH_WEIGHT)	0.332 *	0.377 *	10209.26	-5096.63	10.268
VIABILITY ~ log(TIME_ON_DECK) + log(HAUL_DURATION)	0.333 *	0.379 *	10210.76	-5099.378	11.765
VIABILITY ~ log(TIME_ON_DECK)	0.322 *	0.368 *	10486.97	-5239.486	287.980

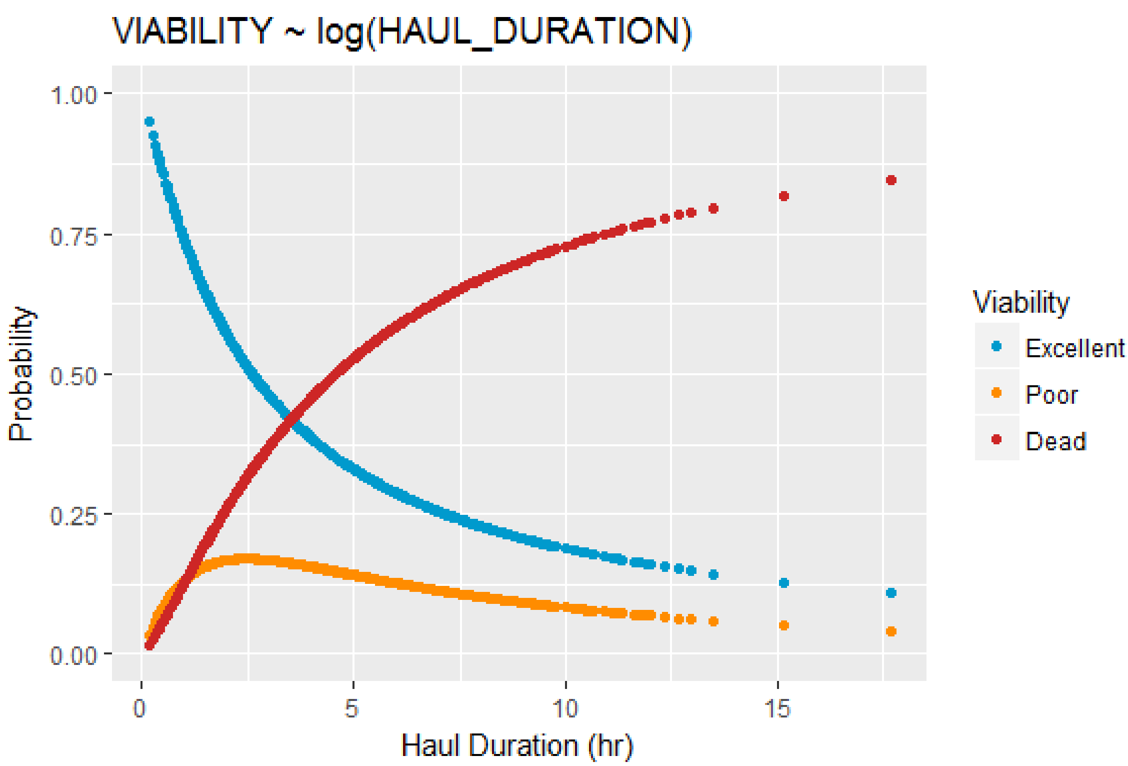

Halibut Length
Number of Halibut
600
400
200
0
Excellent
Poor
Dead
0
50
100
150
200
Length (cm)
VIABILITY
Excellent
Poor
Dead

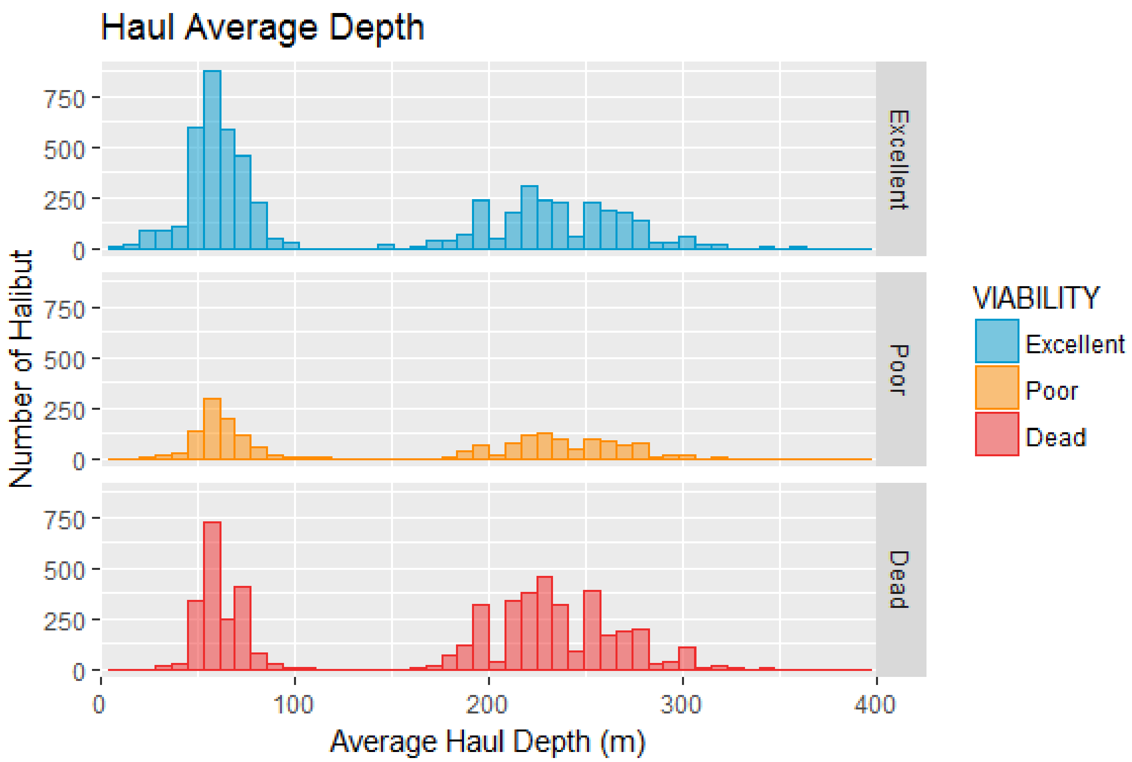

VIABILITY ~ LENGTH_CM
Probability
1.00
0.75
0.50
0.25
0.00
50
100
150
200
Length (cm)
Viability
Excellent
Poor
Dead

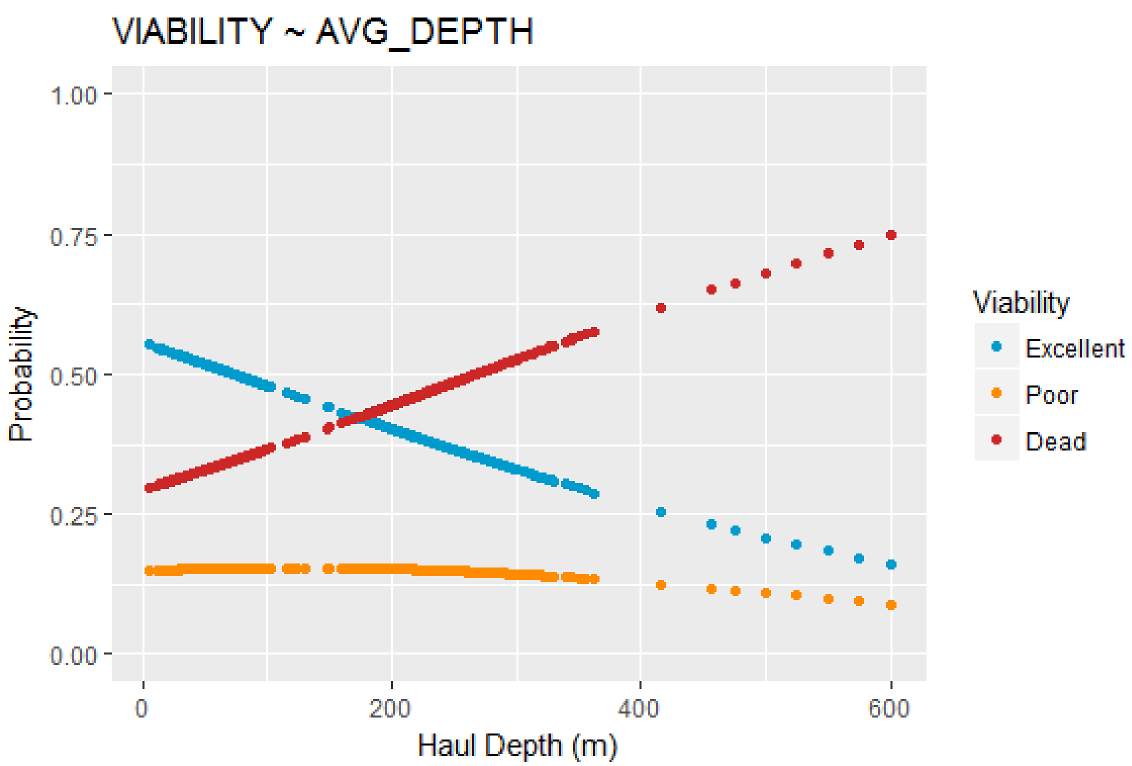

Halibut Time on Deck
Number of Halibut
Time on Deck (minutes)
Excellent
Poor
Dead
VIABILITY
0
25
50
75
100
2000
1500
1000
500
0

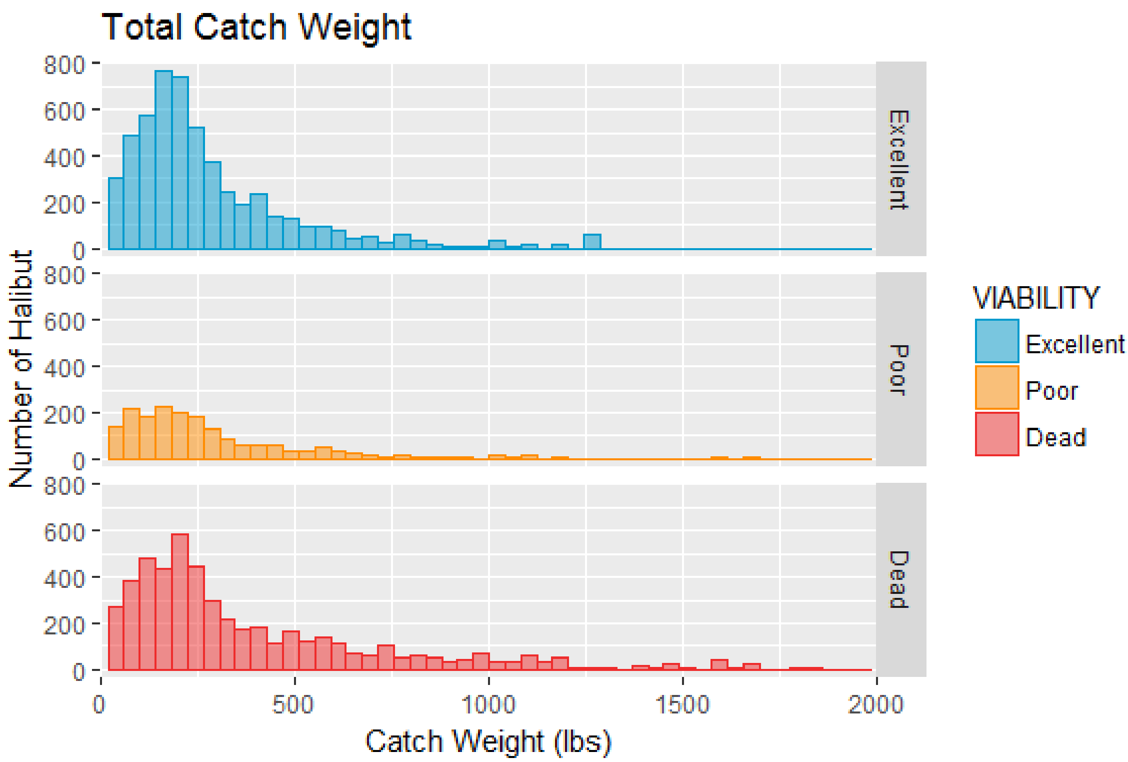

VIABILITY ~ log(TIME_ON_DECK)
Probability
Time on Deck (min)
Viability
Excellent
Poor
Dead
1.00
0.75
0.50
0.25
0.00
0
100
200
300


Haul Duration
Number of Halibut
600
400
200
0
Excellent
Poor
Dead
0
5
10
15
20
Haul Duration (hrs)
VIABILITY
Excellent
Poor
Dead

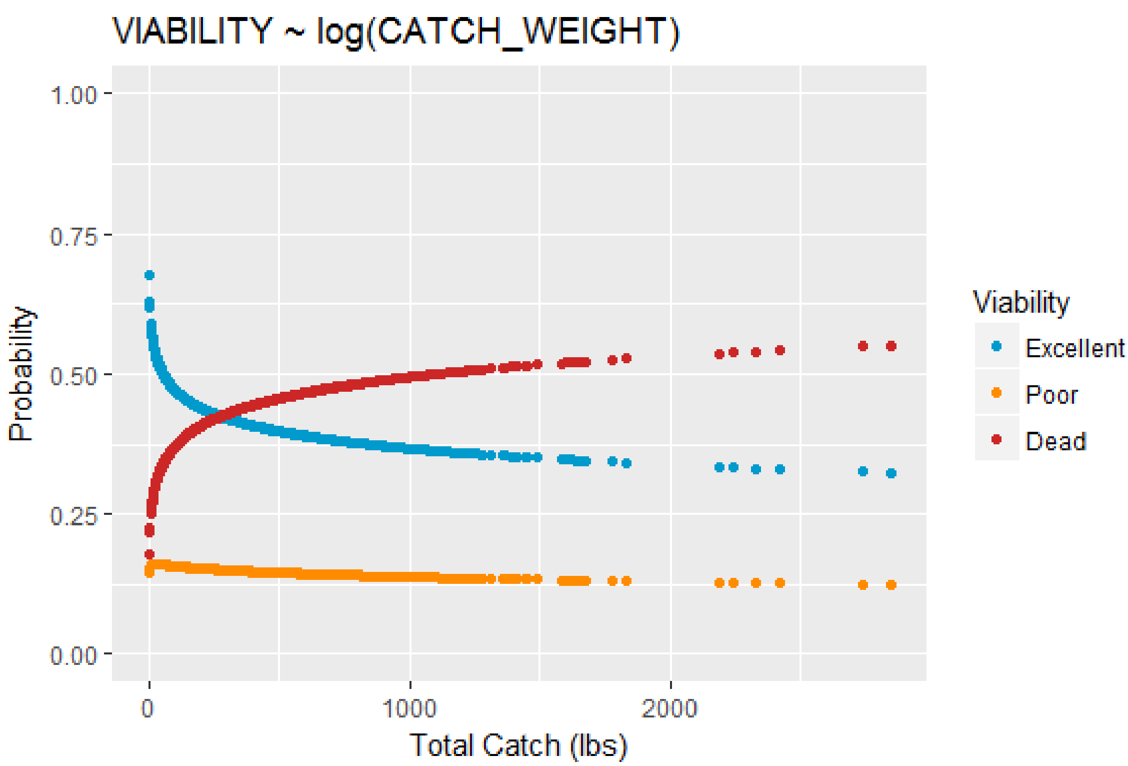

VIABILITY ~ log(HAUL_DURATION)
Probability
1.00
0.75
0.50
0.25
0.00
0
5
10
15
Haul Duration (hr)
Viability
Excellent
Poor
Dead


Haul Average Depth
Number of Halibut
750
500
250
0
Excellent
Poor
Dead
0
100
200
300
400
Average Haul Depth (m)
VIABILITY
Excellent
Poor
Dead

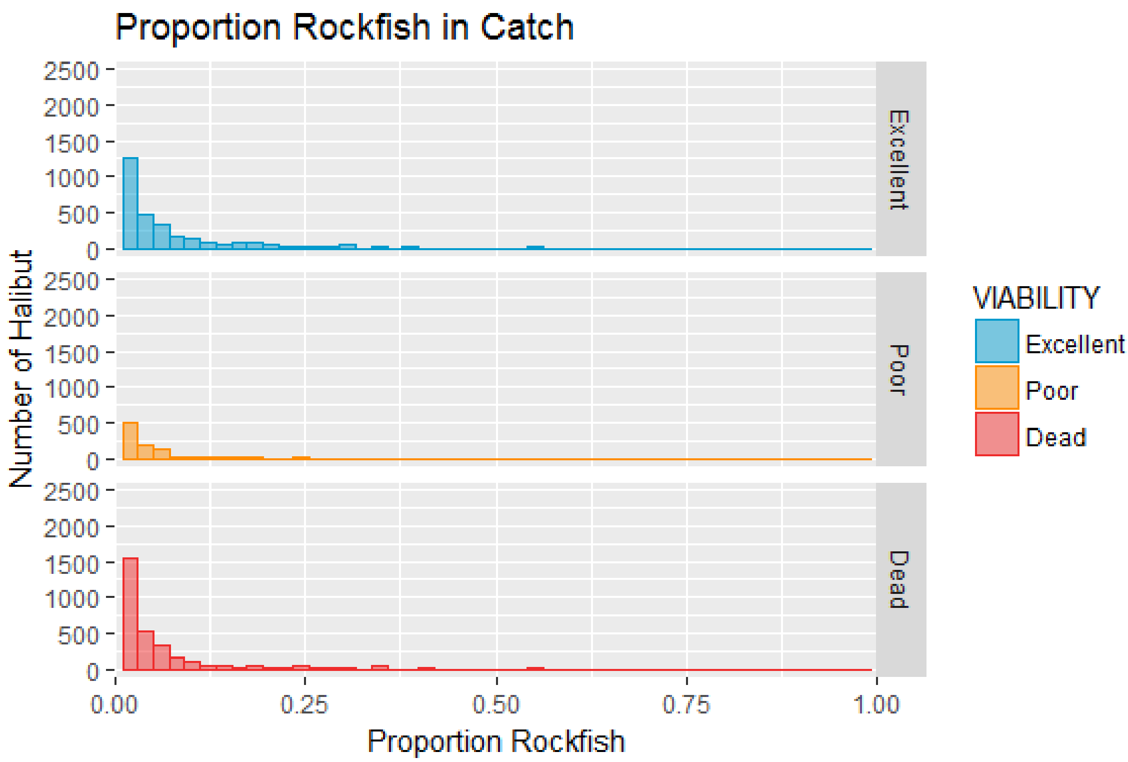

VIABILITY ~ AVG_DEPTH
Probability
1.00
0.75
0.50
0.25
0.00
0
200
400
600
Haul Depth (m)
Viability
Excellent
Poor
Dead

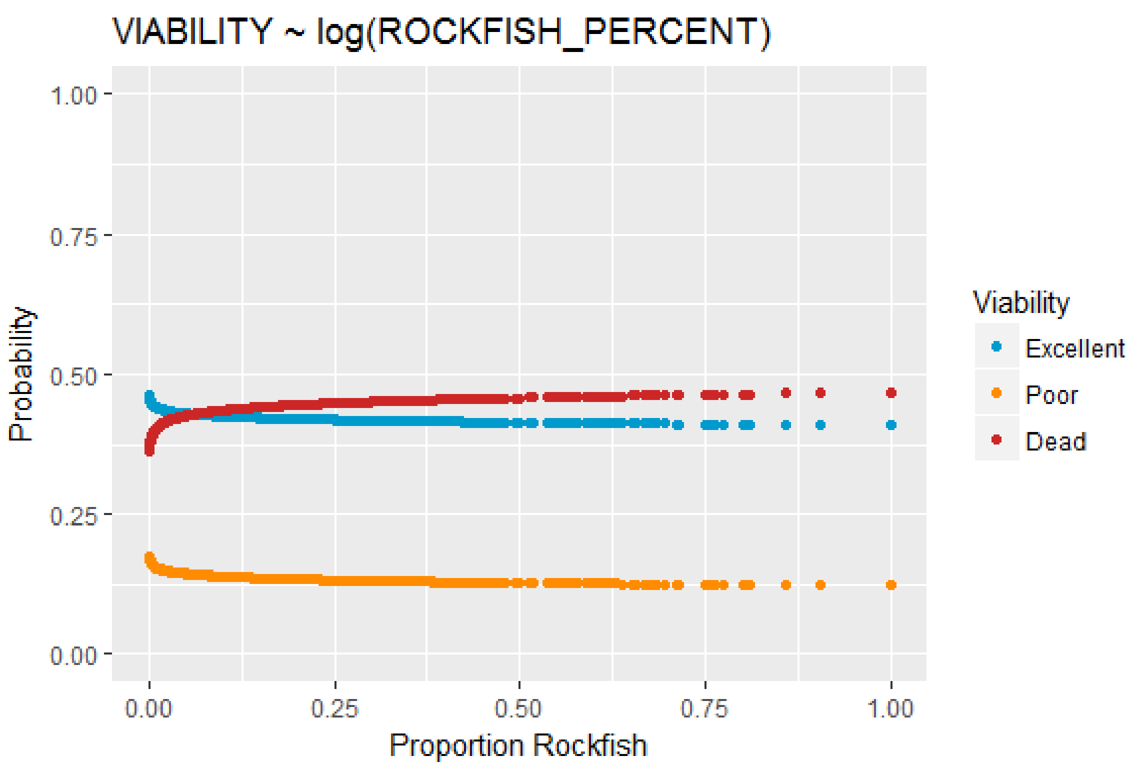


Total Catch Weight
Number of Halibut
Catch Weight (lbs)
Excellent
Poor
Dead
VIABILITY
Excellent
Poor
Dead
800
600
400
200
0
0
500
1000
1500
2000



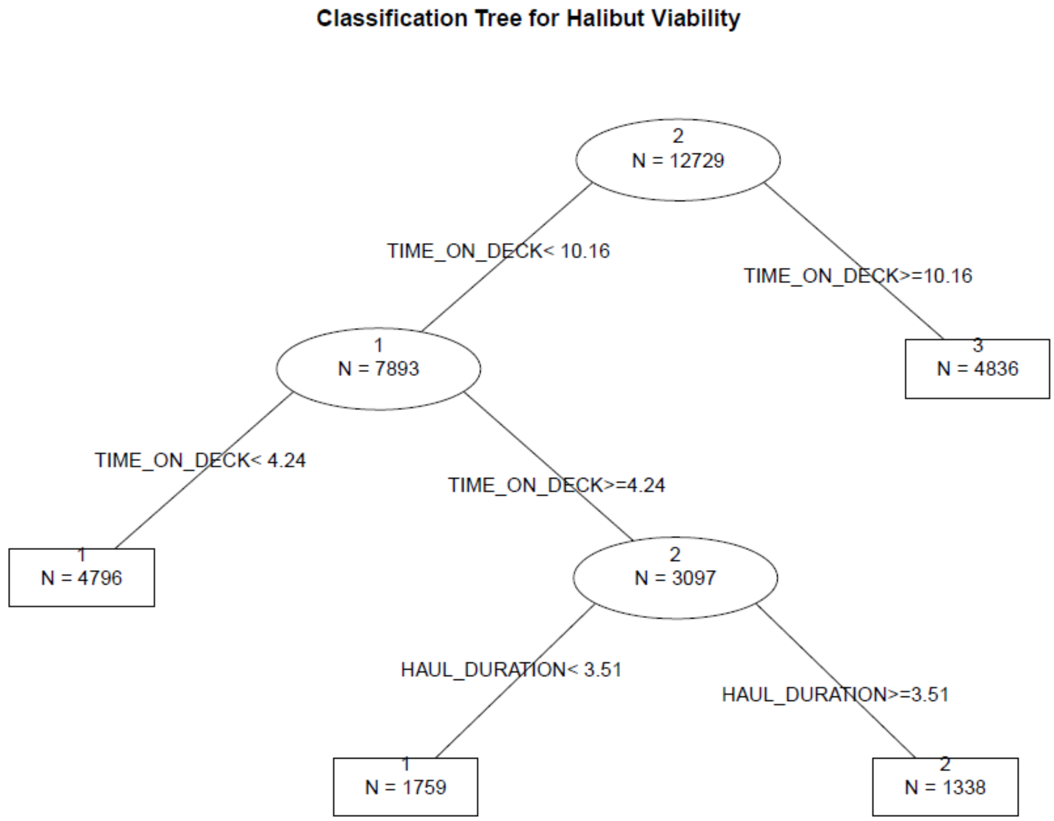
VIABILITY ~ log(CATCH_WEIGHT)
Probability
Total Catch (lbs)
Viability
Excellent
Poor
Dead
1.00
0.75
0.50
0.25
0.00
0
1000
2000


Proportion Rockfish in Catch
Number of Halibut
2500
2000
1500
1000
500
0
Excellent
Poor
Dead
0.00
0.25
0.50
0.75
1.00
Proportion Rockfish
VIABILITY
Excellent
Poor
Dead


VIABILITY ~ log(ROCKFISH_PERCENT)
Probability
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
Proportion Rockfish
Viability
Excellent
Poor
Dead

Classification Tree

The classification tree model included all variables: VIABILITY ~ LENGTH_CM + TIME_ON_DECK + HAUL_DURATION + AVG_DEPTH + CATCH_WEIGHT + ROCKFISH_PERCENT + GEAR. As in the ordinal regression models, time on deck was the most important predictor in the classification tree. Haul duration was also included in the tree model at the third split. Using this classification tree, halibut viability would be predicted to be excellent if time on deck was less than 4.2 minutes or if time on deck was 4.2-10.2 minutes and haul duration was less than 3.5 hrs, poor if time on deck was 4.2-10.2 minutes and haul duration greater than 3.5 hrs, and dead if time on deck was greater than 10.2 minutes.



In the classification tree, 1 = Excellent, 2 = Poor, and 3 = Dead; N indicates the number of halibut assigned to each viability by the classification tree. The table shows the performance of the classification tree at each split. The first split resulted in the biggest improvement to the error rate. Absolute error at the last step indicates the number of records that were incorrectly classified from the training data set (51%).

Split #	Relative Error	Cross Validation Error	Absolute Error
0	1.00	1.00	10807
1	0.63	0.63	6808
2	0.61	0.62	6592
3	0.60	0.61	6484

Summary

Among the predictor variables included in this preliminary analysis, time on deck was the strongest predictor of halibut viability. Haul duration improved ordinal regression models somewhat, and also was included in the classification tree at the last step (improving the absolute error rate by only 1%) while halibut length added a modest improvement to the models but was not included in the classification tree. Temperature is expected to impact halibut viability, but we had insufficient data to evaluate temperature impacts in this study.

References

Galimberti G, Soffritti G, Di Maso M (2012) Classification Trees for Ordinal Responses in R: The rpartScore package. Journal of Statistical Software 47 (10): 1-25

Richards LJ, Schnute JT, Fargo J (1994) Application of a generalized logit model to condition data for trawl-caught Pacific Halibut, *Hippoglossus stenolepsis*. Canadian Journal of Fisheries and Aquatic Sciences 51: 357-364