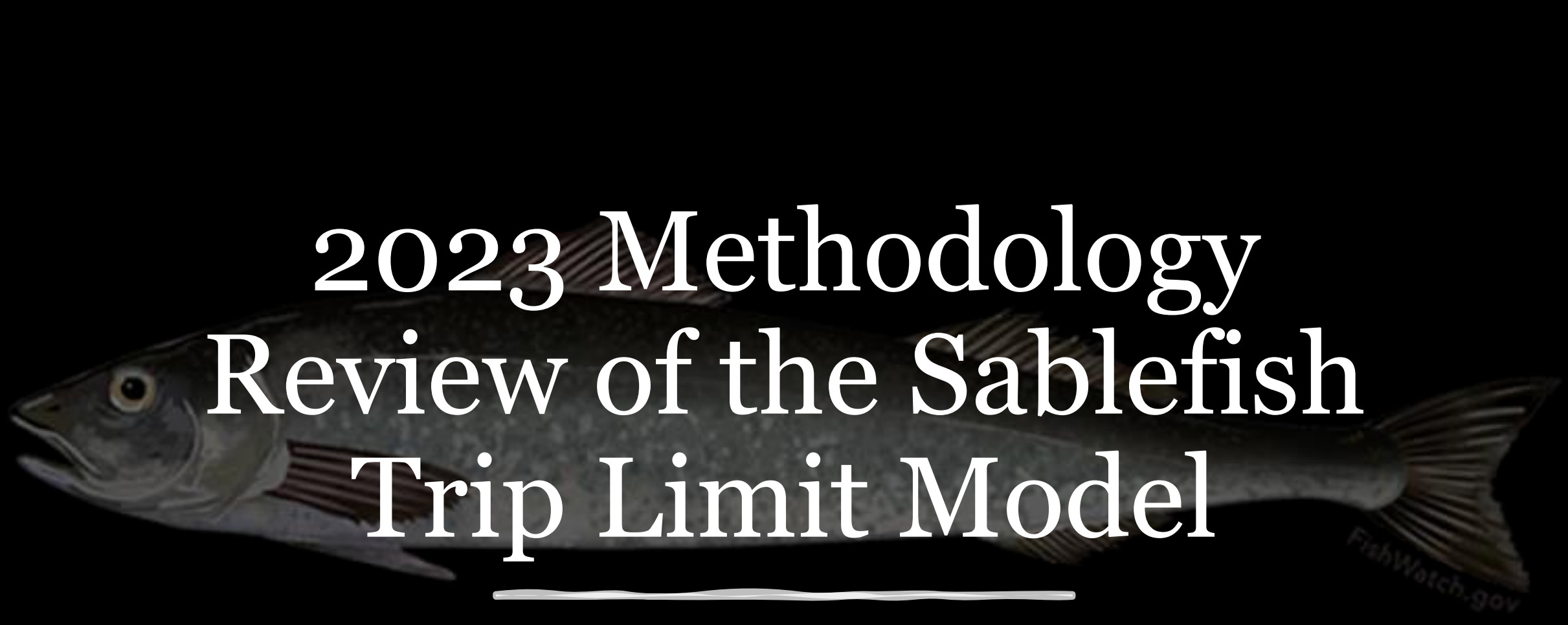


2023 Methodology Review of the Sablefish Trip Limit Model

May 9, 2023

Groundfish and Economic Subcommittees Workshop

Whitney Roberts (WDFW, GMT)

Fishery Overview

Year-round fishery, divided north and south of 36° N. latitude

Limited Entry North (LEN) = weekly + bimonthly limits

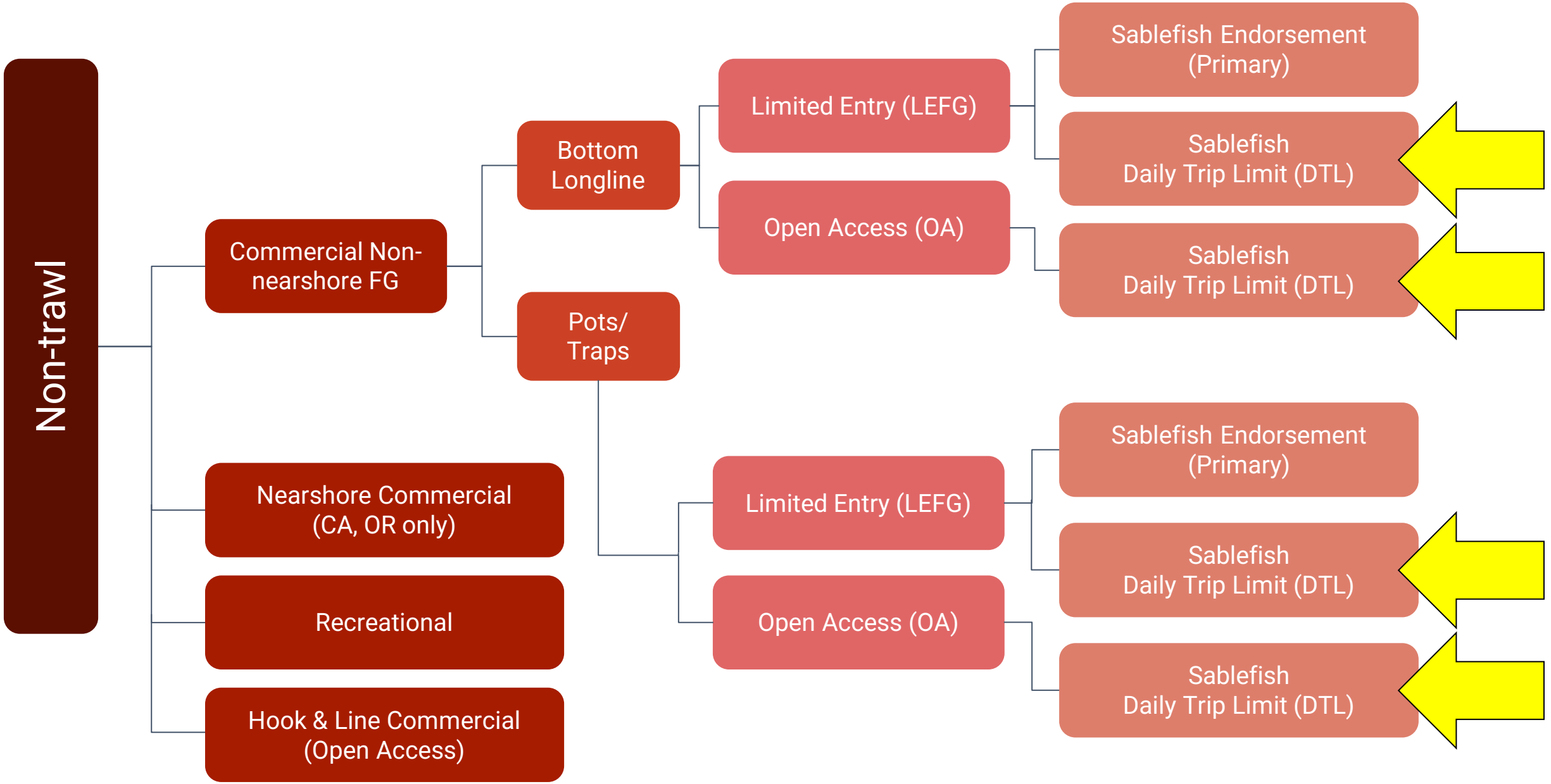
Limited Entry South (LES) = weekly limit

Open Access North (OAN) = ~~daily~~ + weekly + bimonthly limits

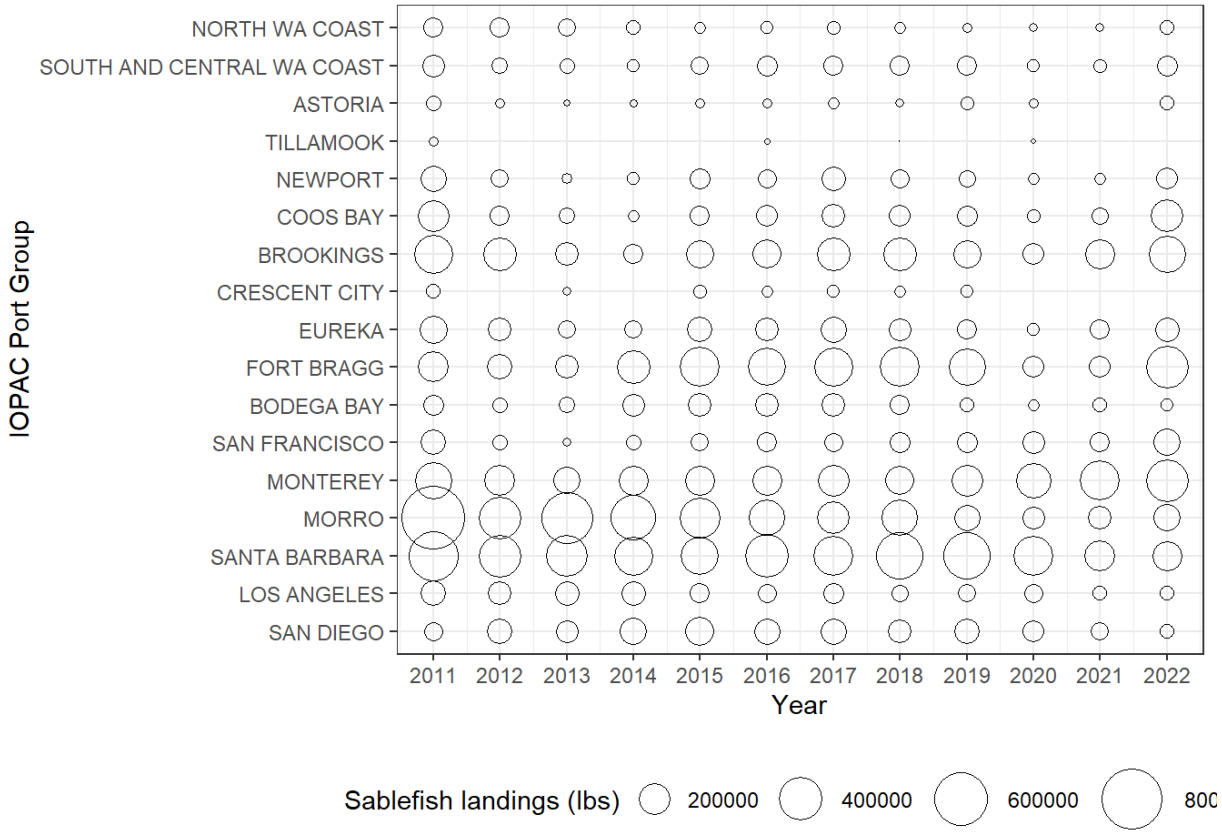
Open Access South (OAS) = weekly + bimonthly limits

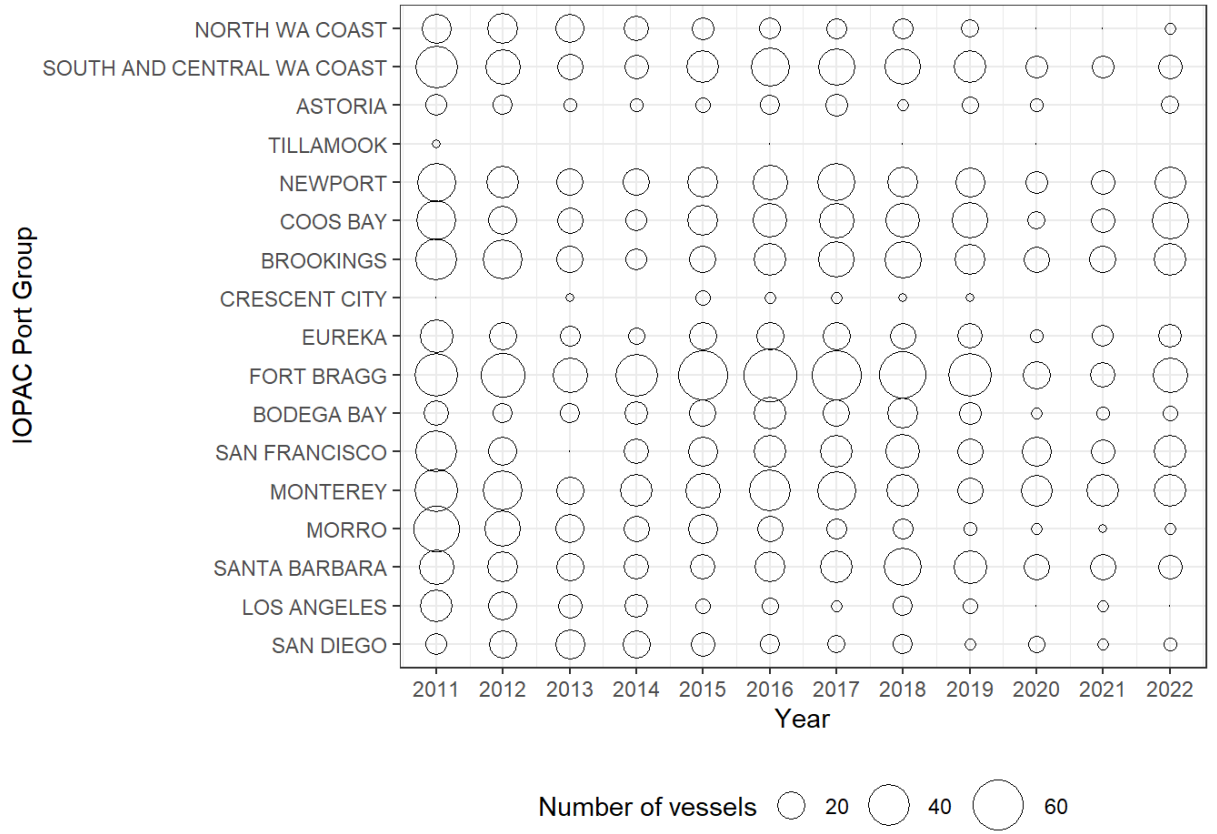
Sablefish landings (mt) by DTL sector, 2011-2022

Year	LEN	LES	OAN	OAS
2011	474	563	427	167
2012	250	378	257	73
2013	189	461	147	61
2014	144	443	257	35
2015	197	408	399	33
2016	229	388	373	25
2017	271	324	418	25
2018	240	393	359	21
2019	185	346	348	13
2020	159	259	175	4
2021	173	174	253	3
2022	312	180	550	2


Non-trawl
Commercial Non-nearshore FG
Bottom Longline
Limited Entry (LEFG)
Sablefish Endorsement (Primary)
Sablefish Daily Trip Limit (DTL)
Open Access (OA)
Sablefish Daily Trip Limit (DTL)
Pots/ Traps
Limited Entry (LEFG)
Sablefish Endorsement (Primary)
Sablefish Daily Trip Limit (DTL)
Open Access (OA)
Sablefish Daily Trip Limit (DTL)
Nearshore Commercial (CA, OR only)
Recreational
Hook & Line Commercial (Open Access)

Distribution of all DTL landings and participation by port





Model Inputs and Outputs

Notably weak predictions

Fleetwide landings = landings per vessel *x* number of vessels (by period)

Sector	Status Quo Inputs	Outputs
LEN	Weekly trip limits + bimonthly trip limits	landings per vessel
	Sablefish price/lb. (inflation adjusted)	# of vessels
OAN	Weekly trip limits	landings per vessel
	Sablefish price/lb. + period adjuster	# of vessels

$$Y_i = f(X_i, \beta) + ei$$

Limited Entry North (LEN)

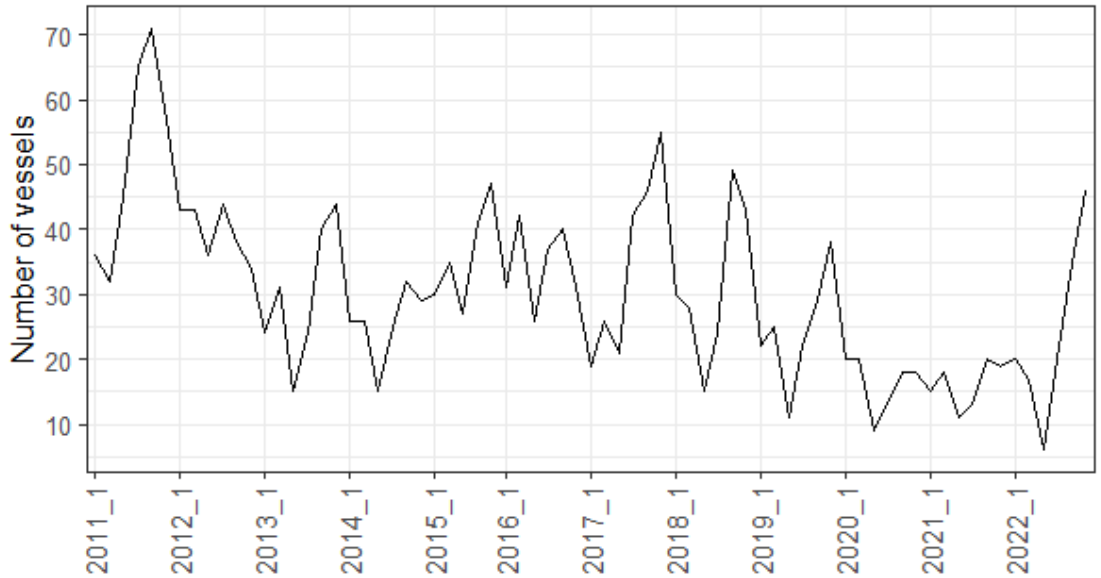
Section 2.1 – Current Model

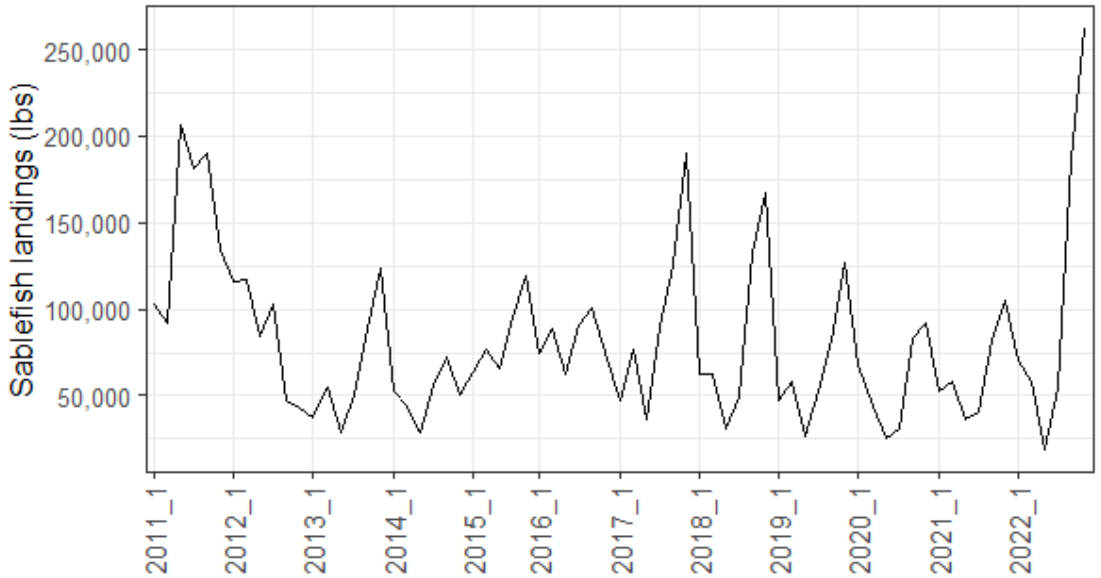
- Section 2.1.1 – Distribution Assumptions
- Section 2.1.2 – Model Run

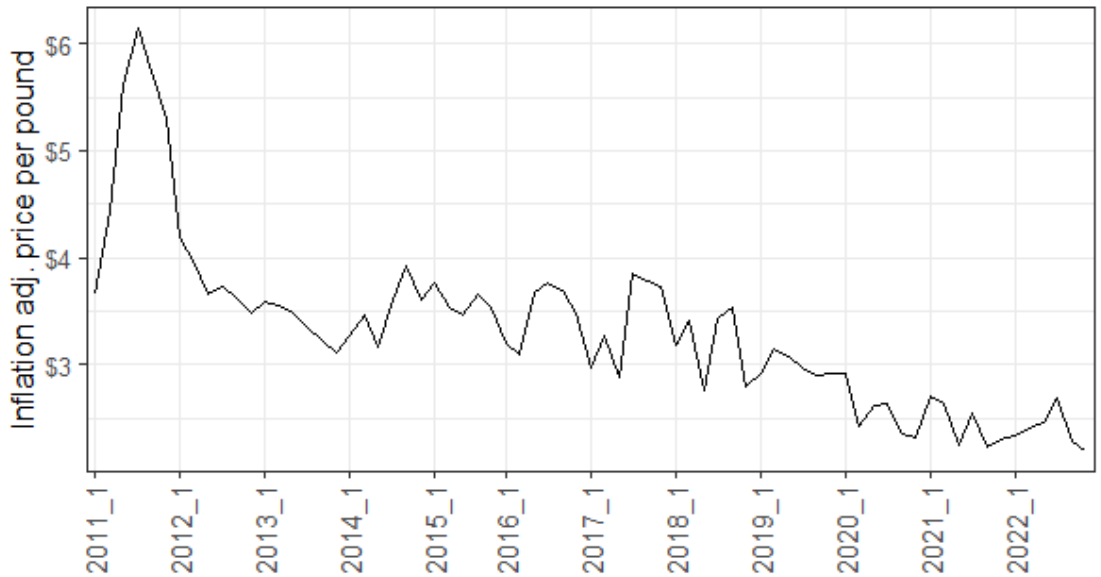
Section 2.2 – Potential Model Improvements

- Section 2.2.1 – Data Weights
- Section 2.2.2 – Log Transformation
- Section 2.2.3 – AFI Prices
- Section 2.2.4 – Dungeness Crab Prices
- Section 2.2.5 – Fuel Prices
- Section 2.2.6 – Generalized Linear Model (GLM)

Section 2.1 – Current Model







Time (Year_Period)

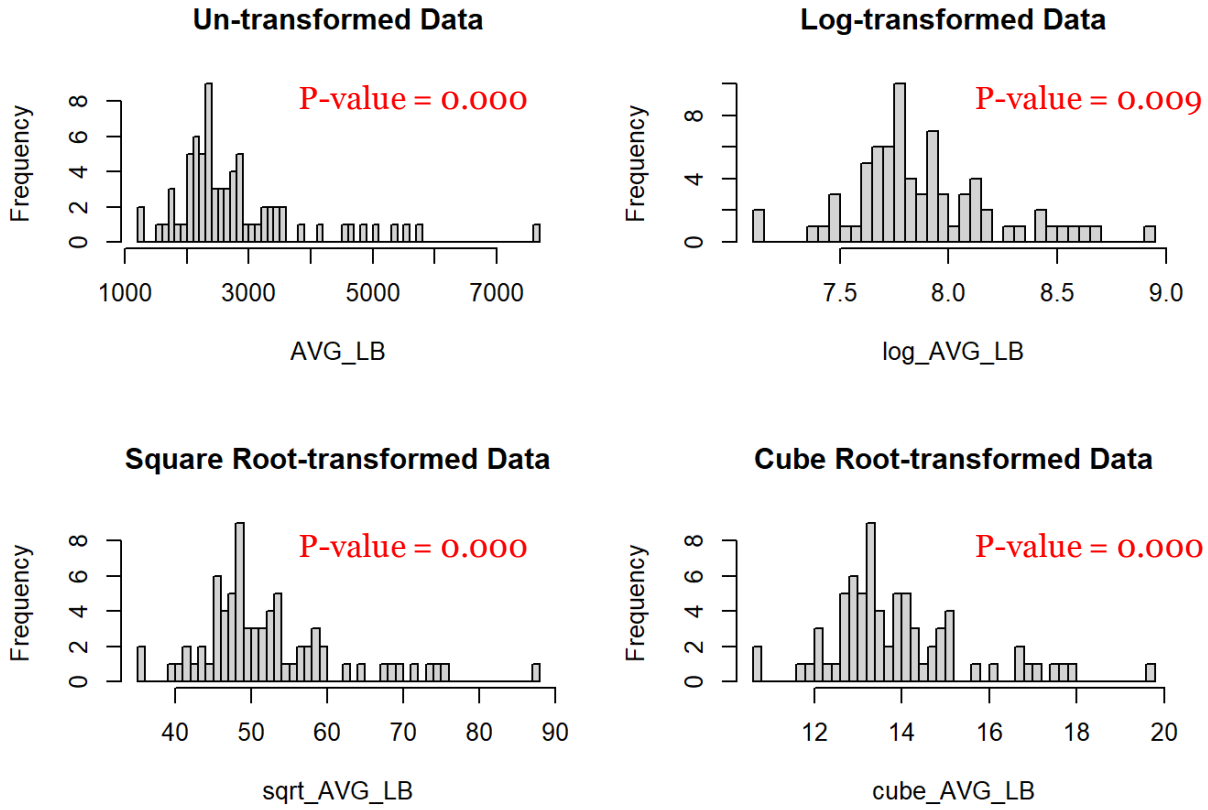
LEN

Section 2.1.1 – Distribution Assumptions

Average landings per vessel

- Historical data for average landings per vessel (response variable) are not normally distributed
- Log transformation normalizes the data more than square-root or cube-root transformations

Value	Raw	Log	Square Root	Cube Root
Skewness	1.820	0.666	1.244	1.053
Skewness p-value	0.000	0.012	0.000	0.000
Kurtosis	3.994	0.728	1.866	1.382
Kurtosis p-value	0.000	0.104	0.001	0.009



*p-value for Shapiro-Wilk normality test

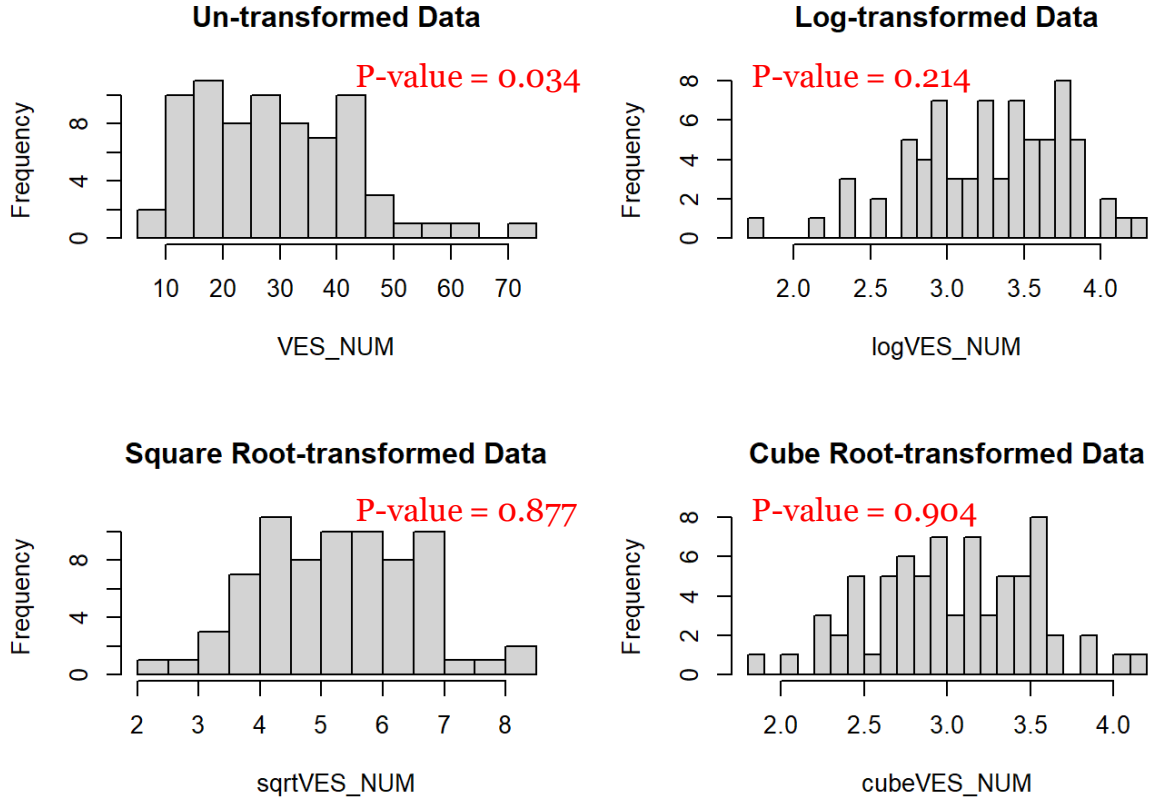
LEN

Section 2.1.1 – Distribution Assumptions

Number of Vessels

- Historical data for number of vessels (response variable) are not normally distributed
- However, the raw data are near-normal (p-value = 0.034) and there are no major outliers that could skew the data
- A negative binomial distribution is explored using GLMs

Value	Raw	Log	Square Root	Cube Root
Skewness	0.636	-0.496	0.095	-0.092
Skewness p-value	0.015	0.956	0.371	0.626
Kurtosis	0.146	-0.029	-0.464	-0.453
Kurtosis p-value	3.000	0.520	0.789	0.784

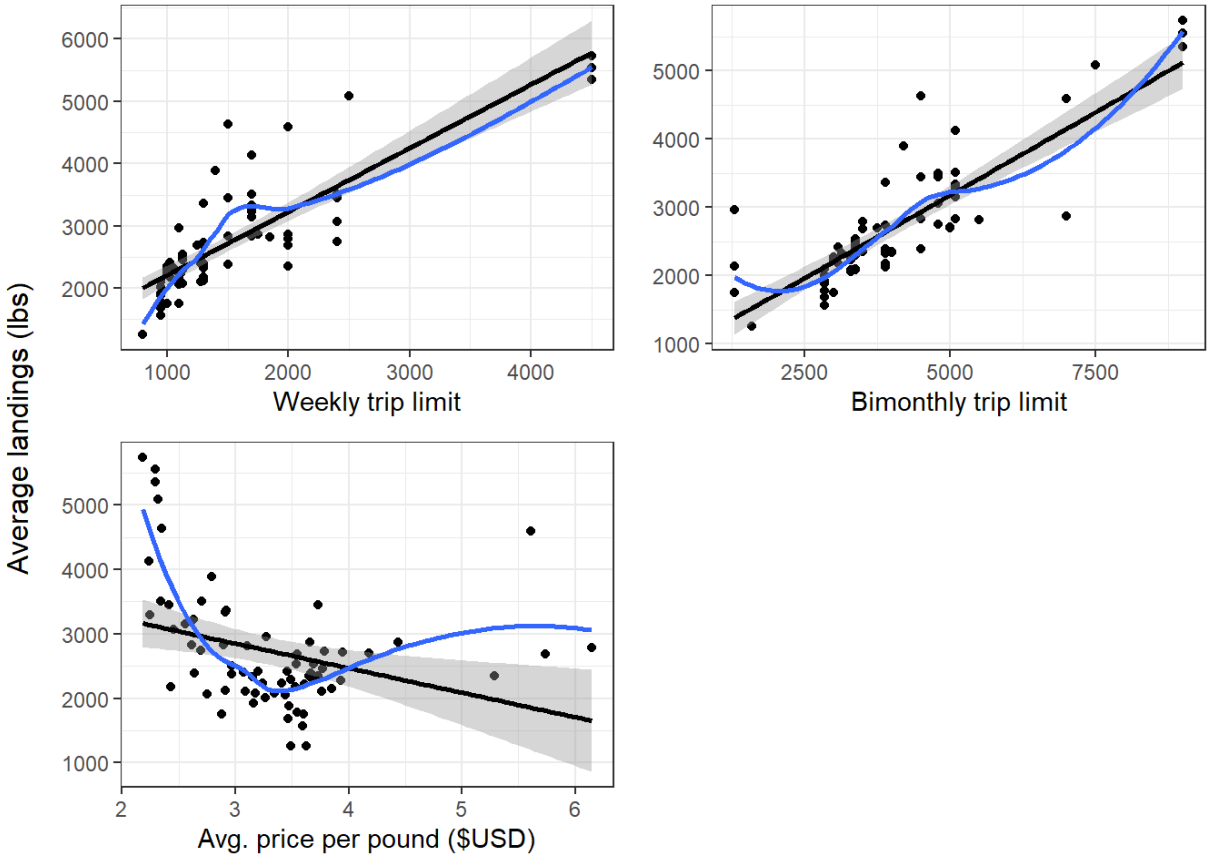


*p-value for Shapiro-Wilk normality test

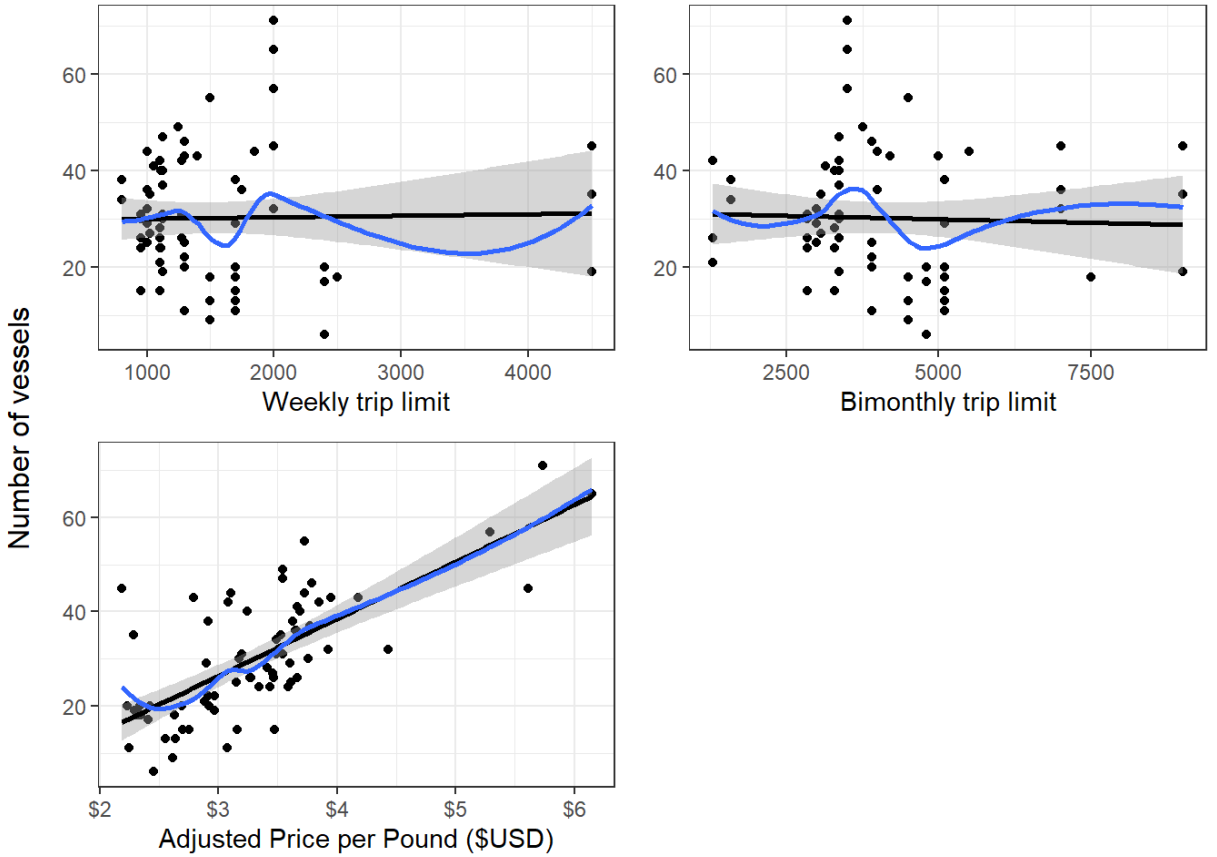
LEN

Section 2.1.2 – Model Run

Response variable = average landings per vessel



Response variable = number of vessels



LEN

Section 2.1.2 – Model Run

Response variable = average landings per vessel

	Weekly	Bimonthly	Wkly + Bimon	Wkly + Bimon + Wkly:Bimon
(Intercept)	1190.48 ***	745.91 ***	798.69 ***	622.17
	(141.06)	(165.47)	(153.16)	(361.61)
TL.WEEKLY	1.02 ***		0.50 ***	0.65 *
	(0.08)		(0.14)	(0.31)
TL.BIMON		0.49 ***	0.29 ***	0.31 ***
		(0.04)	(0.06)	(0.08)
TL.WEEKLY:TL.BIMON				-0.00
				(0.00)
N	71	71	71	71
R2	0.68	0.71	0.75	0.76

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
LEN_land_mod <- lm(AVG_LB ~ TL.WEEKLY + TL.BIMON, data = LEN)
summary(LEN_land_mod)
```

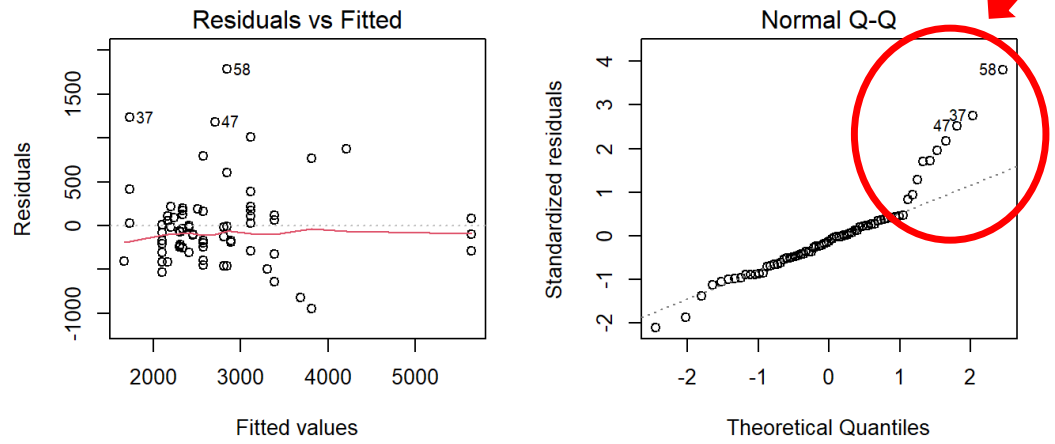
```
##
## Call:
## lm(formula = AVG_LB ~ TL.WEEKLY + TL.BIMON, data = LEN)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -945.24 -271.15  -58.84  141.74 1784.14
##
## Coefficients:
##             Estimate Std. Error t value   Pr(>|t|)
## (Intercept) 798.69376  153.15936   5.215 0.00000188 ***
## TL.WEEKLY     0.50295    0.13809   3.642   0.000523 ***
## TL.BIMON      0.28713    0.06472   4.436 0.00003433 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 472.4 on 68 degrees of freedom
## Multiple R-squared:  0.7546, Adjusted R-squared:  0.7474
## F-statistic: 104.6 on 2 and 68 DF,  p-value: < 0.0000000000000022
```

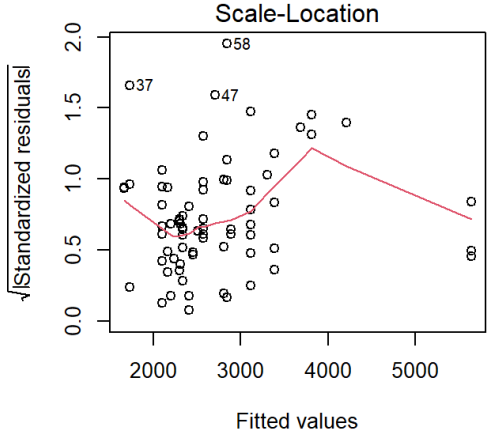
LEN

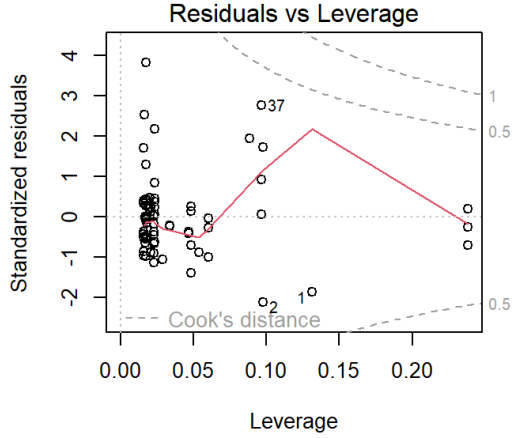
Section 2.1.2 – Model Run

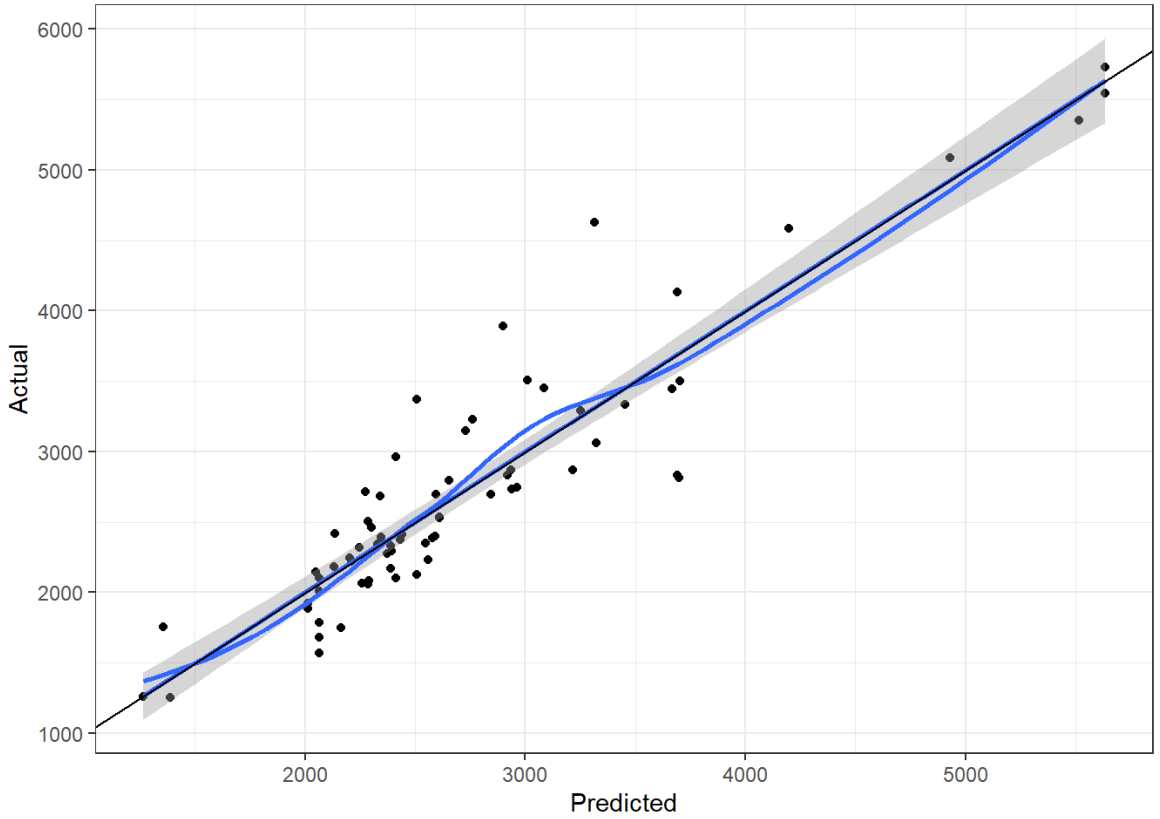
Response variable = average landings per vessel

Very likely due to high sablefish ACLs in recent years









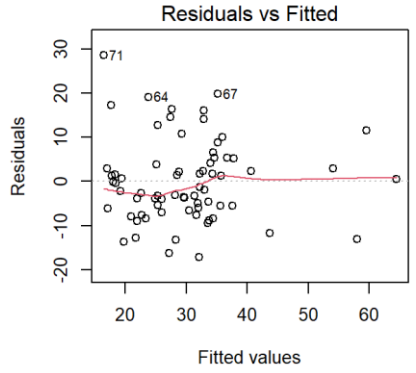
LEN

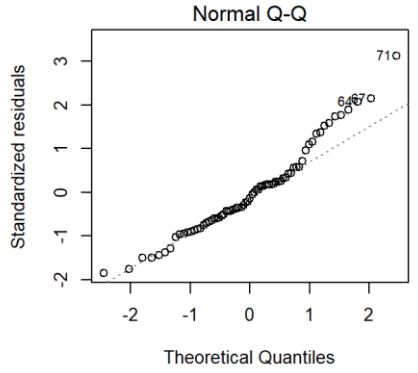
Section 2.1.2 – Model Run

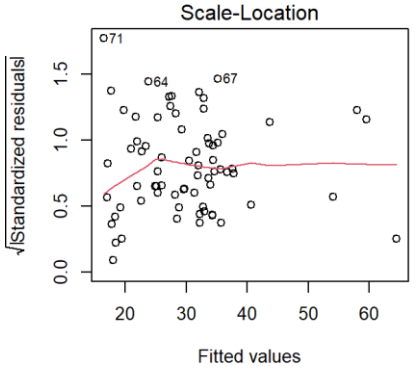
Response variable = number of vessels

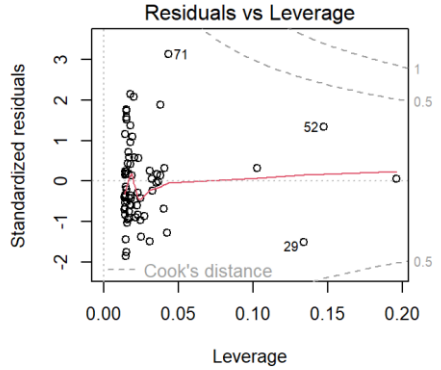
```
LEN_ves_mod <- lm(VES_NUM ~ ADJ_PRICE, data = LEN)
summary(LEN_ves_mod)
```

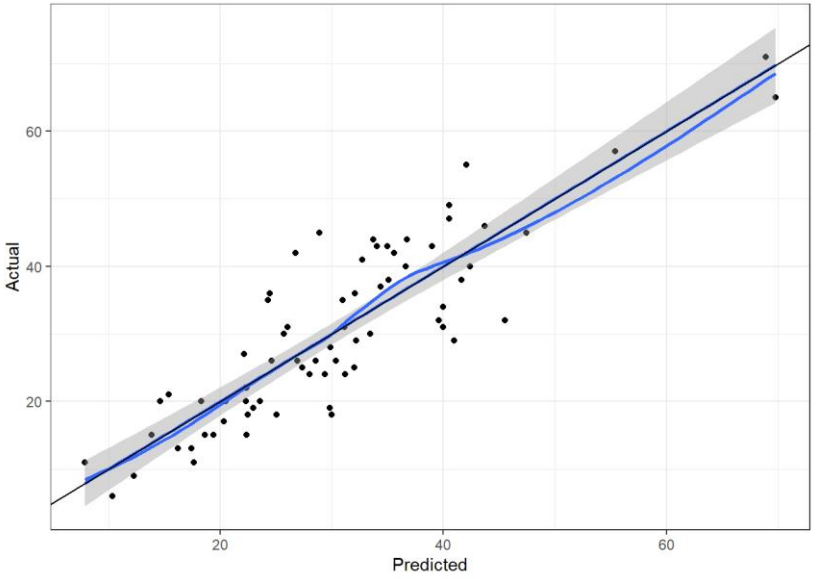
```
##
## Call:
## lm(formula = VES_NUM ~ ADJ_PRICE, data = LEN)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -17.116  -6.108  -1.271   3.979  28.534
##
## Coefficients:
##             Estimate Std. Error t value         Pr(>|t|)
## (Intercept)  -10.013      4.792  -2.090           0.0403 *
## ADJ_PRICE     12.120      1.405   8.624 0.00000000000144 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.32 on 69 degrees of freedom
## Multiple R-squared:  0.5188, Adjusted R-squared:  0.5118
## F-statistic: 74.38 on 1 and 69 DF,  p-value: 0.000000000001444
```









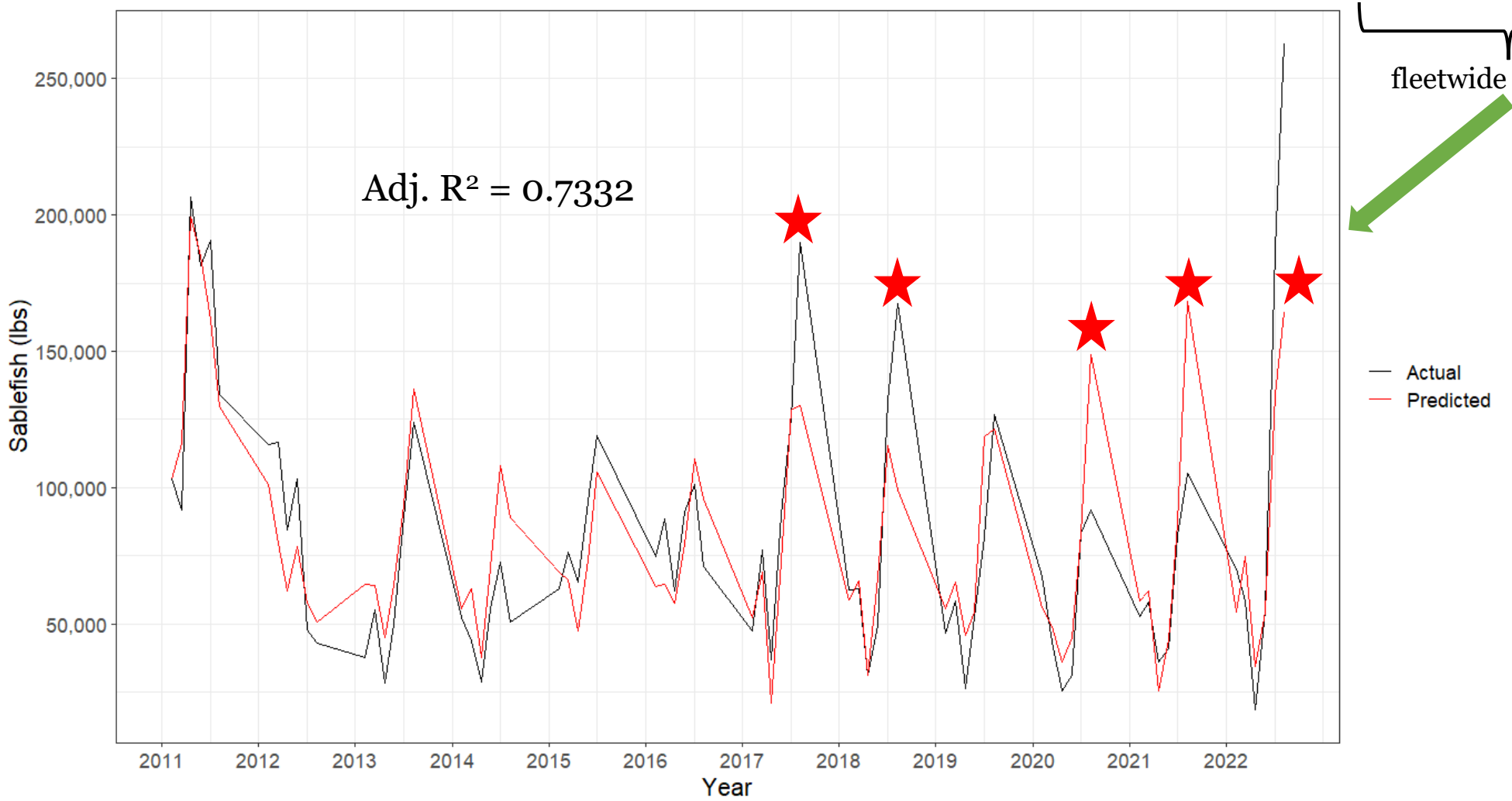


LEN

Section 2.1.2 – Model Run

LEN	Weekly trip limits + bimonthly trip limits	landings per vessel
	Sablefish price/lb. (inflation adjusted)	# of vessels

fleetwide landings



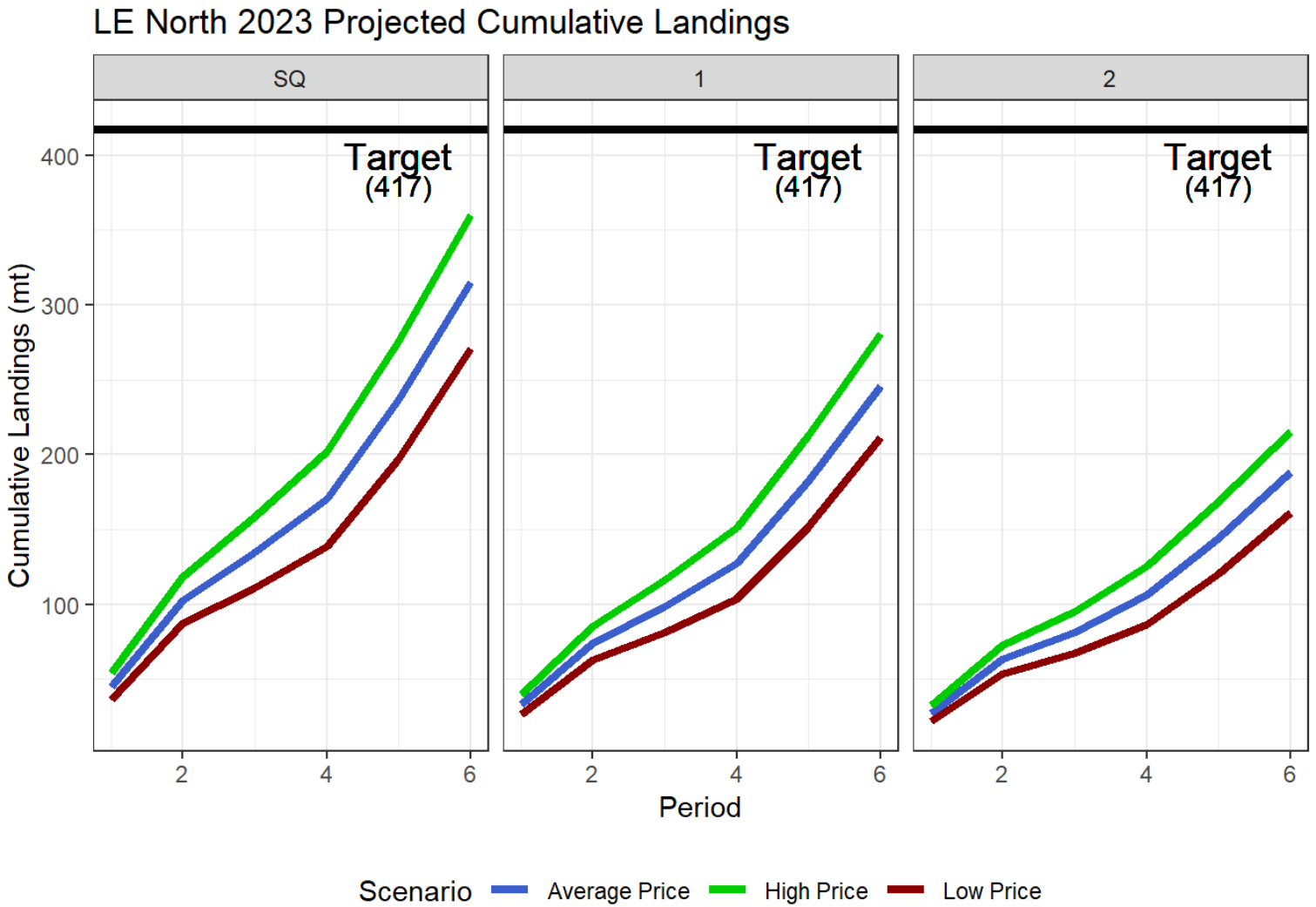
★ Under-predicts 2017, 2018, & 2022

★ Over-predicts 2020 & 2021

LEN

Section 2.1.2 – Model Run

Example of inseason projections used in Council decision making for trip limit adjustments



LEN

Section 2.2 – Potential Model Improvements

Section 2.2.1 – Data Weights

- Most recent year (2022) up-weighted using a score of 5 whereas all prior years receive a score of 1
- Up-weighting most recent year only improves the prediction of average landings per vessel but not number of vessels

Response variable = average landings per vessel

	SQ Model	Data Weighting
(Intercept)	798.69 ***	777.28 ***
	(153.16)	(141.59)
TL.WEEKLY	0.50 ***	0.42 ***
	(0.14)	(0.12)
TL.BIMON	0.29 ***	0.32 ***
	(0.06)	(0.06)
N	71	71
R2	0.75	0.86

*** p < 0.001; ** p < 0.01; * p < 0.05.

Response variable = number of vessels

	SQ Model	Data Weighting
(Intercept)	-10.01 *	-2.73
	(4.79)	(5.17)
ADJ_PRICE	12.12 ***	10.15 ***
	(1.41)	(1.62)
N	71	71
R2	0.52	0.36

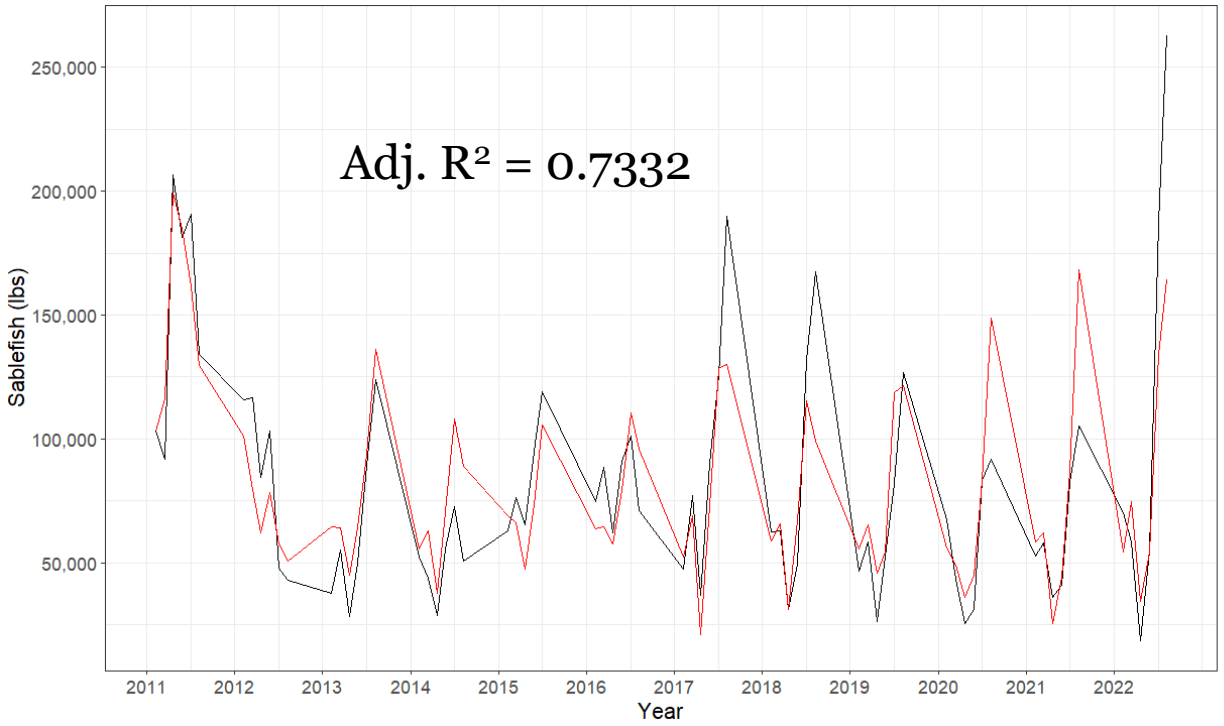
*** p < 0.001; ** p < 0.01; * p < 0.05.

LEN

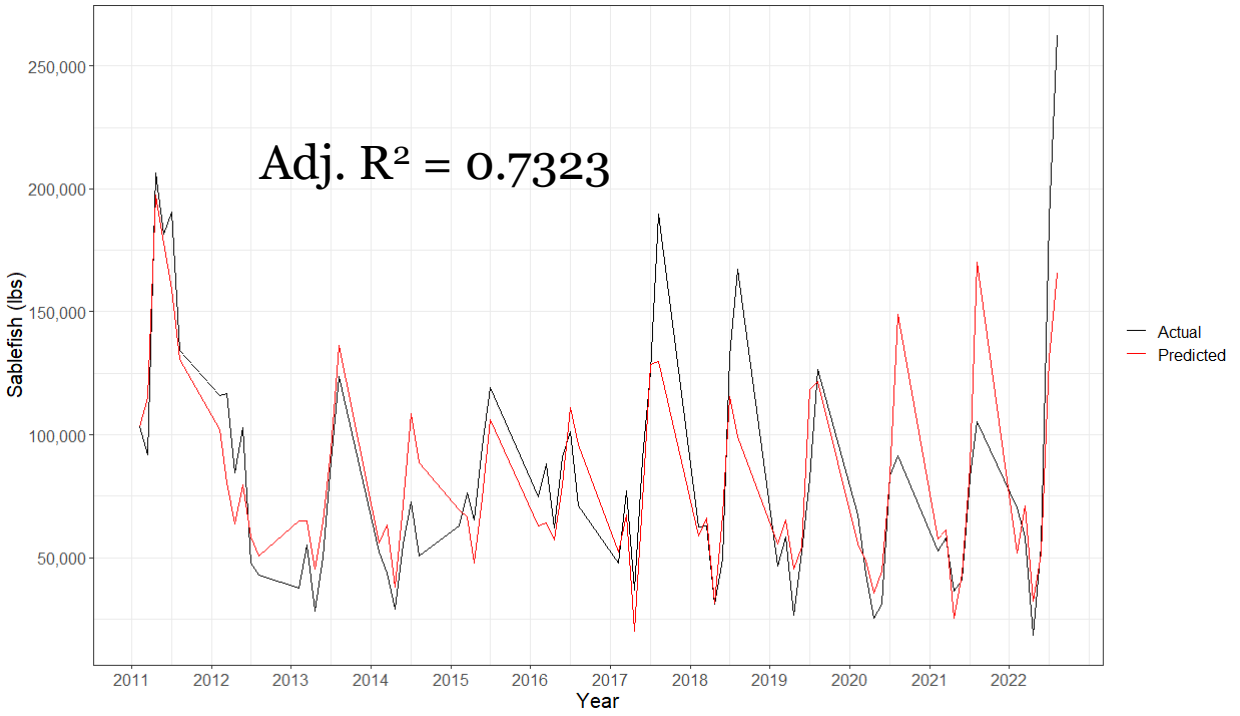
Section 2.2.1 – Data Weights

Very little difference when most recent year is upweighted, compared to not using data weights

Status Quo Model



Data Weights



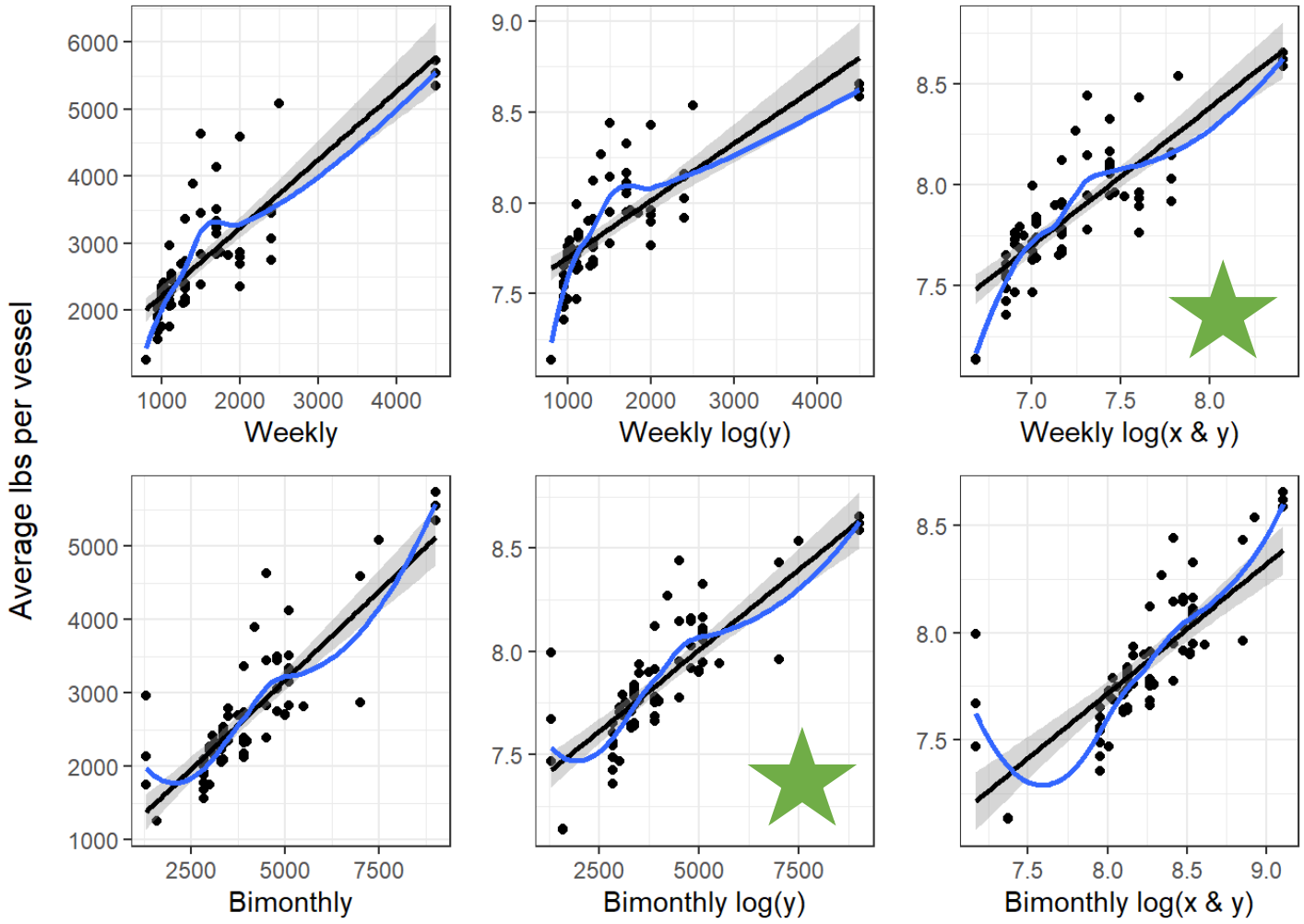
LEN

Section 2.2.2 – Log Transformation

★ Closest linear relationships

Response variable = average landings per vessel

Relationships between un-transformed and log-transformed predictor variables to the response variable average landings per vessel



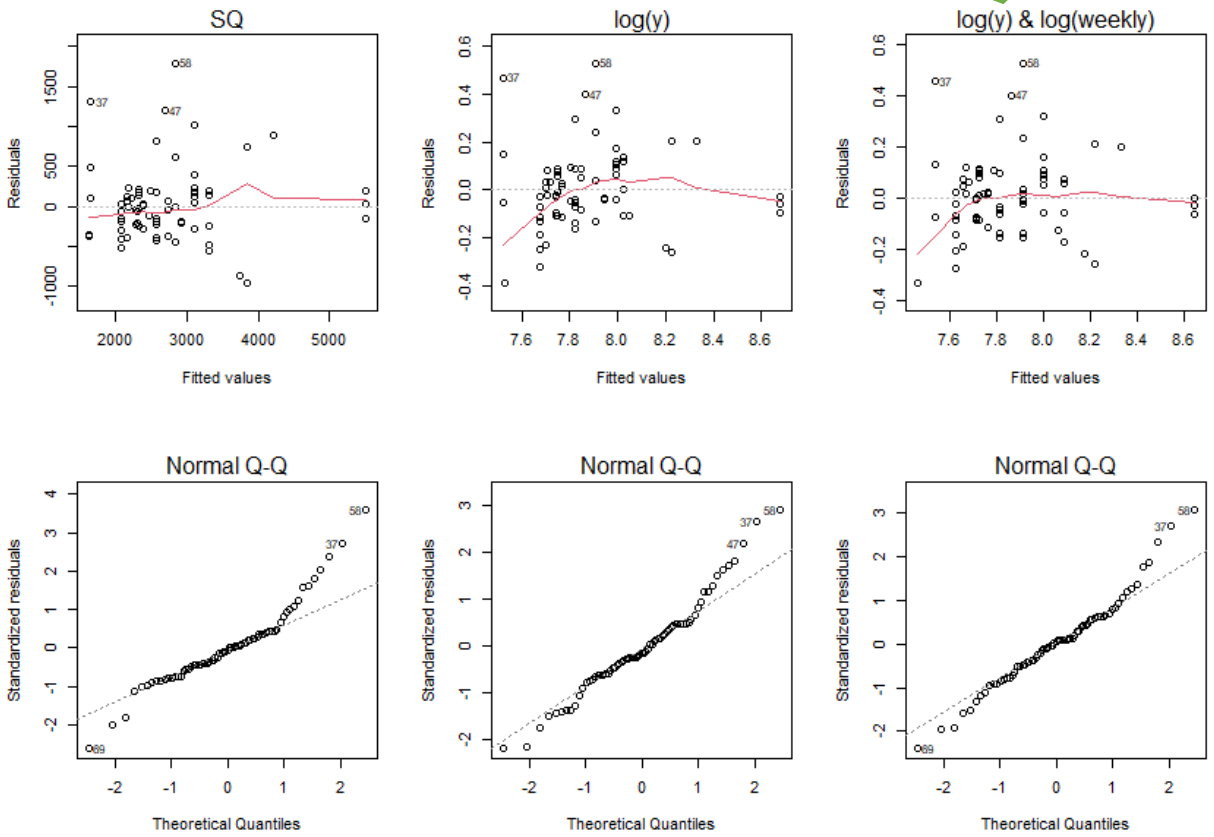
LEN

Section 2.2.2 – Log Transformation

Response variable = average landings per vessel

	SQ	log(y)	log(y) & log(wkly)	log(y) & log(wkly) + log(bimo)
(Intercept)	777.28 ***	7.28 ***	5.23 ***	2.43 ***
	(141.59)	(0.05)	(0.52)	(0.36)
TL.WEEKLY	0.42 ***	0.00 *		
	(0.12)	(0.00)		
TL.BIMON	0.32 ***	0.00 ***	0.00 ***	
	(0.06)	(0.00)	(0.00)	
log(TL.WEEKLY)			0.31 ***	0.40 ***
			(0.08)	(0.07)
log(TL.BIMON)				0.31 ***
				(0.08)
N	71	71	71	71
R2	0.86	0.79	0.82	0.81

*** p < 0.001; ** p < 0.01; * p < 0.05.

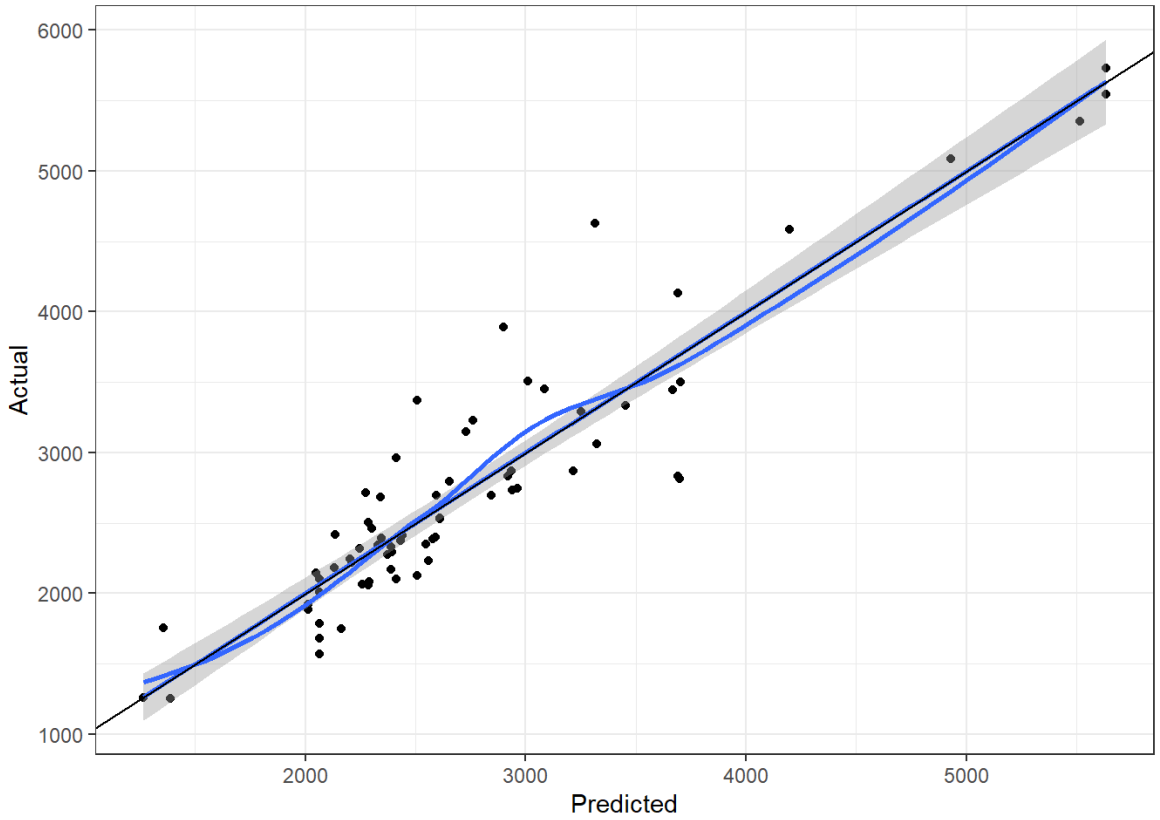


Slight improvement to the model diagnostics

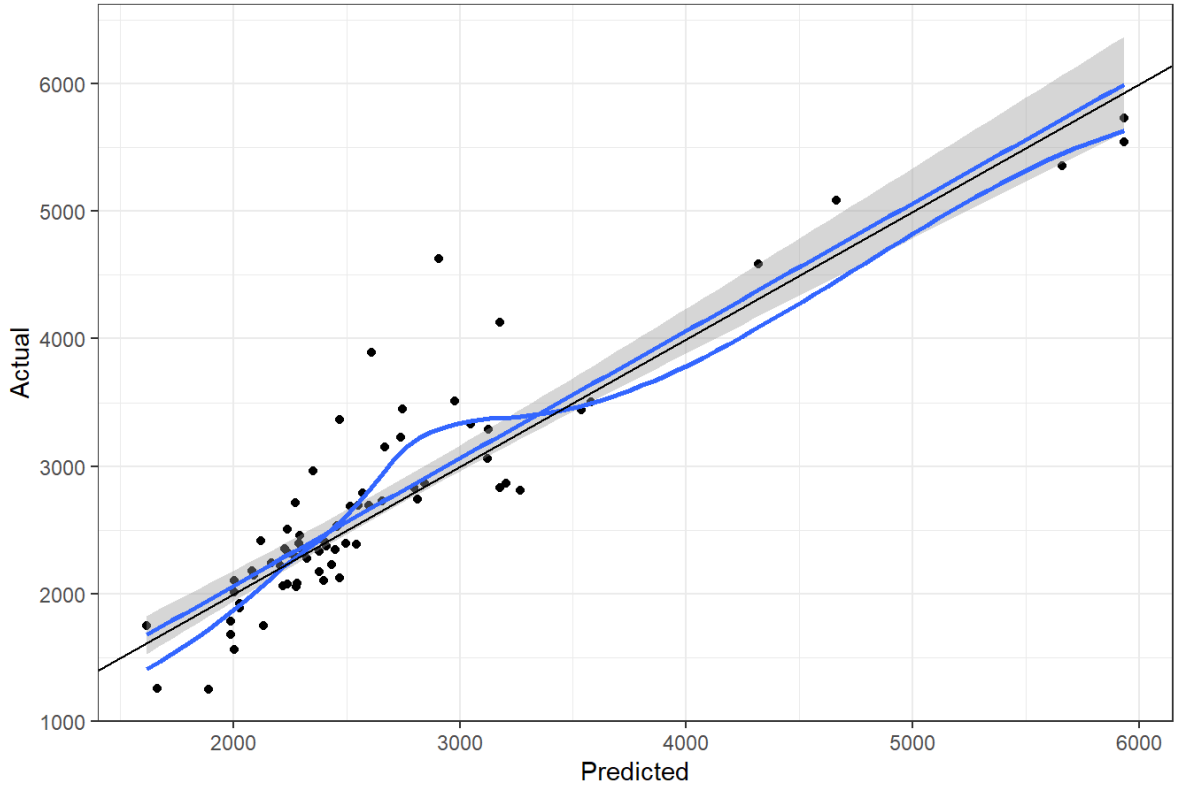
Section 2.2.2 – Log Transformation

Response variable = average landings per vessel

Status Quo Model



Log Transformation



LEN

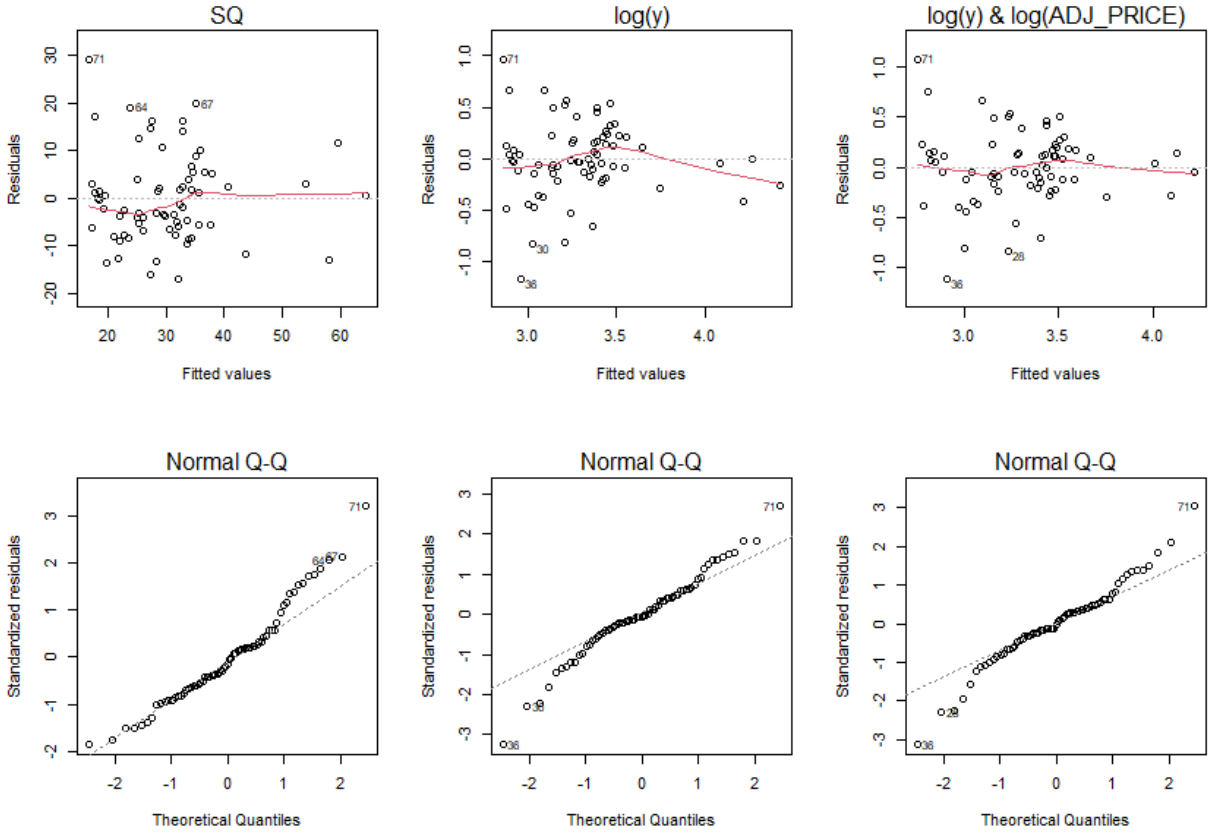
Section 2.2.2 – Log Transformation

Response variable = number of vessels

	SQ	log(y)	log(y) & log(avg price)
(Intercept)	-10.01 *	1.98 ***	1.62 ***
	(4.79)	(0.19)	(0.23)
ADJ_PRICE	12.12 ***	0.40 ***	
	(1.41)	(0.06)	
log(ADJ_PRICE)			1.43 ***
			(0.20)
N	71	71	71
R2	0.52	0.43	0.44

*** p < 0.001; ** p < 0.01; * p < 0.05.

Log-transforming introduces heteroskedasticity

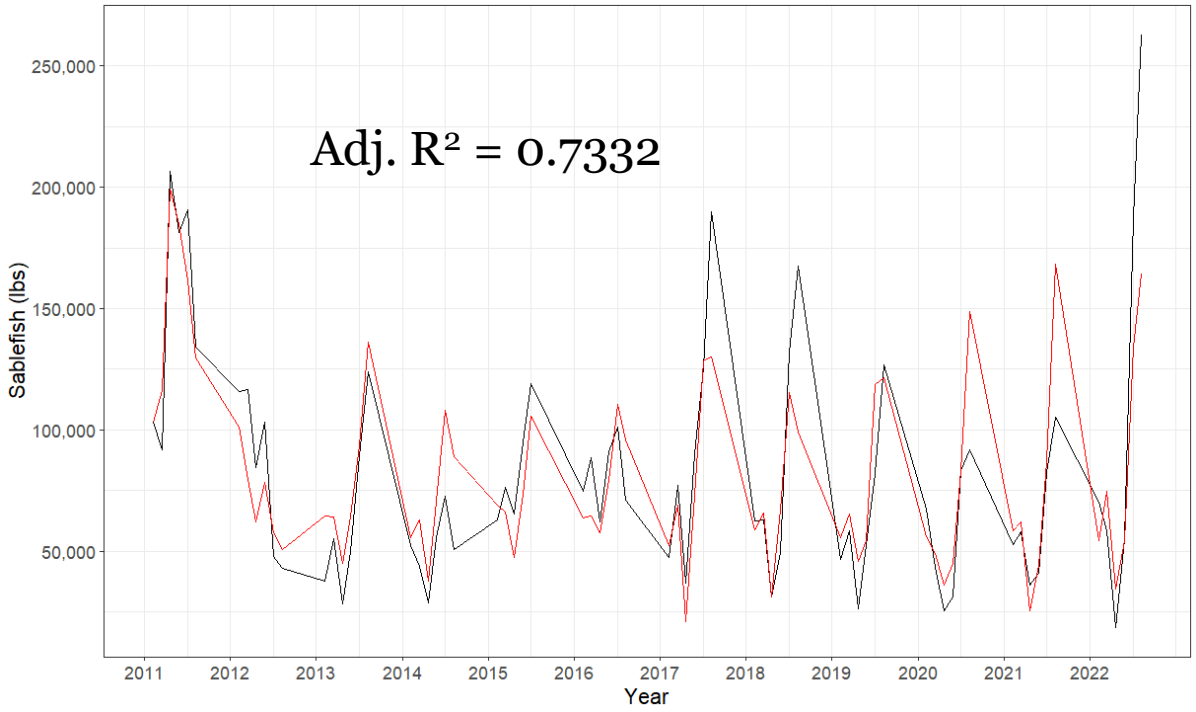


LEN

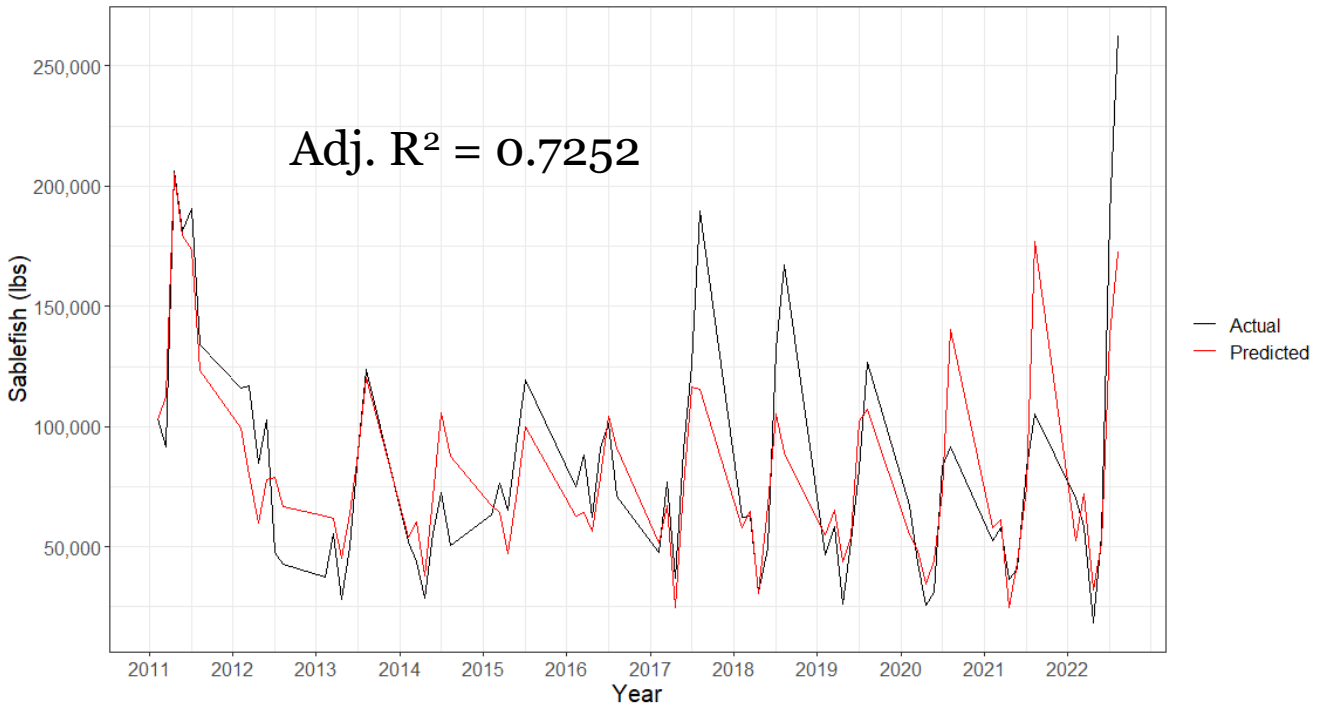
Section 2.2.2 – Log Transformation

- **Final approach:** Log-transform the average landings per vessel response variable and the weekly limit predictor variable only and up-weight the most recent year of landings per vessel data
- Fit to historical data is slightly lower but log-transforming average landings per vessel improves model diagnostics

Status Quo Model



Data Weights + Log Transformation



LEN

Section 2.2.3 – AFI Prices

- Inflation-adjusted prices are currently calculated with (by period):

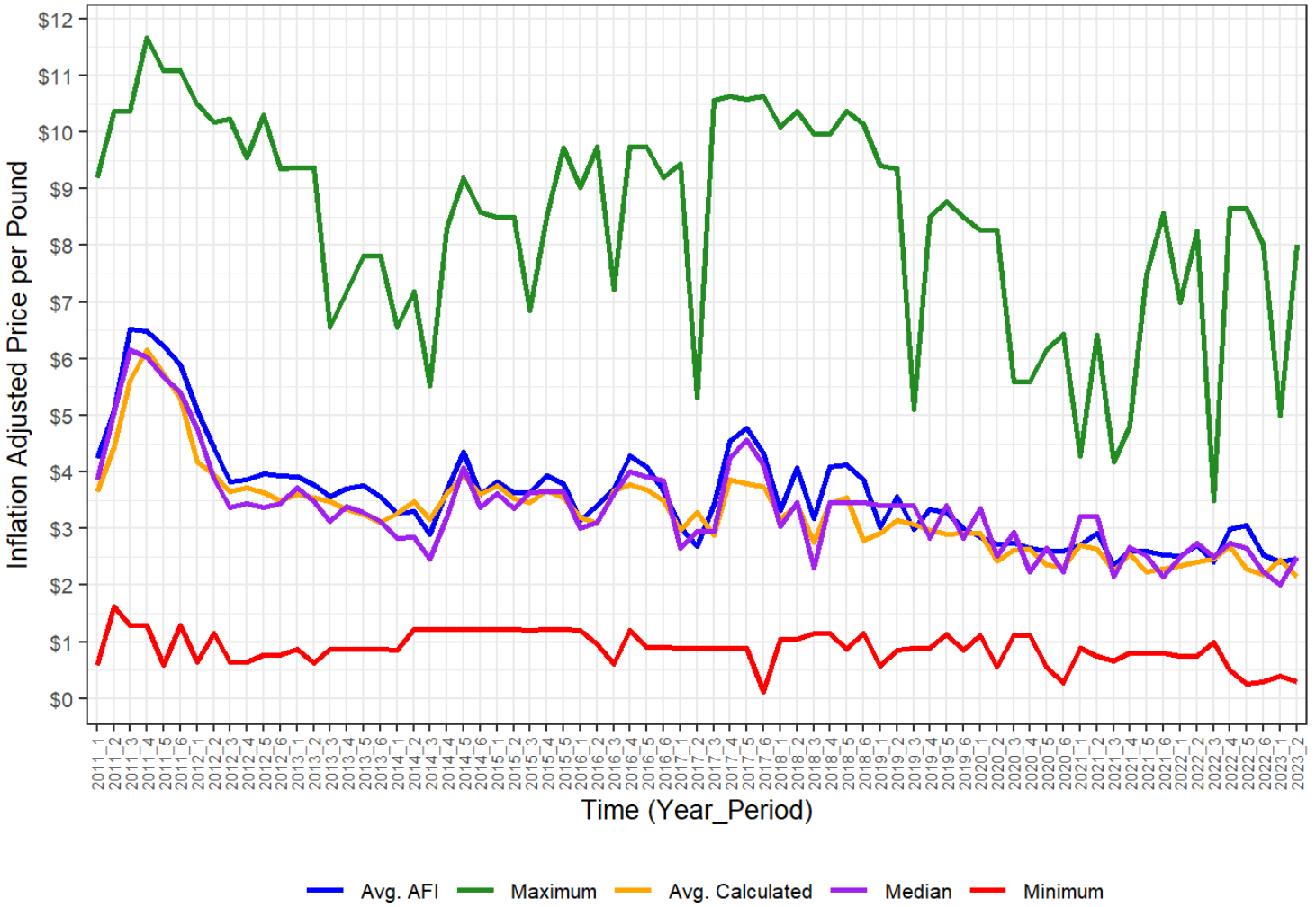
$$Infl.Adj.Price\ per\ Pound = \frac{(Exvessel\ Value/Round\ Weight\ Lbs.)}{Price\ Index}$$

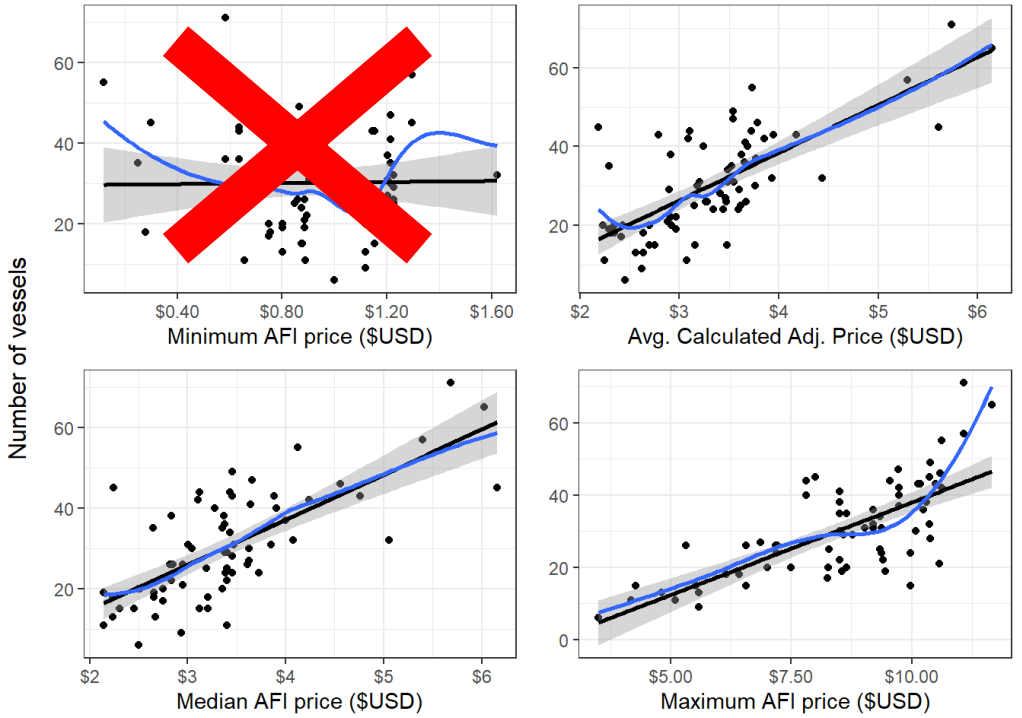
- AFI_PRICE_PER_POUND -> new field in PacFIN that includes pre-adjusted prices
- GMT concluded that maintaining calculation method is most appropriate but using AFI_EXVESSEL_REVENUE instead of manually applying a price index
- AFI_PRICE_PER_POUND still used to explore minimum, median, and maximum price covariates

hypothetical comparison 

	Lbs. Landed	Revenue	Price per Lb.	Price Re-Calculated
Fish Ticket A	10,000	$30,000	$3.00	$3.00
Fish Ticket B	1,000	$5,000	$5.00	$5.00
Combined	11,000	$35,000	**$4.00**	**$3.18**

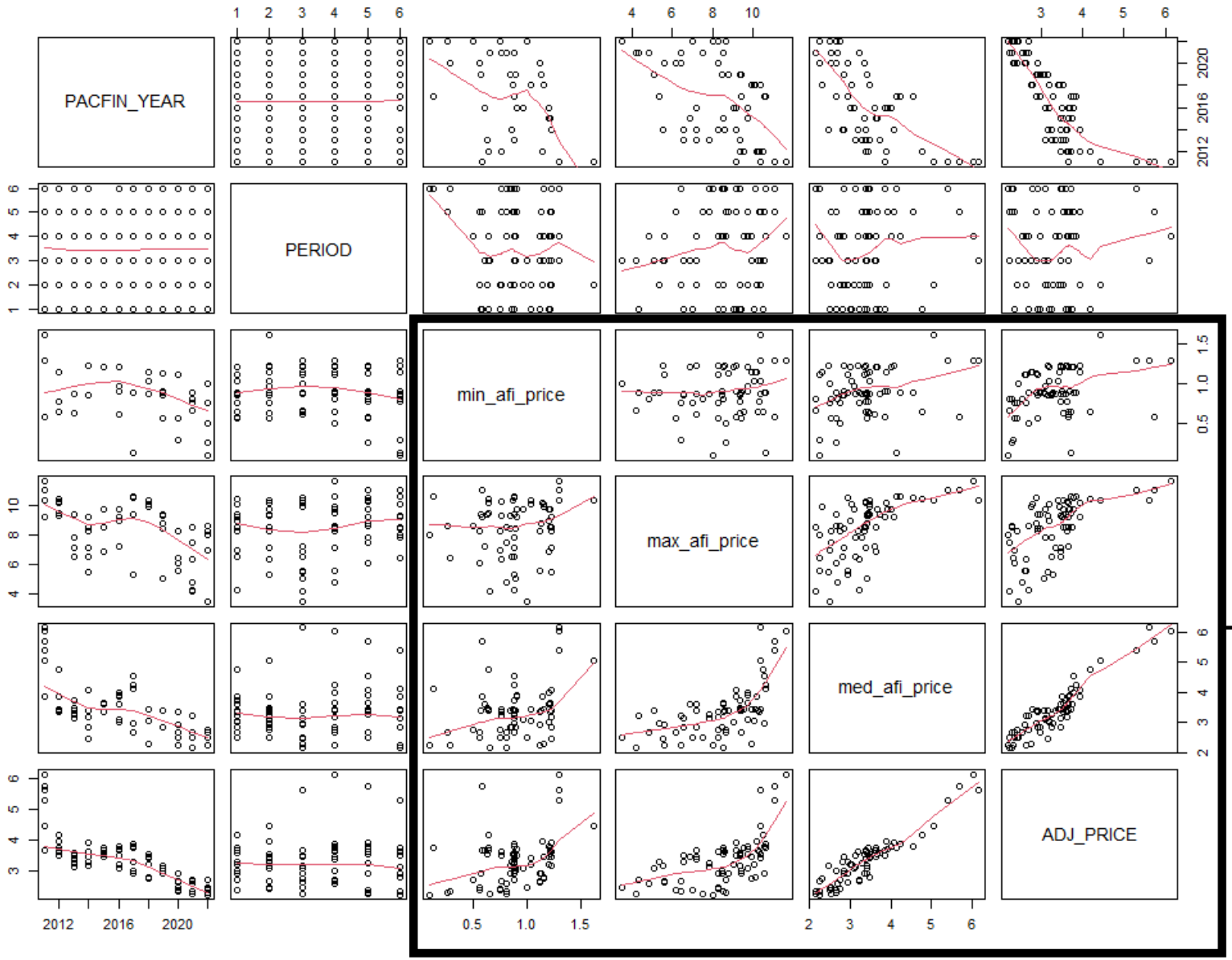
Section 2.2.3 – AFI Prices





LEN

Section 2.2.3 – AFI Prices



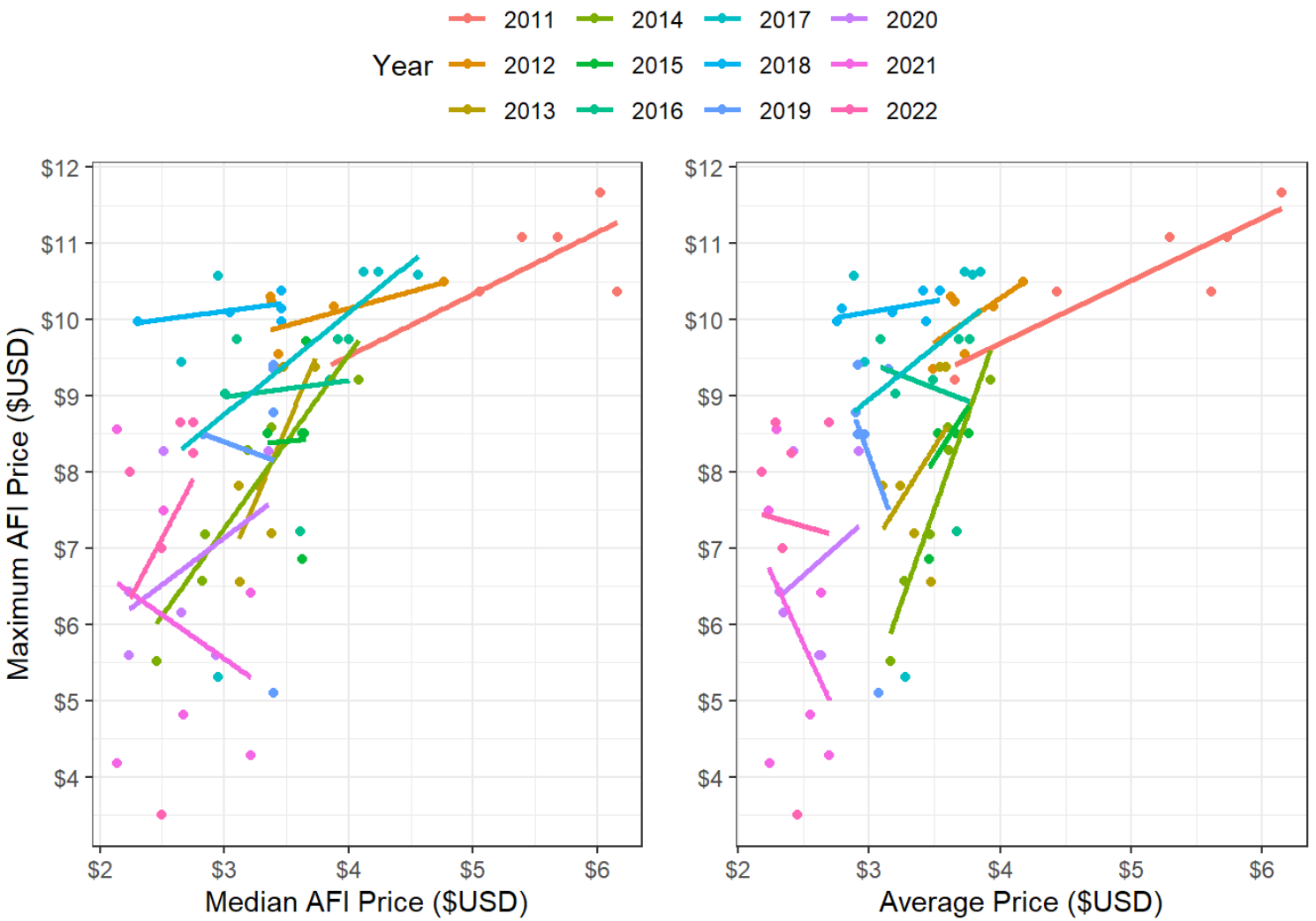
Minimum = no obvious correlation

Maximum = non-linear correlation with median and average

Median = linear correlation with average

LEN

Section 2.2.3 – AFI Prices



Median and average price correlation does not show a clear pattern across years

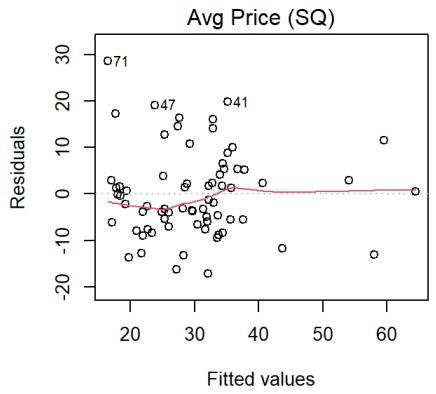
LEN

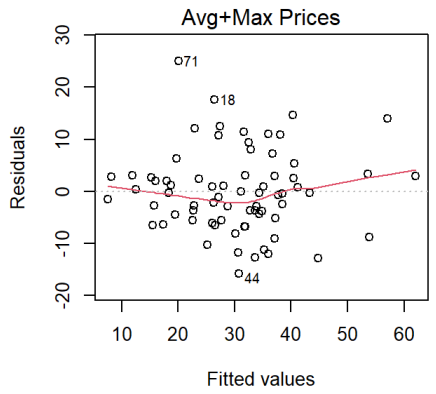
Section 2.2.3 – AFI Prices

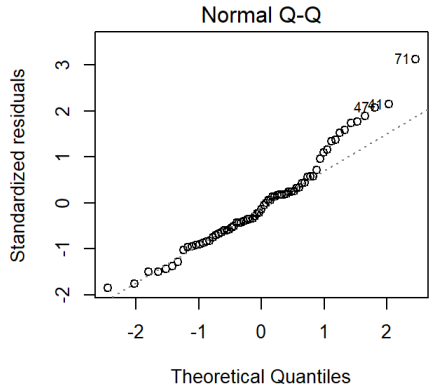
Response variable = number of vessels

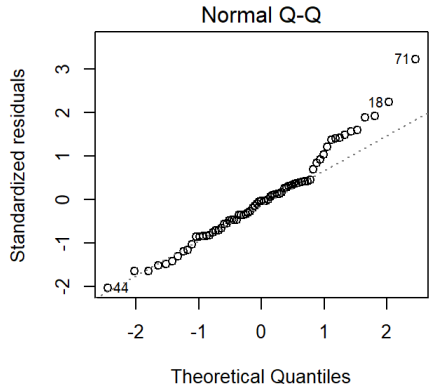
	Model SQ	Max AFI Price	Avg+Max AFI Price	Med AFI Price	Med+Max AFI Price
(Intercept)	-10.01 *	-13.16 *	-22.48 ***	-7.50	-20.40 ***
	(4.79)	(5.12)	(4.74)	(4.58)	(4.70)
ADJ_PRICE	12.12 ***		7.61 ***		
	(1.41)		(1.48)		
max_afi_price		5.11 ***	3.23 ***		3.24 ***
		(0.59)	(0.62)		(0.64)
med_afi_price				11.16 ***	6.85 ***
				(1.32)	(1.42)
N	71	71	71	71	71
R2	0.52	0.52	0.66	0.51	0.64

*** p < 0.001; ** p < 0.01; * p < 0.05.









Likelihood ratio test to determine statistical significance of adding maximum AFI price

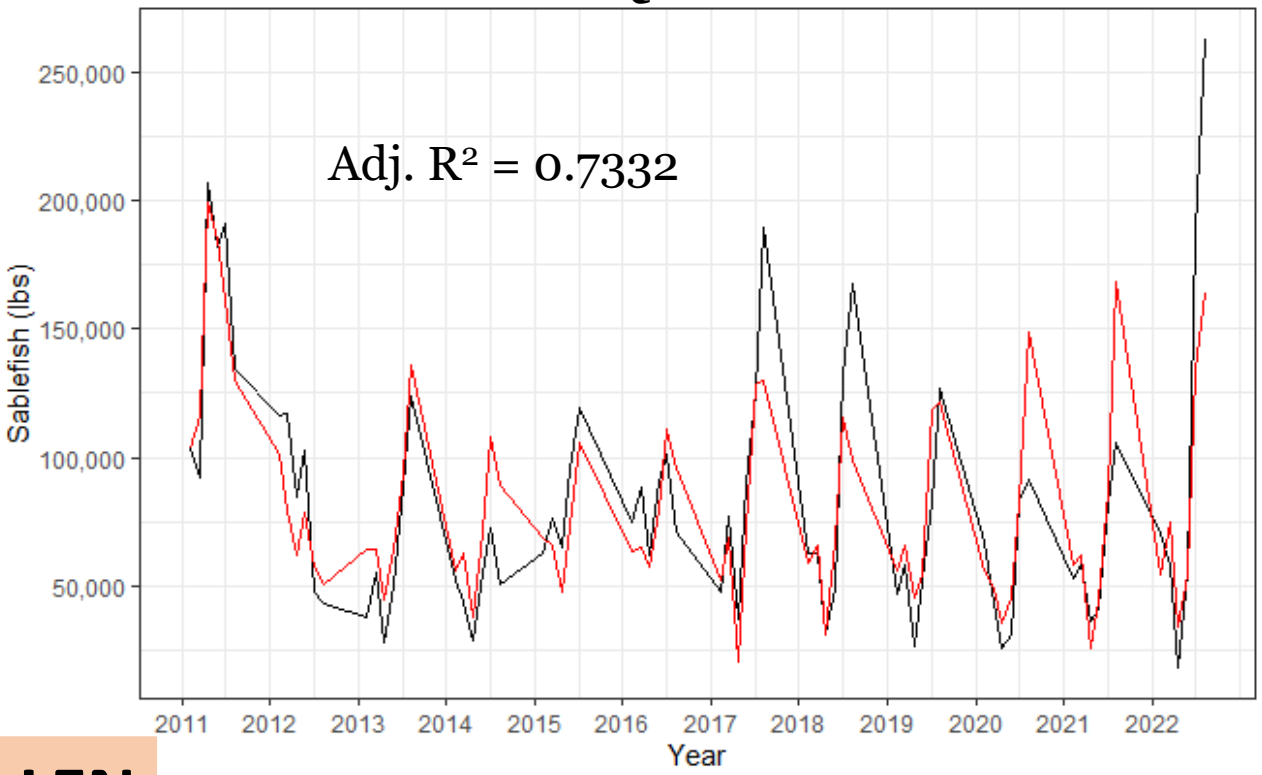
#Df	LogLik	Df	Chisq	Pr(>Chisq)
4	-246			
3	-258	-1	23.4	1.34e-06

LEN

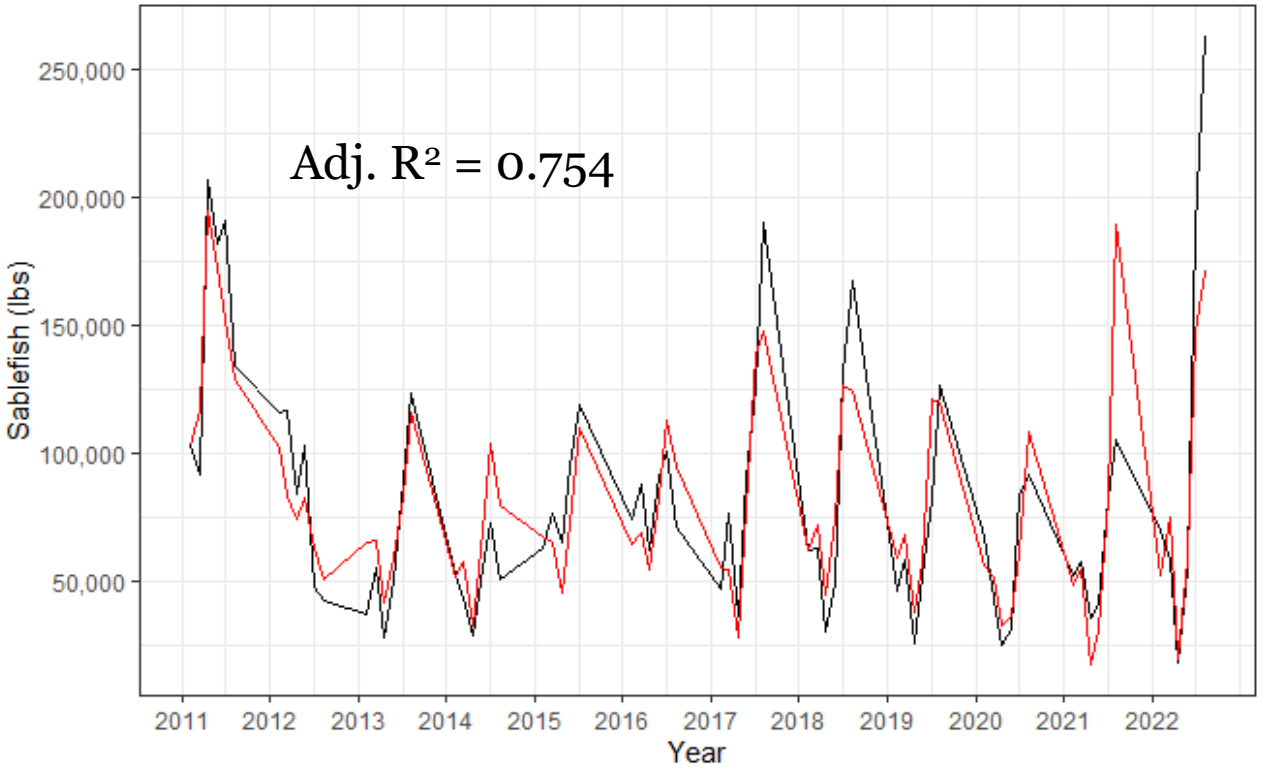
Section 2.2.3 – AFI Prices

- **Final approach:**
  - Log-transform average landings per vessel and weekly limit
  - Up-weight the most recent year of landings per vessel data
  - Add maximum sablefish price per pound to predict number of vessels
- Fit to historical data is higher and better predicts 2017-2021

Status Quo Model



Data Weights + Log Transformation + Maximum AFI Price

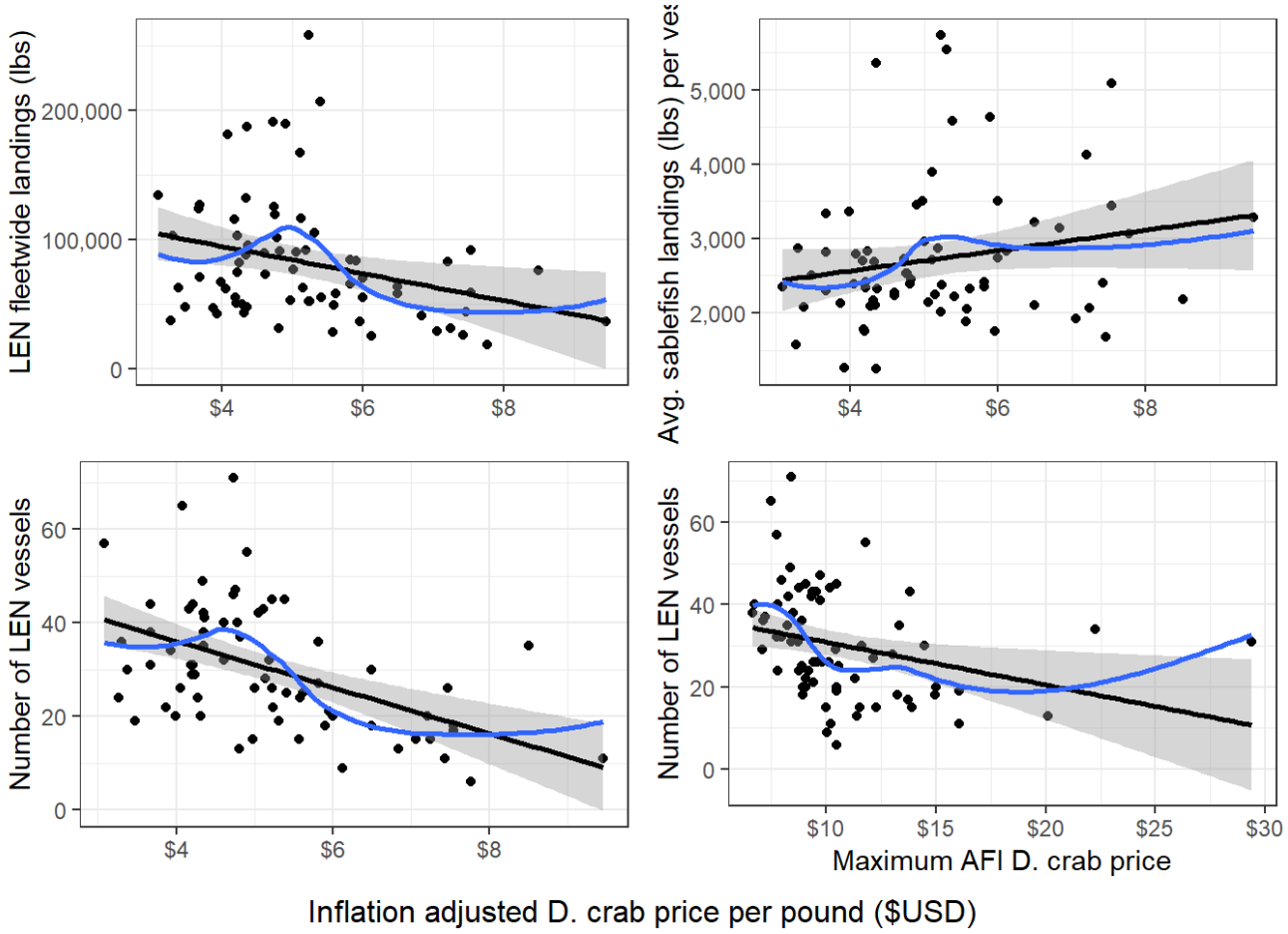


LEN

Section 2.2.4 – Dungeness Crab Prices

THOMSON_FISHERY_CODE == 1

NOMINAL_TO_ACTUAL_PACFIN_SPECIES_CODE == “DCRB”



LEN

Section 2.2.4 – Dungeness Crab Prices

Response variable = number of vessels

	Avg+Max Sablefish Prices	+ Avg. Crab Price	+ Max Crab Price	Avg Crab Price	Max Crab Price
(Intercept)	-22.48 ***	-11.67	-19.00 **	55.81 ***	41.28 ***
	(4.74)	(8.44)	(6.37)	(5.61)	(4.72)
ADJ_PRICE	7.61 ***	7.42 ***	7.41 ***		
	(1.48)	(1.47)	(1.50)		
max_afi_price	3.23 ***	2.81 ***	3.18 ***		
	(0.62)	(0.67)	(0.63)		
adj_crab_price		-1.27		-4.93 ***	
		(0.83)		(1.05)	
max_crab_price			-0.22		-1.04 *
			(0.27)		(0.42)
N	71	71	71	71	71
R2	0.66	0.67	0.66	0.24	0.08

*** p < 0.001; ** p < 0.01; * p < 0.05.

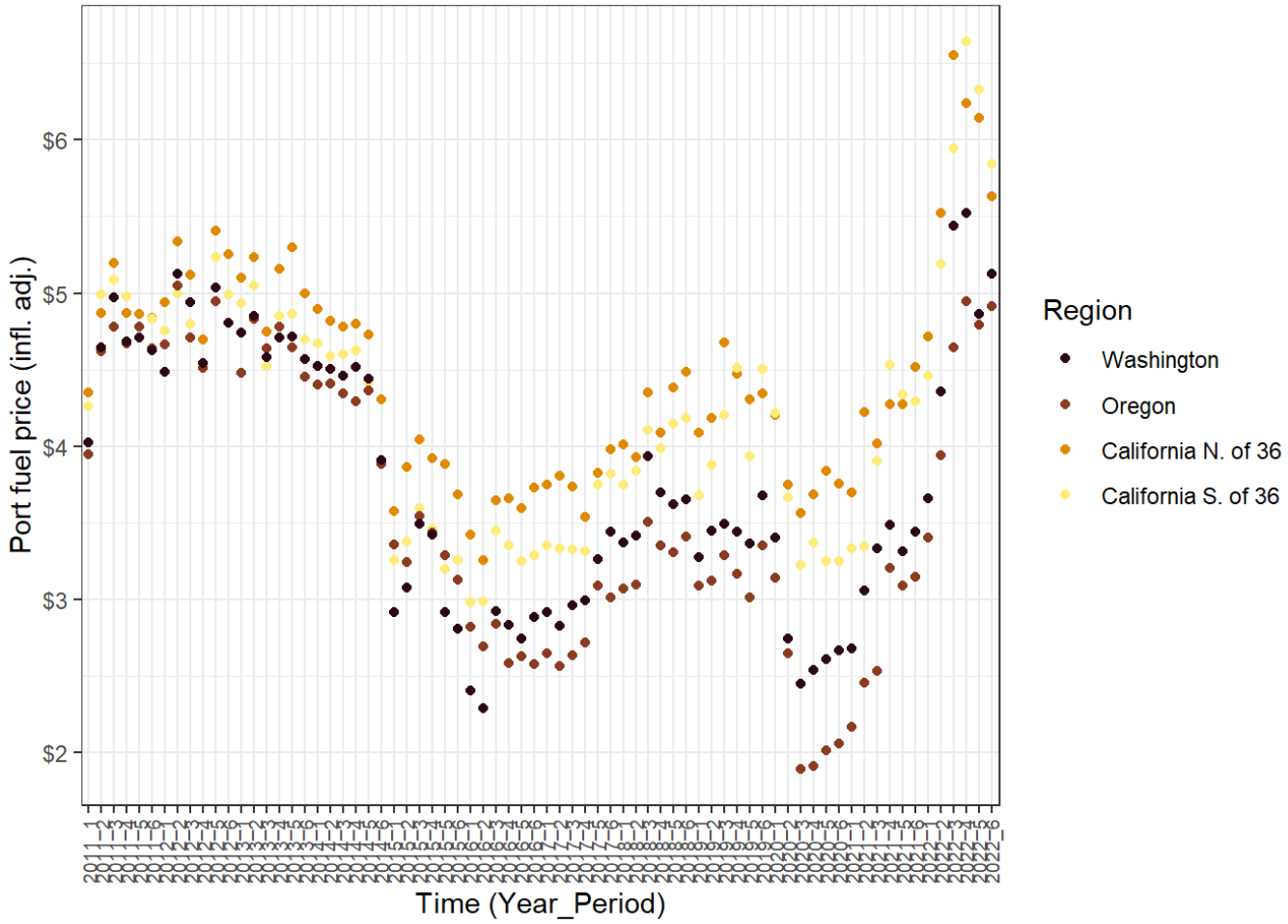
Likelihood ratio test indicates no statistically significant difference when average D. crab prices are added

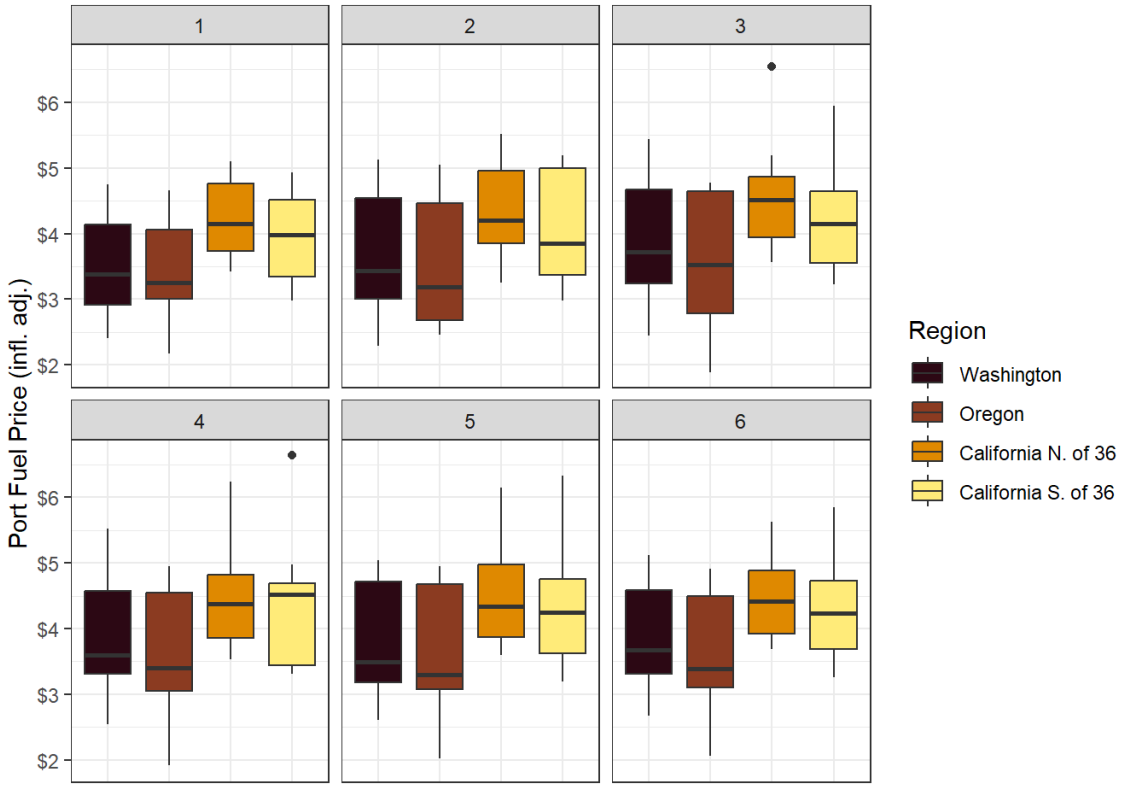
#Df	LogLik	Df	Chisq	Pr(>Chisq)
5	-245			
4	-246	-1	2.47	0.116

LEN

Section 2.2.5 – Fuel Prices

Dockside fuel price data are from the EFIN Monthly Marine Fuel Prices database managed by PSMFC



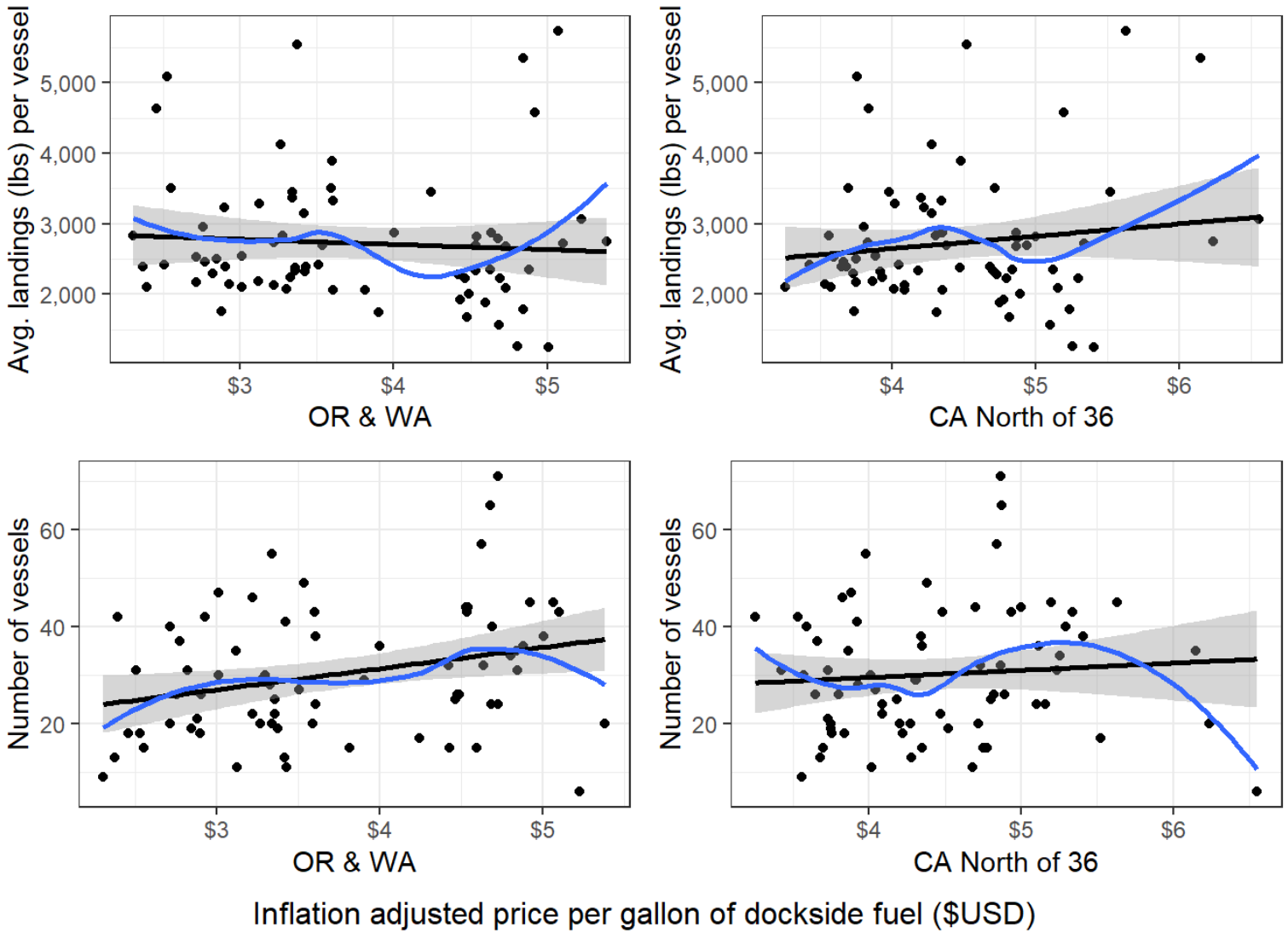


Fuel price "regions":

- OR+WA combined
- CA north of 36° N. lat.

LEN

Section 2.2.5 – Fuel Prices



LEN

Section 2.2.5 – Fuel Prices

	Avg+Max Sablefish Prices	OR+WA Fuel	CA North Fuel	Avg+Max Sable & OR+WA Fuel	Avg+Max Sable & CA N. Fuel	Avg+Max Sable & OR+WA & CA N. Fuel
(Intercept)	-22.48 ***	13.97 *	23.59 *	-24.00 ***	-26.45 ***	-30.65 *
	(4.74)	(6.79)	(10.19)	(5.58)	(7.55)	(12.23)
ADJ_PRICE	7.61 ***			7.38 ***	7.52 ***	8.03 ***
	(1.48)			(1.56)	(1.49)	(1.89)
max_afi_price	3.23 ***			3.24 ***	3.26 ***	3.30 ***
	(0.62)			(0.63)	(0.63)	(0.64)
adj_fuel_OR_WA		4.35 *		0.61		-1.81
		(1.77)		(1.17)		(4.13)
adj_fuel_CAN			1.49		0.91	2.92
			(2.26)		(1.35)	(4.77)
N	71	71	71	71	71	71
R2	0.66	0.08	0.01	0.66	0.66	0.66

*** p < 0.001; ** p < 0.01; * p < 0.05.

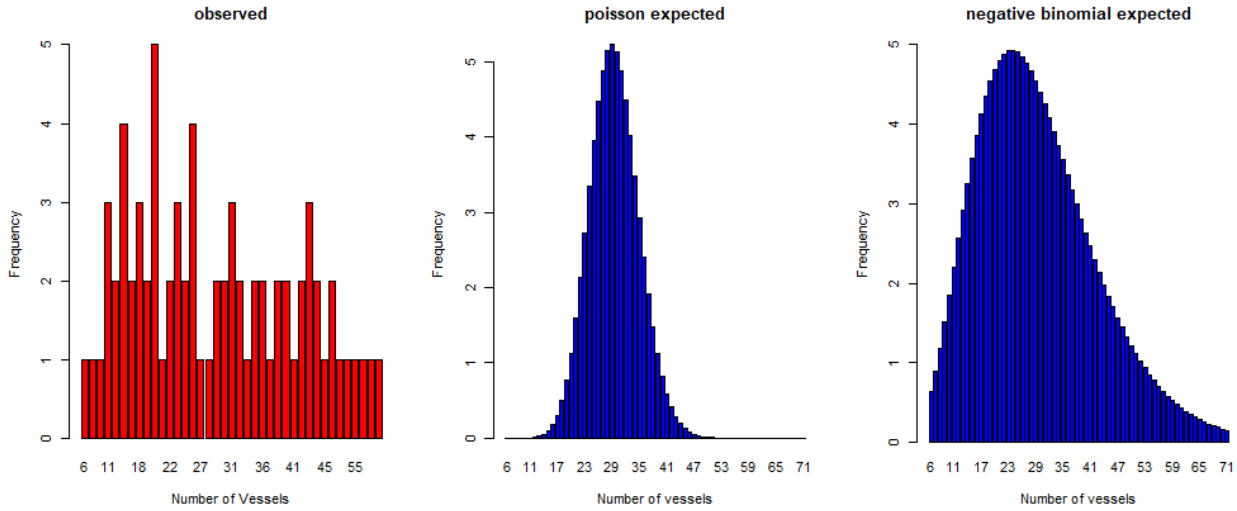
Likelihood ratio test indicates no statistically significant difference when OR/WA fuel prices are added

#Df	LogLik	Df	Chisq	Pr(>Chisq)
5	-246			
4	-246	-1	0.287	0.592

LEN

Section 2.2.6 – Generalized Linear Model

- GLMs useful when response variable does not follow normal distribution -> number of vessels
  - Assumed negative binomial distribution
- Ranked all GLM model variations using the following predictor variables based on AIC scores:
  - Average inflation-adjusted sablefish price
  - Median AFI sablefish price
  - Maximum AFI sablefish price
  - Bimonthly period (fixed effect)
  - Average inflation-adjusted Dungeness crab price
  - Maximum Dungeness crab price
  - OR/WA dockside fuel price
  - CA dockside fuel price in ports north of 36° N. lat.




```
model.full <- glm.nb(as.formula(
  paste("VES_NUM",
        paste(0, "+", paste(covars, collapse = " + ")),
        sep = " ~ ")),
  data = LEN,
  na.action = "na.fail")

model.suite <- MuMIn::dredge(model.full,
                             rank = "AIC",
                             fixed = c("PERIOD"))
```

LEN

Section 2.2.6 – Generalized Linear Model

	adj_crab_price	adj_fuel_CAN	adj_fuel_OR_WA	ADJ_PRICE	max_afi_price	max_crab_price	med_afi_price	PERIOD	df	logLik	AIC	delta	weight
1				0.213	0.104			+	9	-228	475	0	0.206483465365749
2		-0.267	0.238	0.155	0.0975			+	11	-226	475	0.076	0.198781142501648
3	-0.0366			0.205	0.0963			+	10	-228	475	0.301	0.177662832608923
	-0.0327	-0.257	0.229	0.15	0.0911			+	12	-226	476	0.683	0.146769478329992
				0.207	0.102	-0.00863		+	10	-228	476	0.805	0.13808644631333
		-0.374	0.339		0.0937		0.124	+	11	-227	476	0.892	0.132216634880358

Likelihood ratio test results:

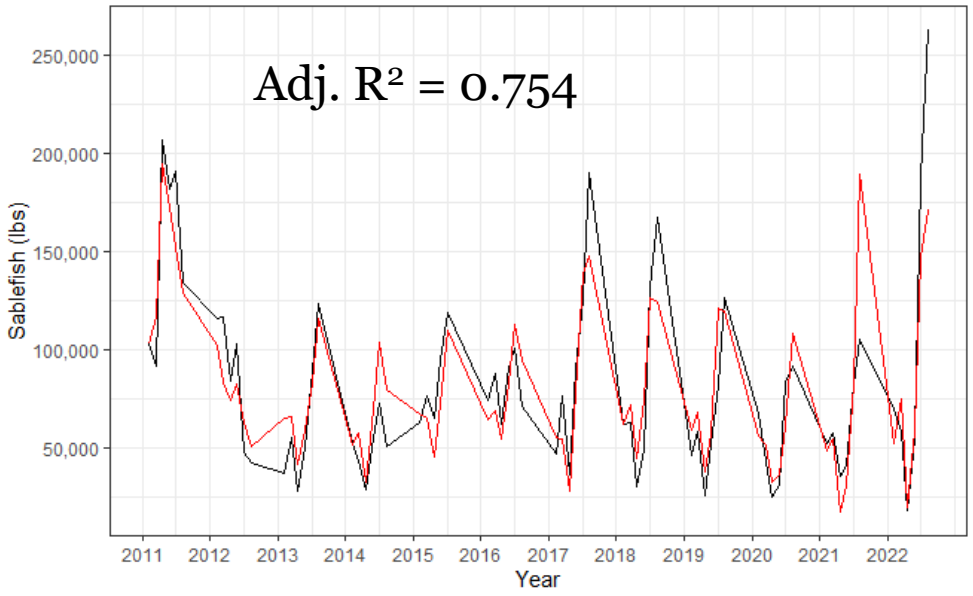
	Full Model		Nested Model	P-value
3	avg sable price + max sable price + avg crab price	1	avg sable price + max sable price	0.1963
2	avg sable price + max sable price + CA fuel + OR/WA fuel	1	avg sable price + max sable price	0.1380
	avg sable price + max sable price + CA fuel	1	avg sable price + max sable price	0.9043

Final approach

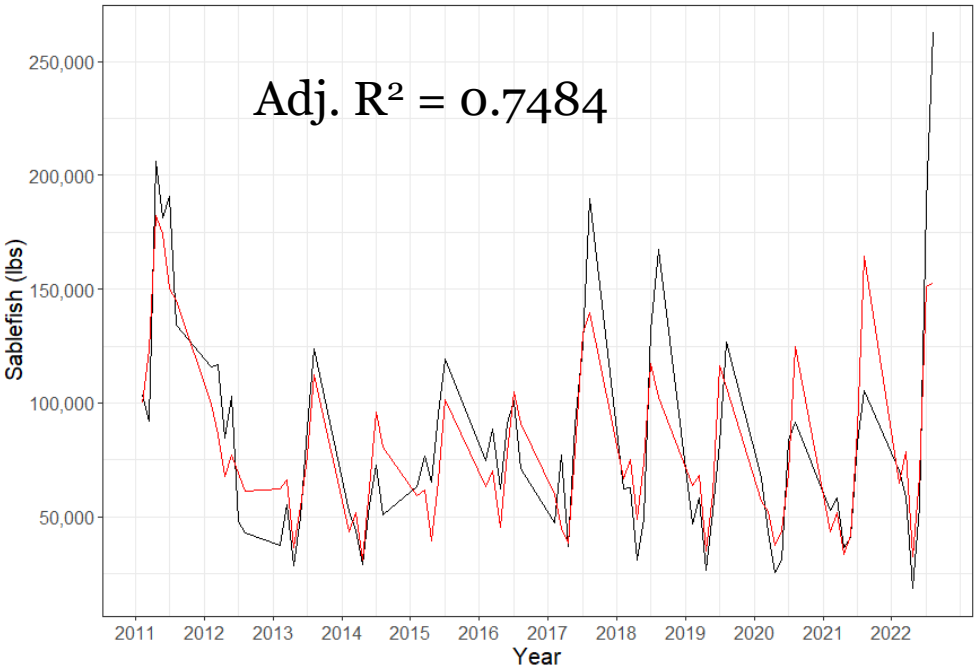
LEN

Section 2.2.6 – Generalized Linear Model

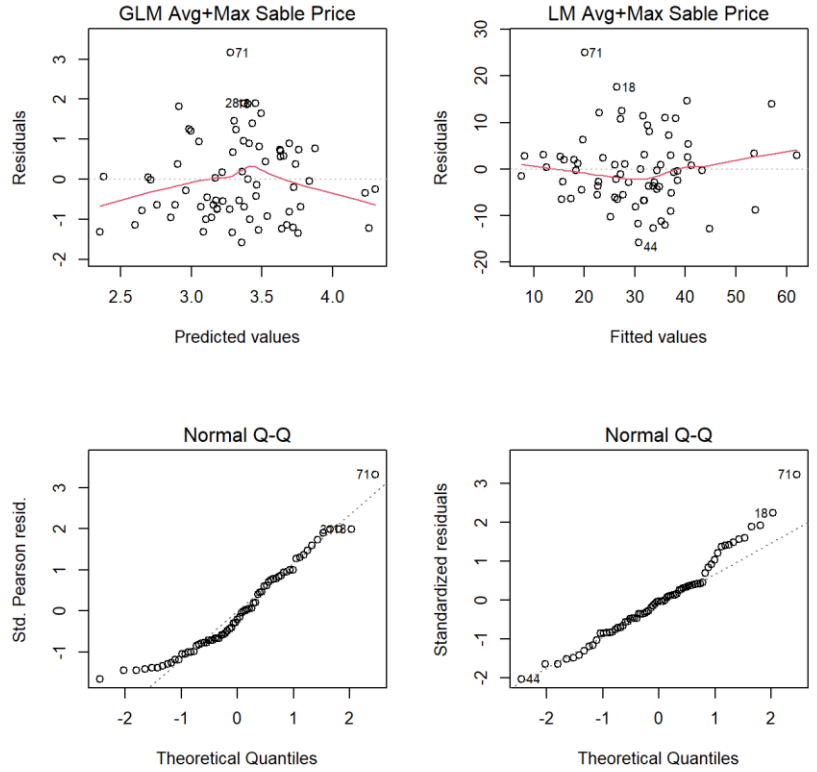
Status Quo Model



Generalized Linear Model



No improvement in fit to historical data compared to linear regression using the same predictors



Using a GLM improves normal Q-Q plot

LEN

Questions on LEN?

Open Access North (OAN)

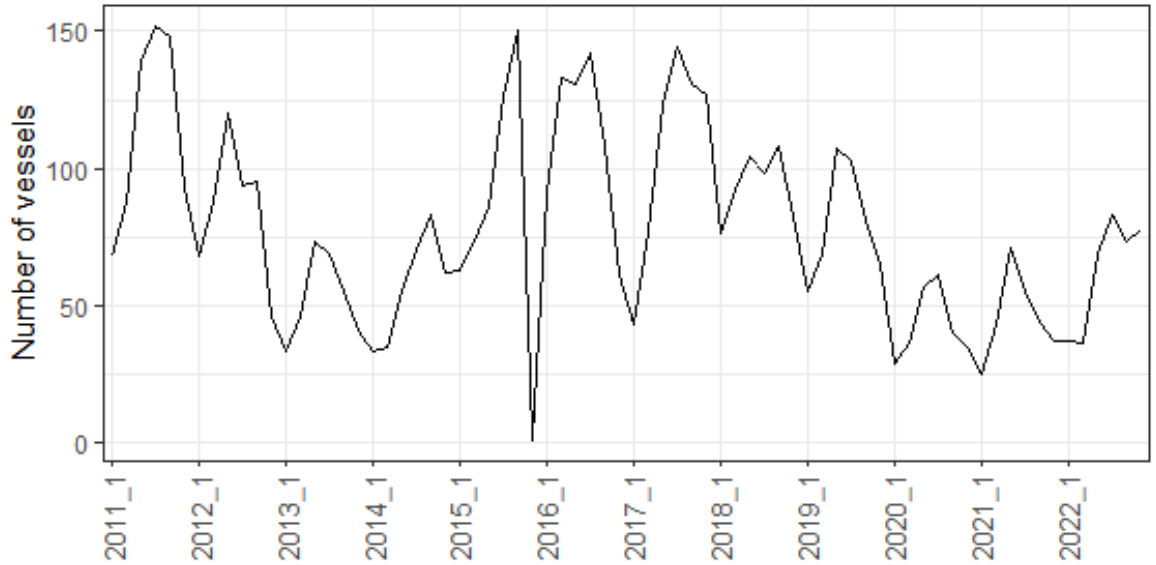
Section 3.1 – Current Model

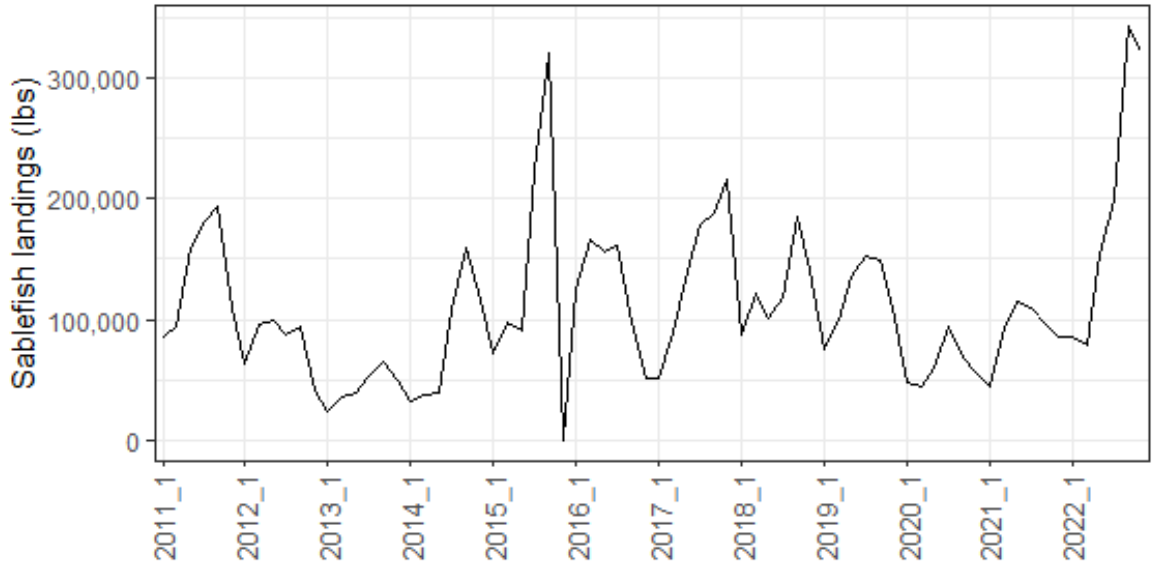
- Section 3.1.1 – Distribution Assumptions
- Section 3.1.2 – Model Run

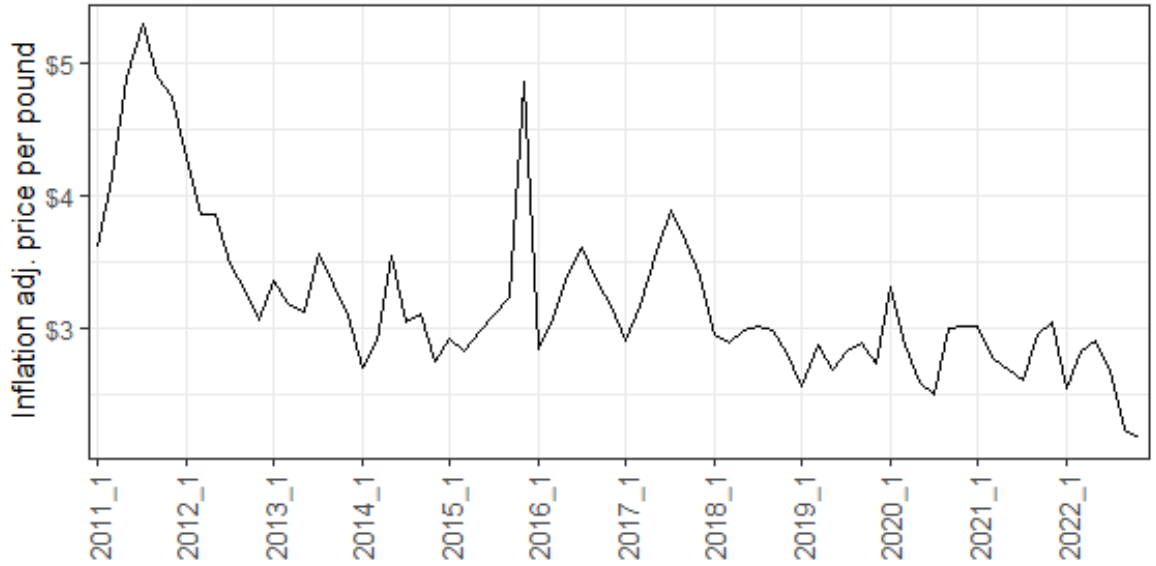
Section 3.2 – Potential Model Improvements

- Section 3.2.1 – Log Transformation
- Section 3.2.2 – AFI Prices
- Section 3.2.3 – Dungeness Crab Prices
- Section 3.2.4 – Fuel Prices
- Section 3.2.5 – Generalized Linear Model (GLM)

Section 3.1 – Current Model







Time (Year_Period)

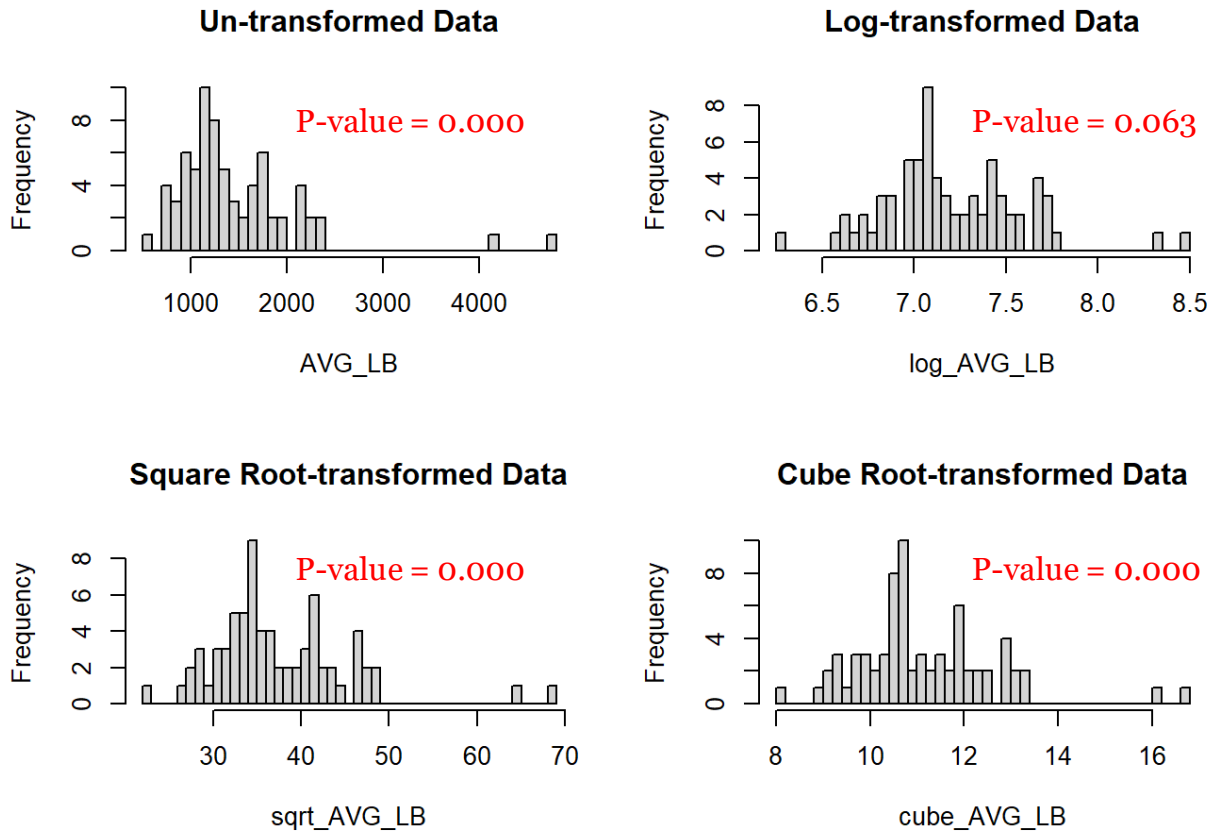
OAN

Section 3.1.1 – Distribution Assumptions

Average landings per vessel

- Historical data for average landings per vessel (response variable) are not normally distributed
- Log transformation is only transformation that normalizes the data

Value	Raw	Log	Square Root	Cube Root
Skewness	2.445	0.568	1.439	1.132
Skewness p-value	0.000	0.027	0.000	0.000
Kurtosis	8.517	1.097	3.664	2.553



*p-value for Shapiro-Wilk normality test

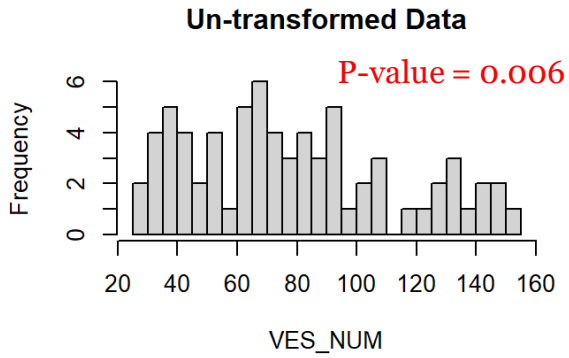
OAN

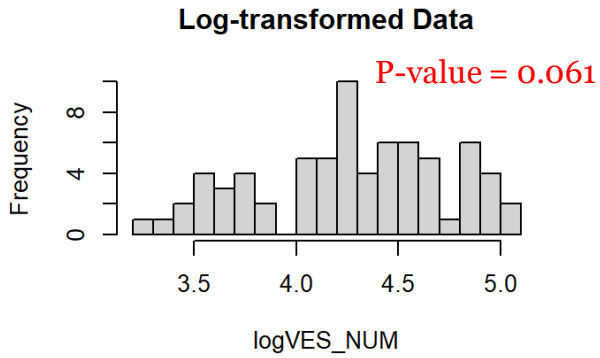
Section 3.1.1 – Distribution Assumptions

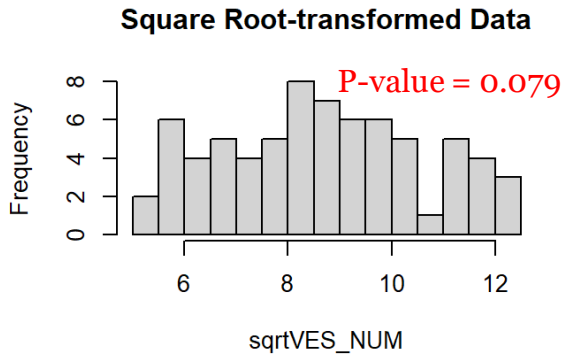
Number of Vessels

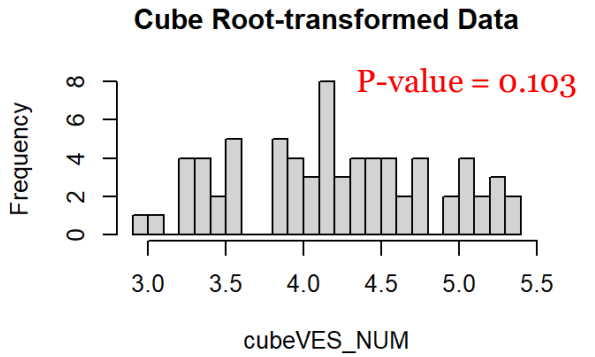
- Historical data for number of vessels (response variable) are not normally distributed
- A negative binomial distribution is explored using GLMs

Value	Raw	Log	Square Root	Cube Root
Skewness	0.466	-0.256	0.117	-0.005
Skewness p-value	0.057	-0.879	0.344	0.507
Kurtosis	-0.778	-0.865	-0.949	-0.953









*p-value for Shapiro-Wilk normality test

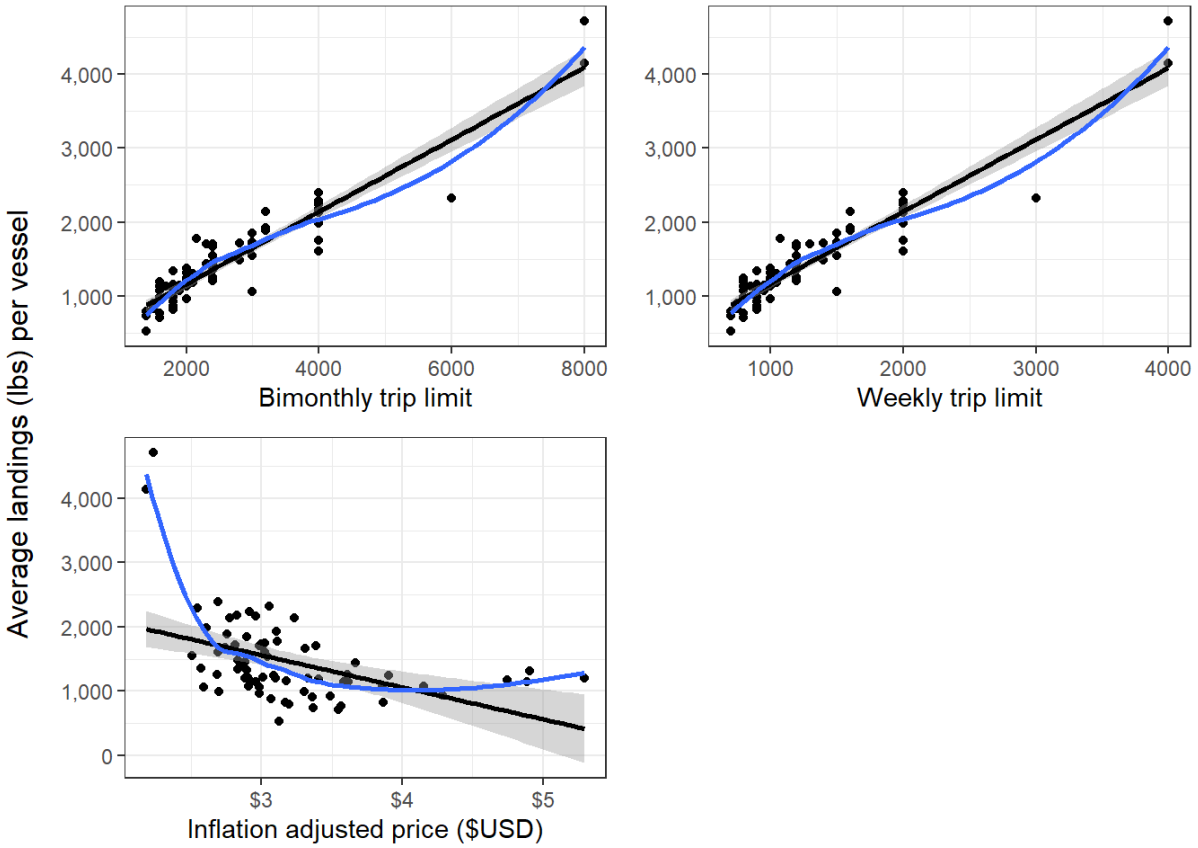
OAN

Section 3.1.2 – Model Run

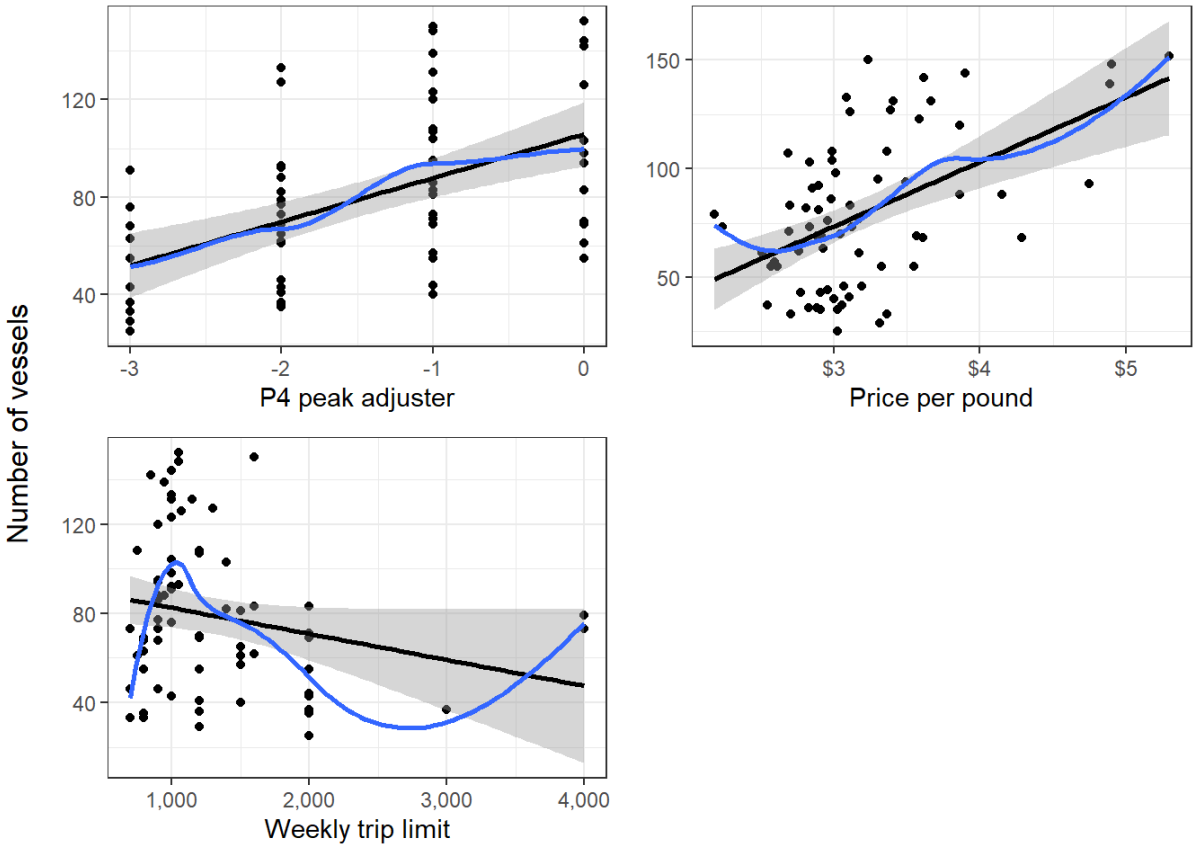
Period 4 Peak Adjuster:

Period 1 = -3	**Period 4 = 0**
Period 2 = -2	Period 5 = -1
Period 3 = -1	Period 6 = -2

Response variable = average landings per vessel



Response variable = number of vessels



OAN

Section 3.1.2 – Model Run

	Weekly	Bimonthly	Wkly + Bimon	Wkly + Bimon + Wkly:Bimon
(Intercept)	201.14 **	193.63 **	196.11 **	357.49 *
	(64.34)	(64.91)	(64.95)	(144.04)
TL.WEEKLY	0.97 ***		0.57	0.49
	(0.04)		(0.57)	(0.57)
TL.BIMON		0.49 ***	0.20	0.14
		(0.02)	(0.28)	(0.29)
TL.WEEKLY:TL.BIMON				0.00
				(0.00)
N	71	71	71	71
R2	0.87	0.87	0.88	0.88

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
##
## Call:
## lm(formula = AVG_LB ~ TL.WEEKLY, data = OAN, weights = WEIGHT)
##
## Weighted Residuals:
##     Min      1Q  Median      3Q     Max
## -958.45 -125.84    6.46  125.14  835.96
##
## Coefficients:
##              Estimate Std. Error t value            Pr(>|t|)
## (Intercept) 112.59656   56.11239   2.007              0.0487 *
## TL.WEEKLY     1.05544    0.02959  35.675 <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 271.4 on 69 degrees of freedom
## Multiple R-squared:  0.9486, Adjusted R-squared:  0.9478
## F-statistic:  1273 on 1 and 69 DF,  p-value: < 0.00000000000000022
```

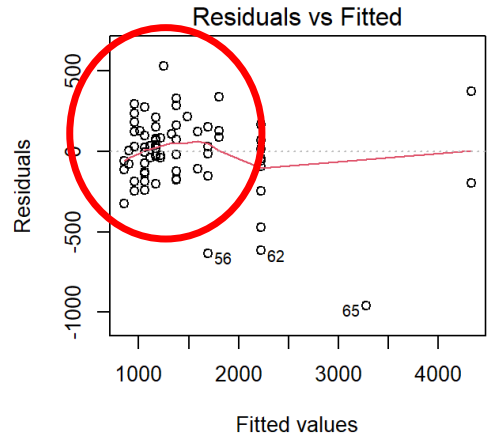
For the OAN sector, using both weekly and bimonthly limits is duplicative because bimonthly limits are nearly always 2X the weekly limit

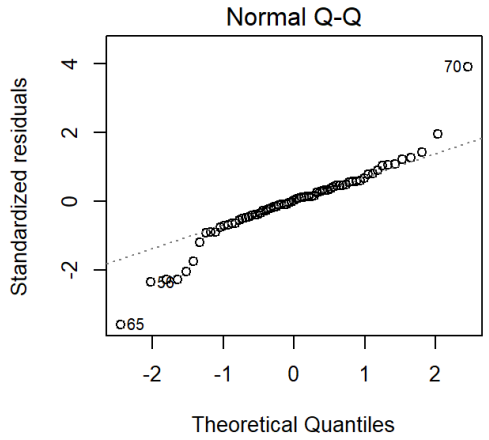
OAN

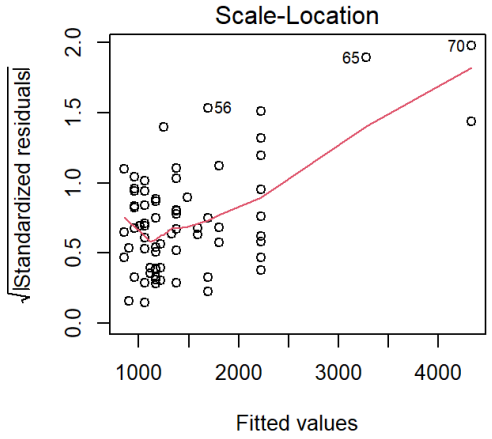
Section 3.1.2 – Model Run

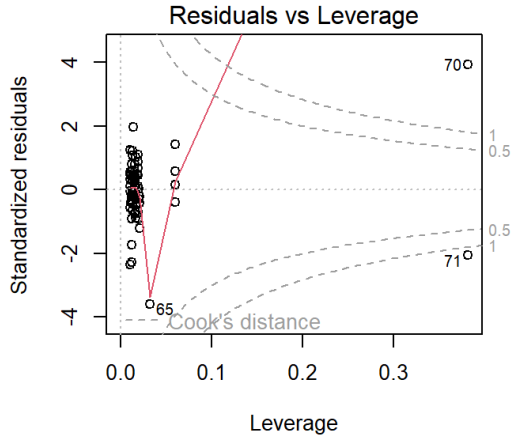
Response variable = average landings per vessel

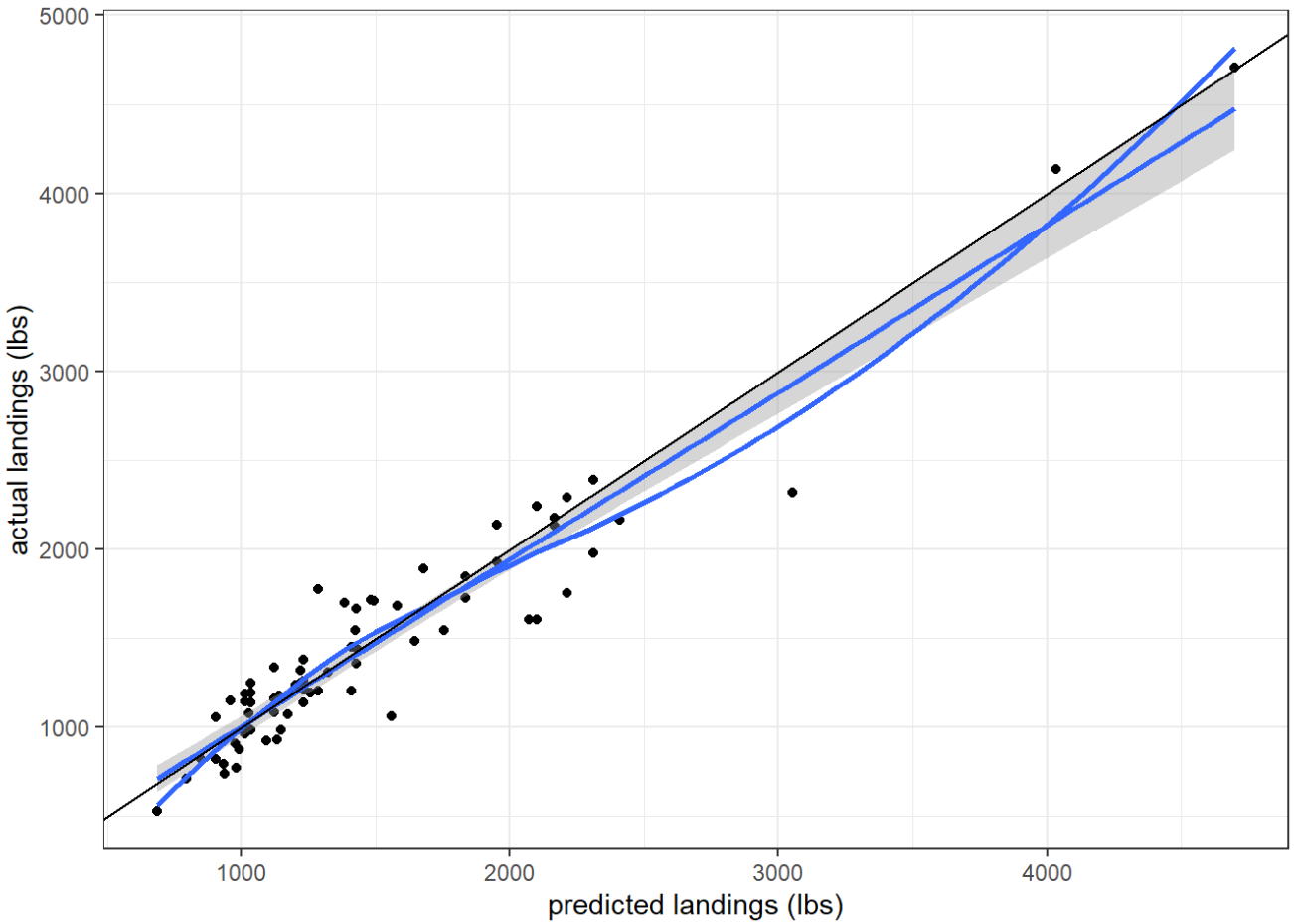
- Residuals are clustered together
- Trend line in scale-location plot
- Normal Q-Q plot is heavily tailed on both ends









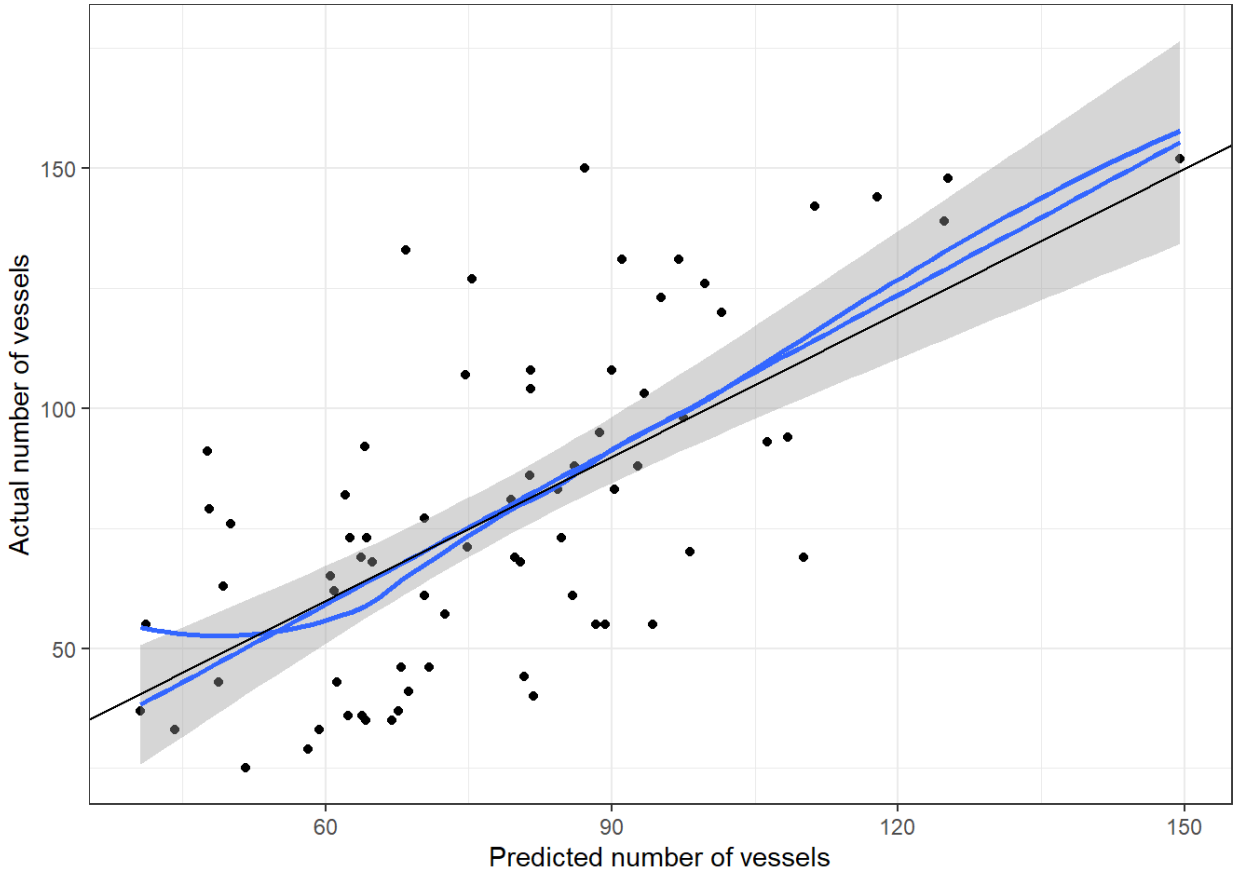


OAN

Section 3.1.2 – Model Run

Response variable = number of vessels

```
##
## Call:
## lm(formula = VES_NUM ~ PER.4.PEAK + ADJ_PRICE, data = OAN, weights = WEIGHT)
##
## Weighted Residuals:
##     Min      1Q  Median      3Q     Max
## -59.10 -24.62   1.08  19.60  69.76
##
## Coefficients:
##             Estimate Std. Error t value   Pr(>|t|)
## (Intercept)   28.776     16.319   1.763     0.0823 .
## PER.4.PEAK    15.401      3.025   5.091 0.00000302 ***
## ADJ_PRICE     22.816      4.894   4.662 0.00001510 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 28.1 on 68 degrees of freedom
## Multiple R-squared:  0.4455, Adjusted R-squared:  0.4292
## F-statistic: 27.32 on 2 and 68 DF,  p-value: 0.000000001959
```

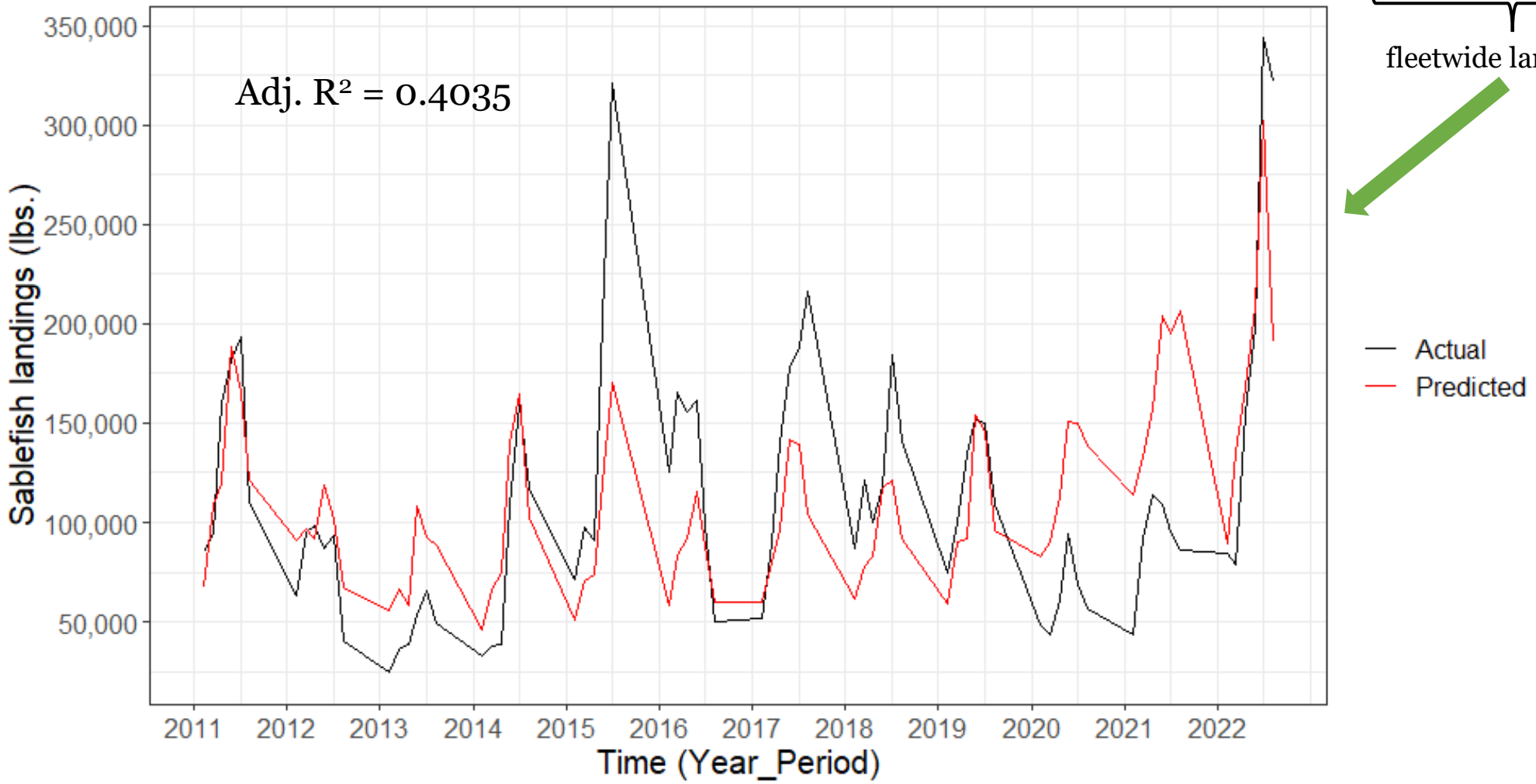


OAN

Section 3.1.2 – Model Run

OAN	Weekly trip limits	landings per vessel
	Sablefish price/lb. + period adjuster	# of vessels

fleetwide landings



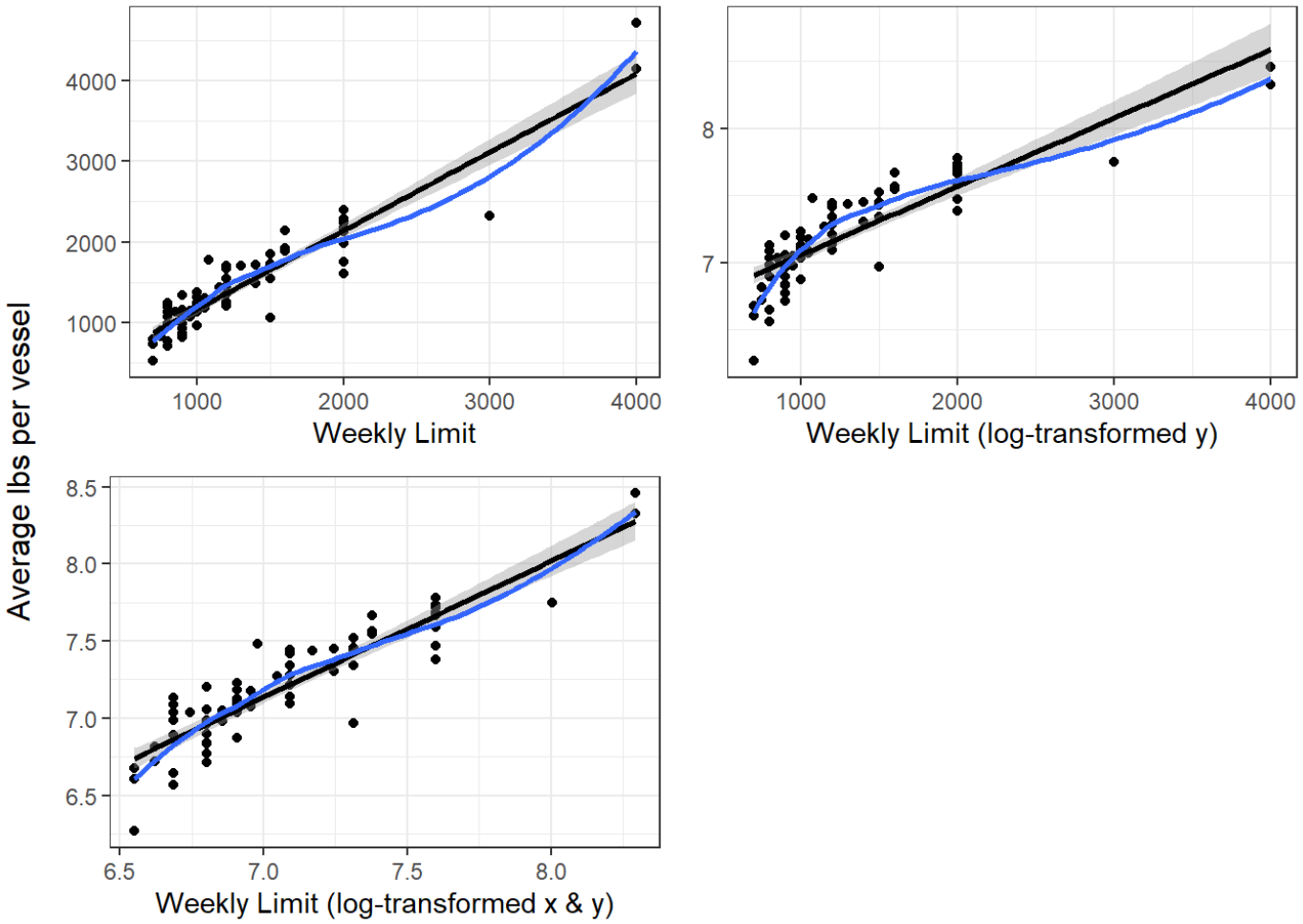
OAN model struggles to capture volatility

OAN

Section 3.2 – Potential Model Improvements

Section 3.2.1 – Log Transformation

Response variable = average landings per vessel



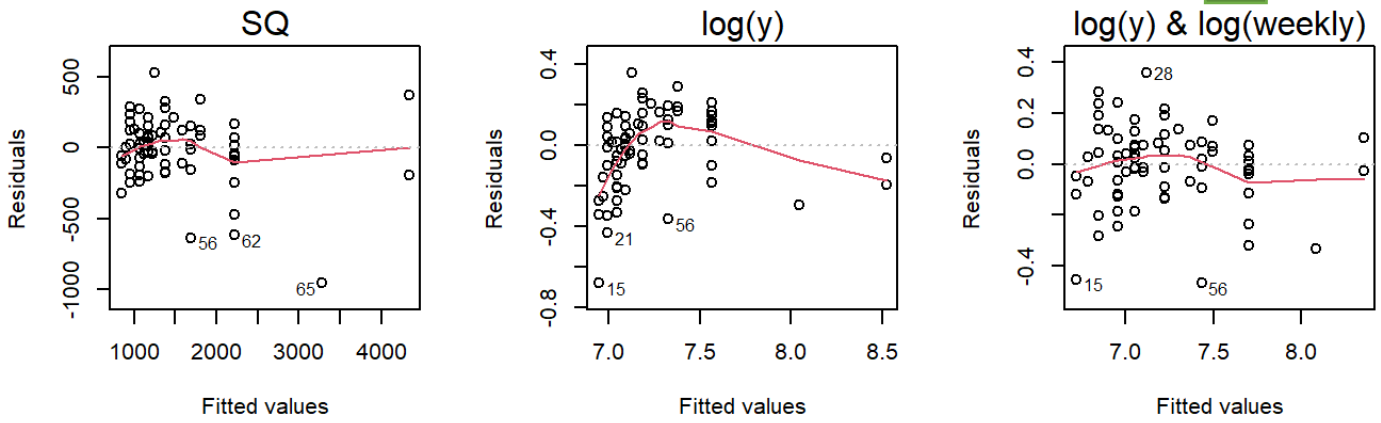
	SQ	log(y)	log(x) & log(y)
(Intercept)	112.60 *	6.61 ***	0.59 *
	(56.11)	(0.04)	(0.25)
TL.WEEKLY	1.06 ***	0.00 ***	
	(0.03)	(0.00)	
log(TL.WEEKLY)			0.94 ***
			(0.03)
N	71	71	71
R2	0.95	0.86	0.91

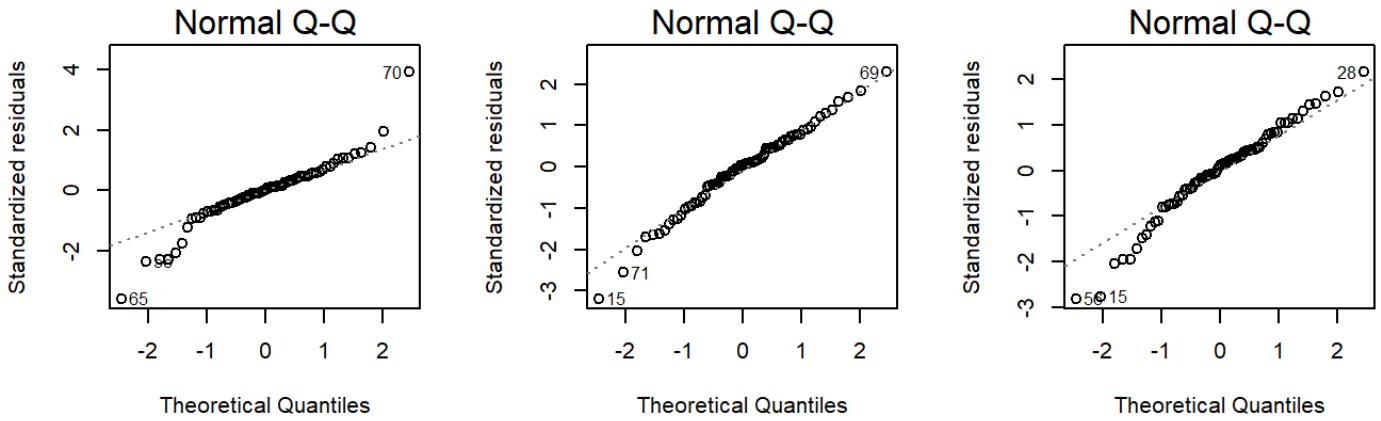
*** p < 0.001; ** p < 0.01; * p < 0.05.

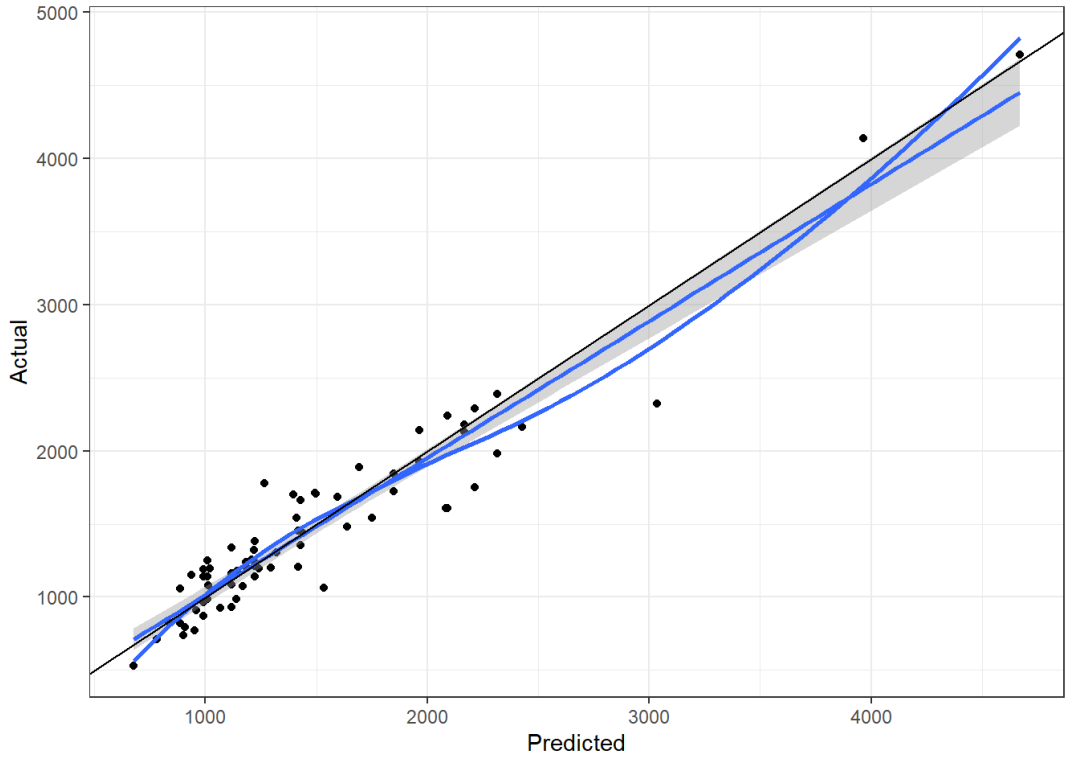
OAN

Section 3.2.1 – Log Transformation

Response variable = average landings per vessel





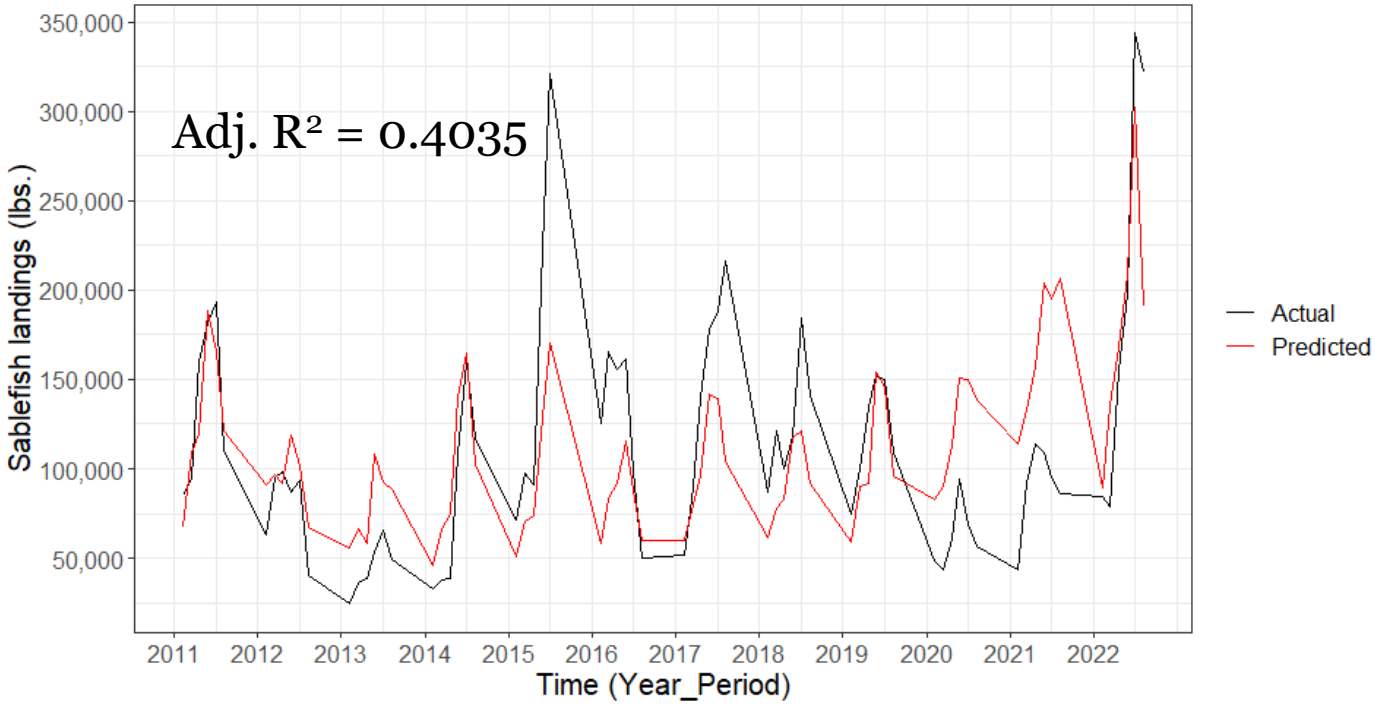


OAN

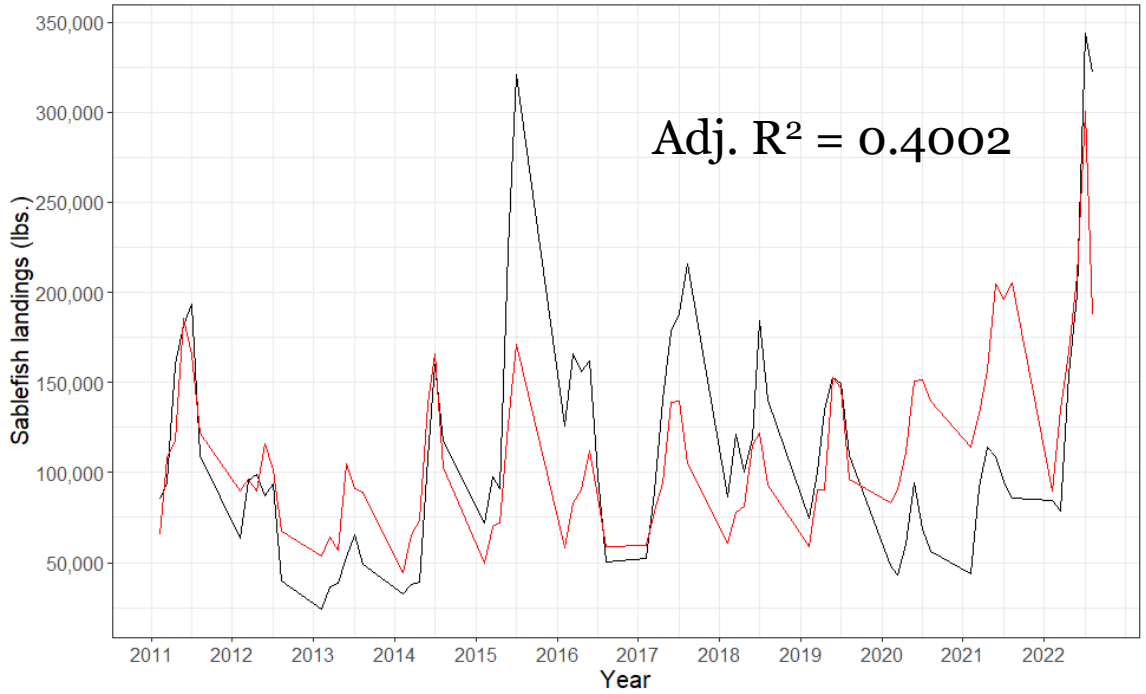
Section 3.2.1 – Log Transformation

- **Final approach:** Log-transform the average landings per vessel response variable and the weekly limit predictor variable
- Fit to historical data is slightly lower but log-transforming average landings per vessel improves model diagnostics

Status Quo Model



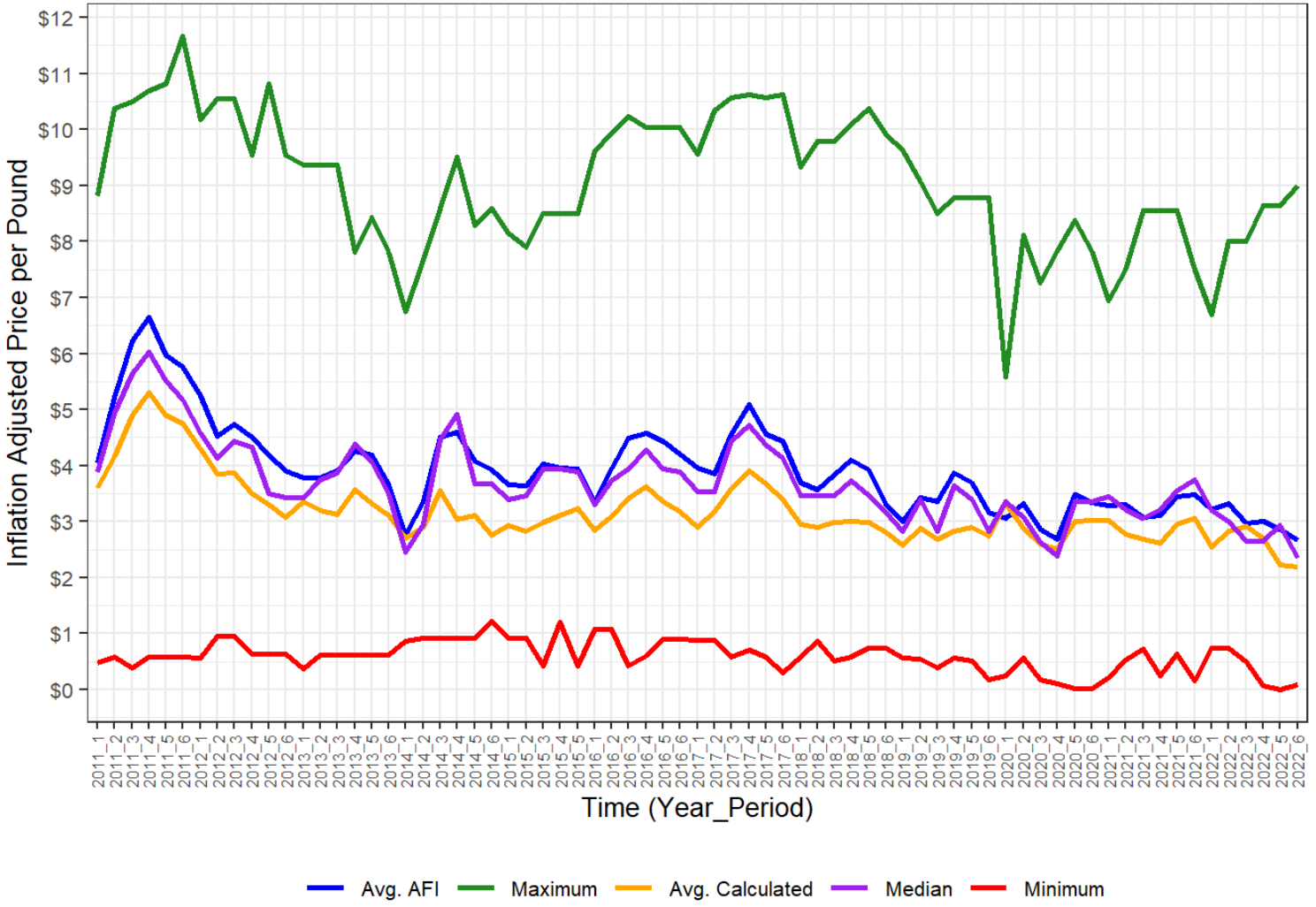
Log Transformation

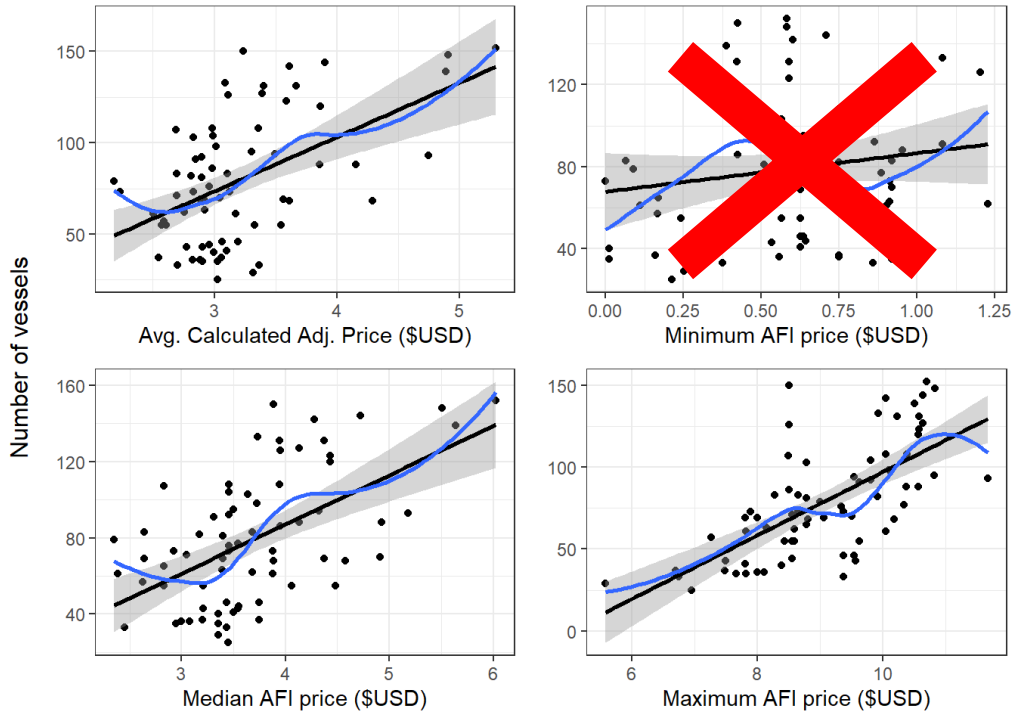


OAN

Section 3.2.2 – AFI Prices

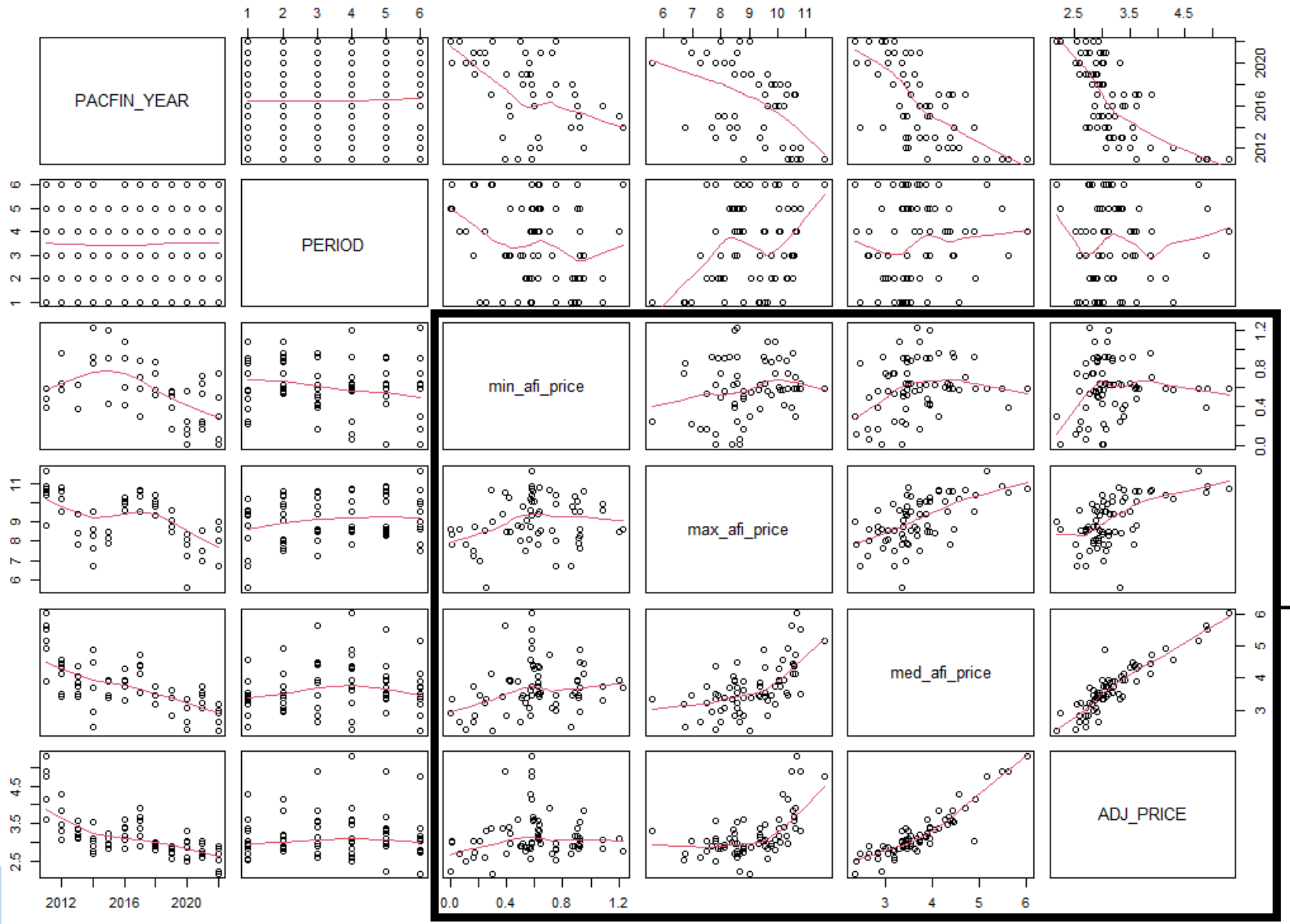
Less variation in maximum price compared to LEN sector





OAN

Section 3.2.2 – AFI Prices



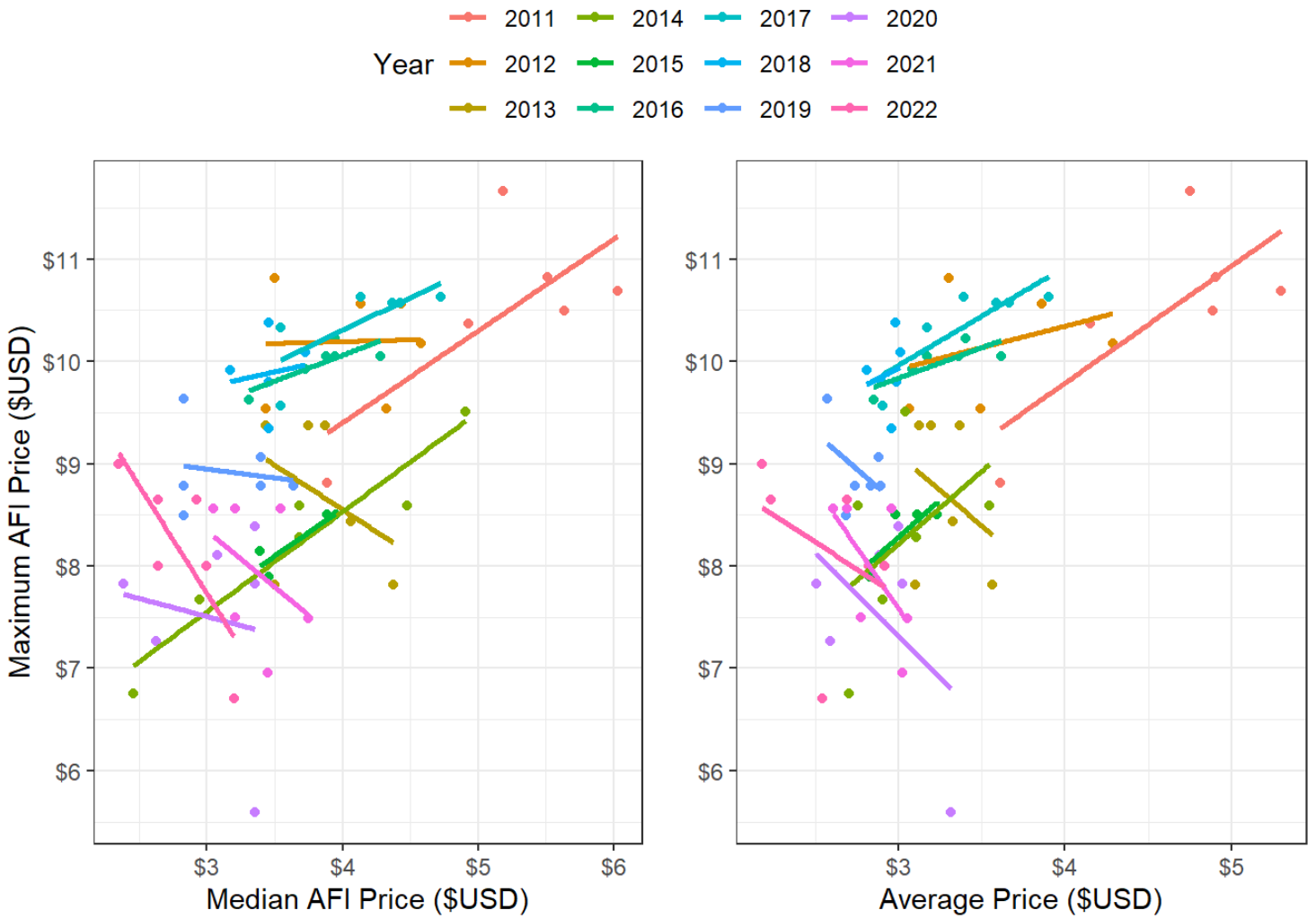
Minimum = no obvious correlation

Maximum = some correlation with median and average

Median = linear correlation with average

OAN

Section 3.2.2 – AFI Prices



Median and average price correlation does not show a clear pattern across years

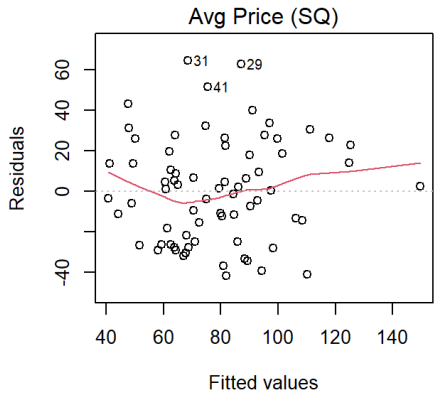
OAN

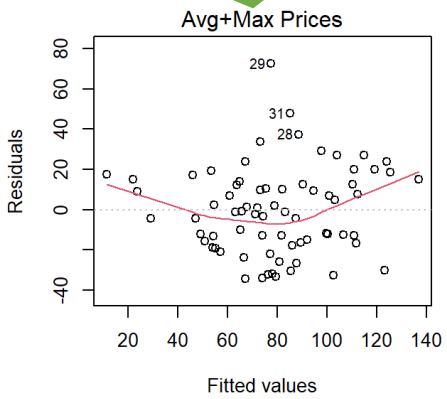
Section 3.2.2 – AFI Prices

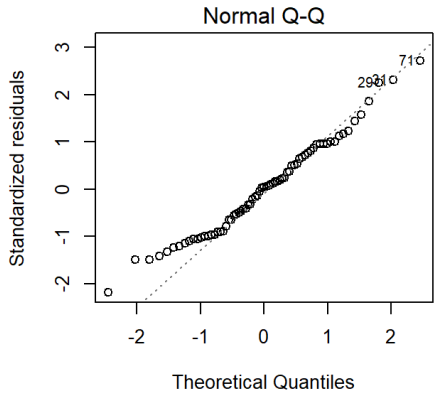
Response variable = number of vessels

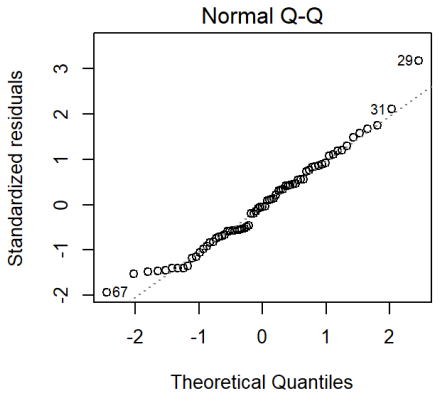
	Model SQ	Max AFI Price	Avg+Max AFI Price	Med AFI Price	Med+Max AFI Price
(Intercept)	28.78	-55.96 **	-59.59 **	34.49 *	-57.27 **
	(16.32)	(20.24)	(20.17)	(14.82)	(20.00)
ADJ_PRICE	22.82 ***		7.48		
	(4.89)		(4.79)		
PER.4.PEAK	15.40 ***	11.85 ***	11.94 ***	14.96 ***	11.82 ***
	(3.02)	(2.57)	(2.55)	(3.02)	(2.54)
max_afi_price		16.81 ***	14.67 ***		14.51 ***
		(2.12)	(2.51)		(2.51)
med_afi_price				18.14 ***	6.25
				(3.79)	(3.74)
N	71	71	71	71	71
R2	0.45	0.62	0.63	0.45	0.64

*** p < 0.001; ** p < 0.01; * p < 0.05.









Likelihood ratio test to determine statistical significance of adding maximum AFI price

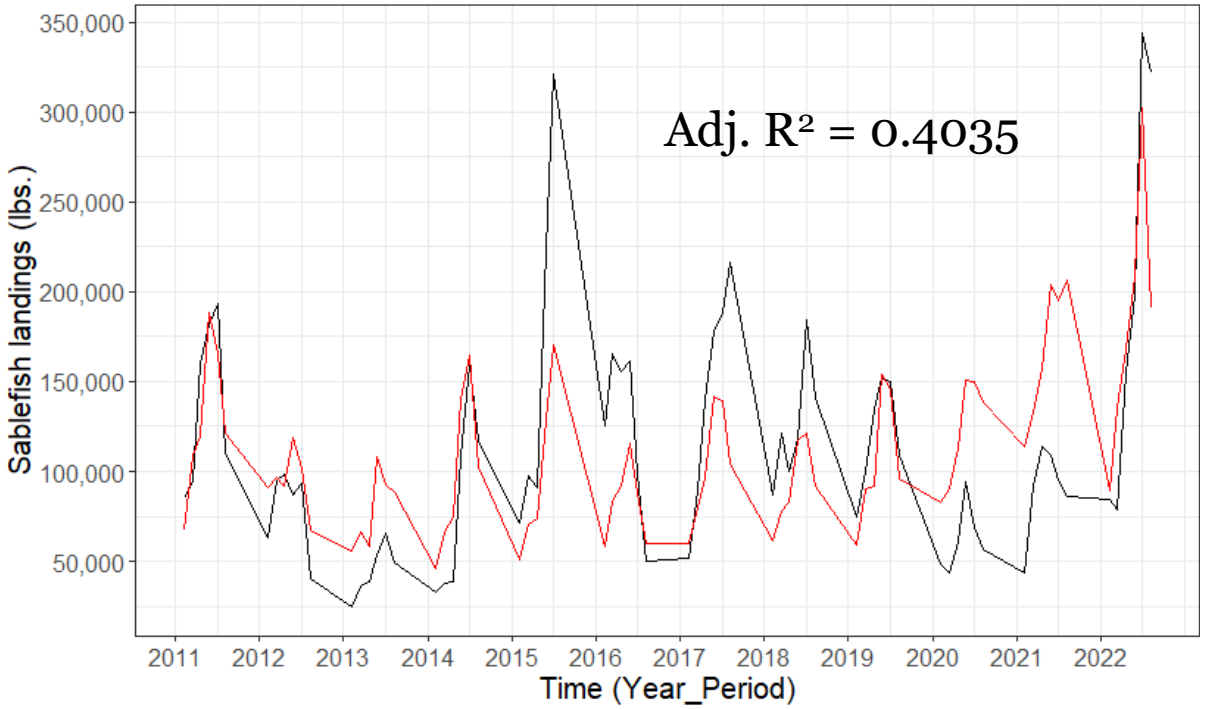
#Df	LogLik	Df	Chisq	Pr(>Chisq)
4	-331			
5	-317	1	29.3	6.12e-08

OAN

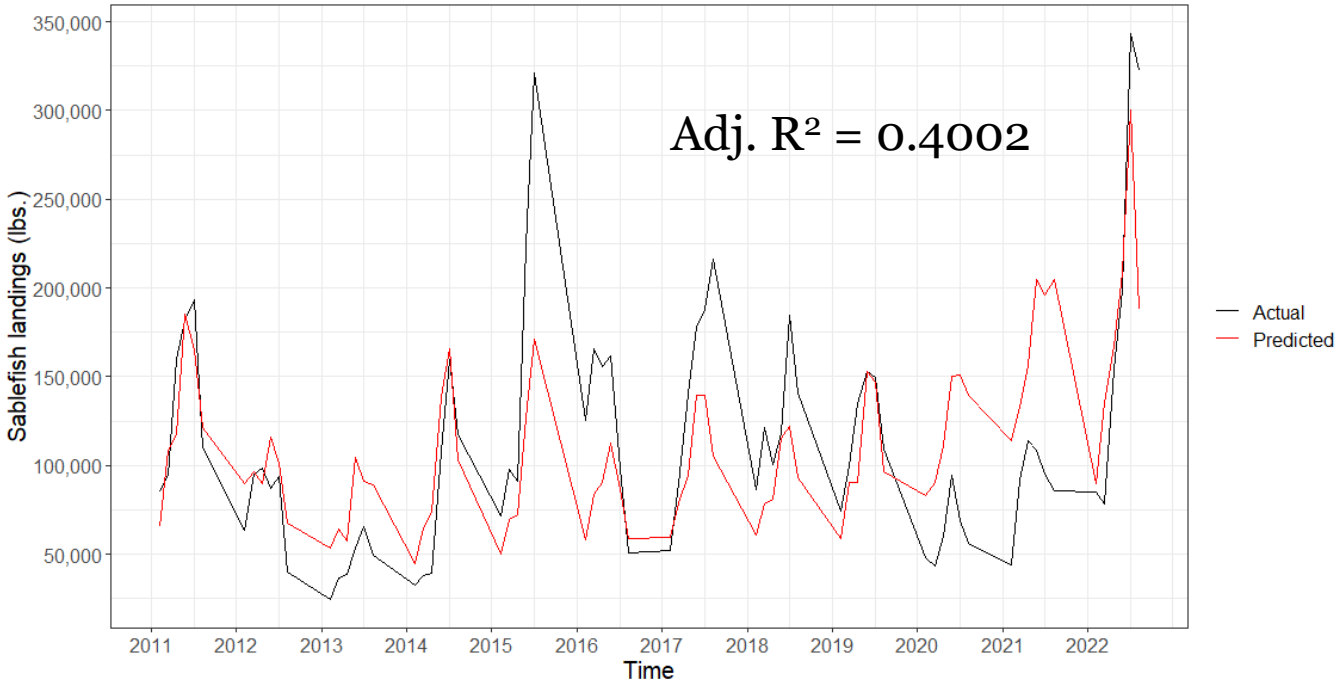
Section 3.2.2 – AFI Prices

- **Final approach:** Log-transform the average landings per vessel response variable and the weekly limit predictor variable; add maximum sablefish price per pound
- Fit to historical data is slightly lower but adding maximum sablefish price improves model diagnostics

Status Quo Model



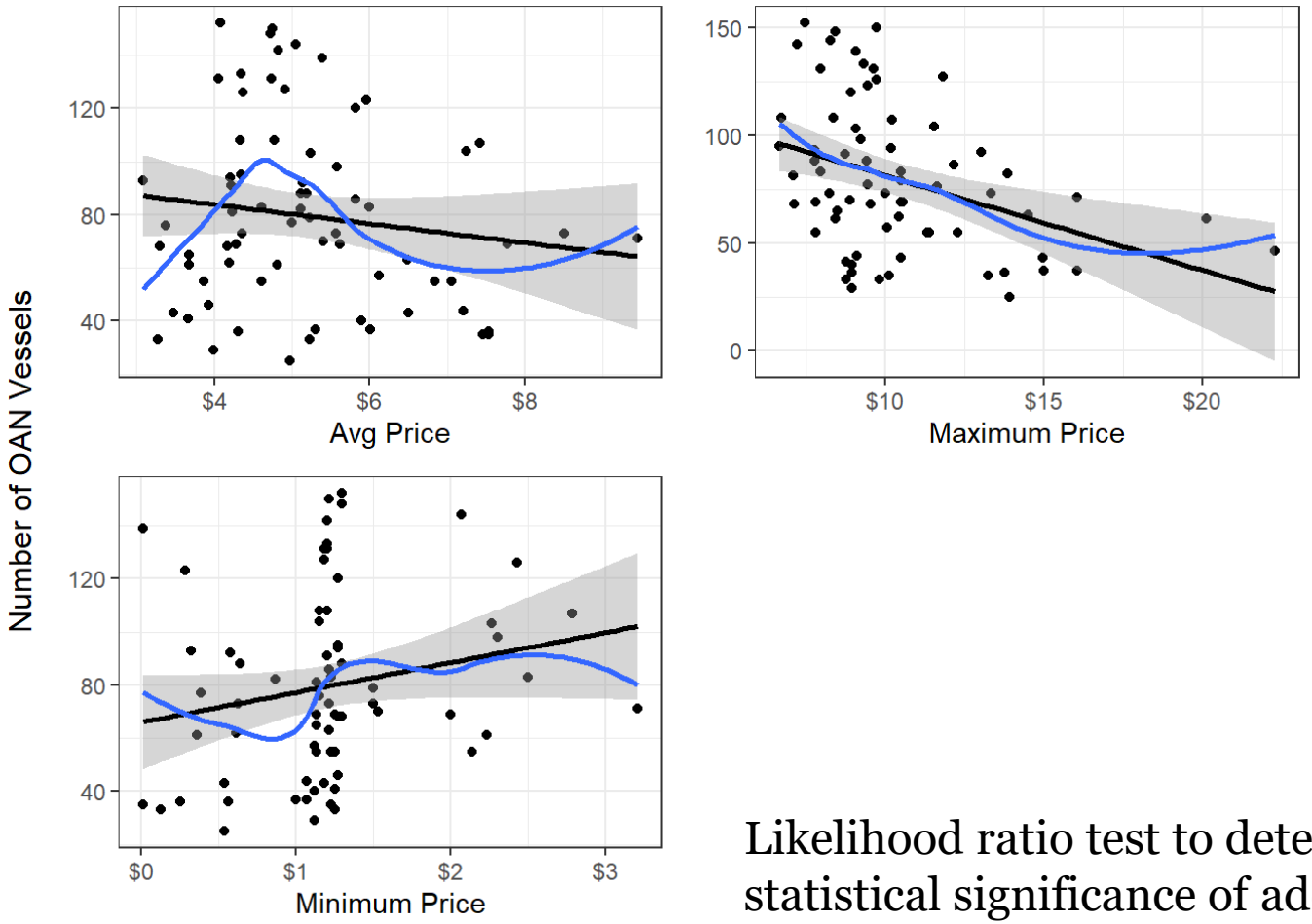
Log Transformation + Maximum AFI Price



OAN

Section 3.2.3 – Dungeness Crab Prices

Response variable = number of vessels



	Model SQ	Max Crab Price	Avg Sable + Max Crab Prices
(Intercept)	28.34	136.02 ***	61.77 **
	(16.35)	(12.33)	(22.02)
ADJ_PRICE	22.97 ***		19.61 ***
	(4.90)		(5.01)
PER.4.PEAK	15.24 ***	13.81 ***	13.39 ***
	(3.03)	(3.38)	(3.07)
max_crab_price		-3.77 **	-2.44 *
		(1.17)	(1.11)
N	70	70	70
R2	0.45	0.37	0.48

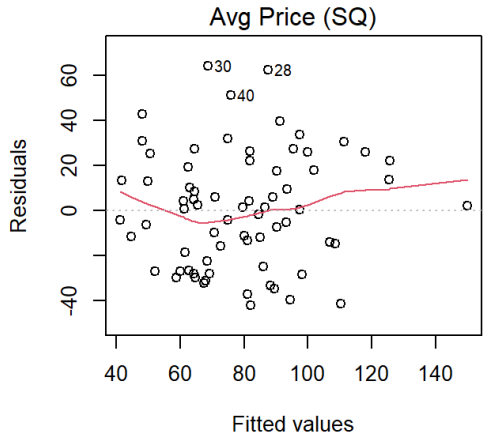
*** p < 0.001; ** p < 0.01; * p < 0.05.

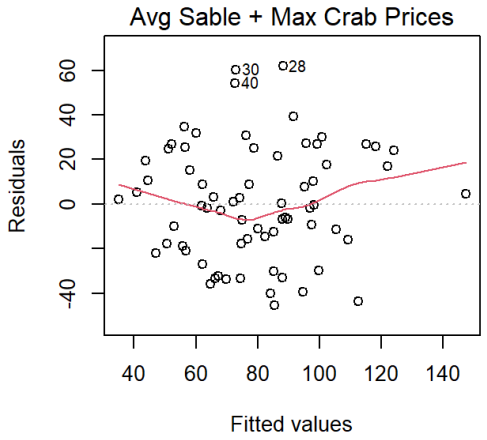
Likelihood ratio test to determine statistical significance of adding maximum D. crab prices

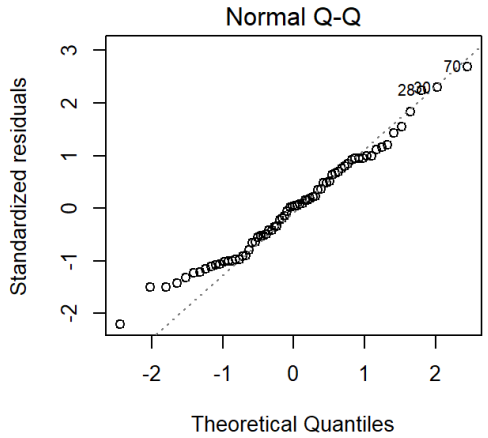
#Df	LogLik	Df	Chisq	Pr(>Chisq)
5	-324			
4	-327	-1	4.93	0.0264

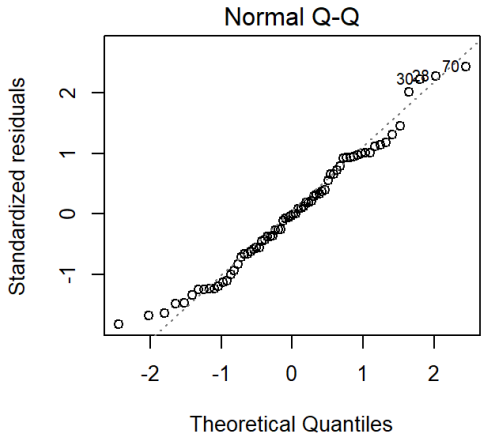
OAN

Section 3.2.3 – Dungeness Crab Prices

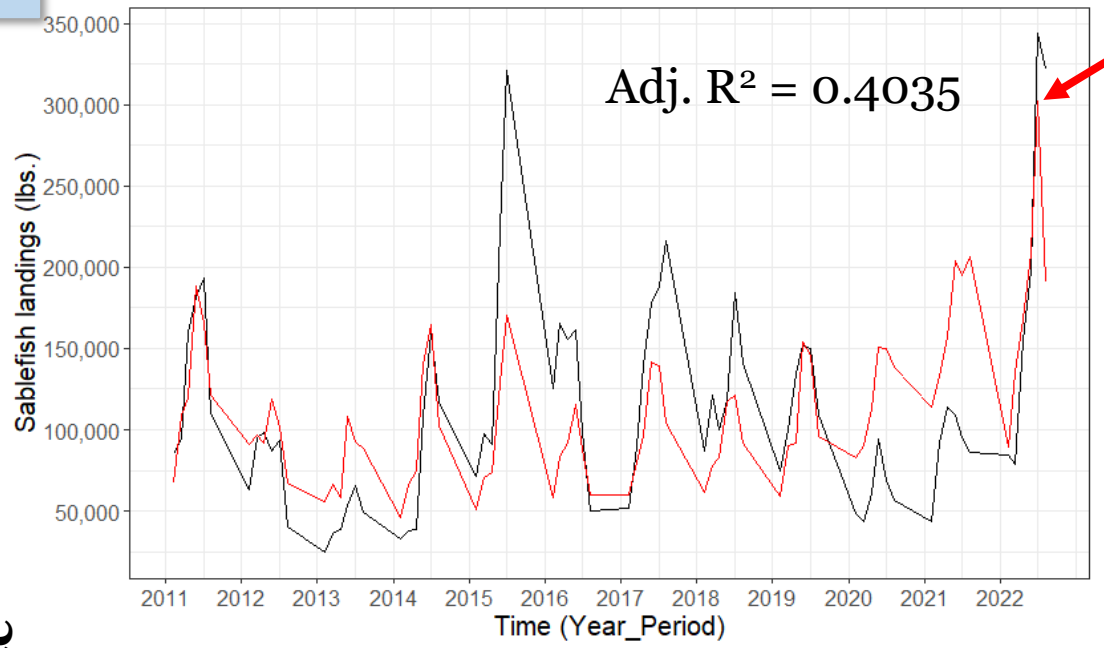




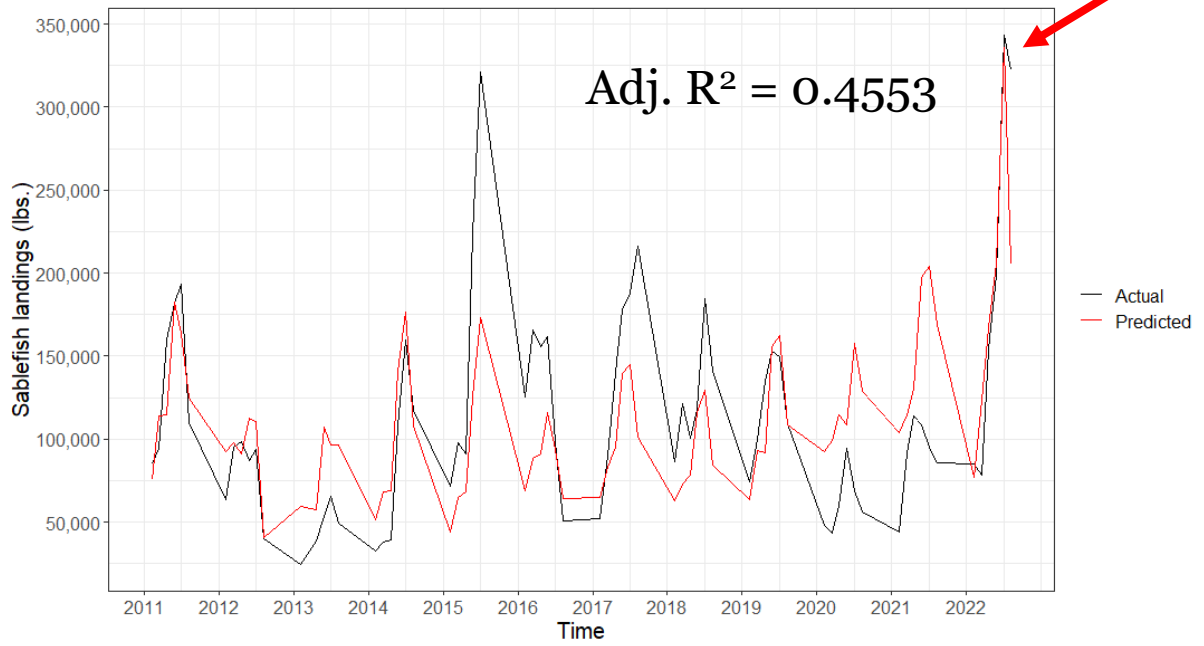




Status Quo Model

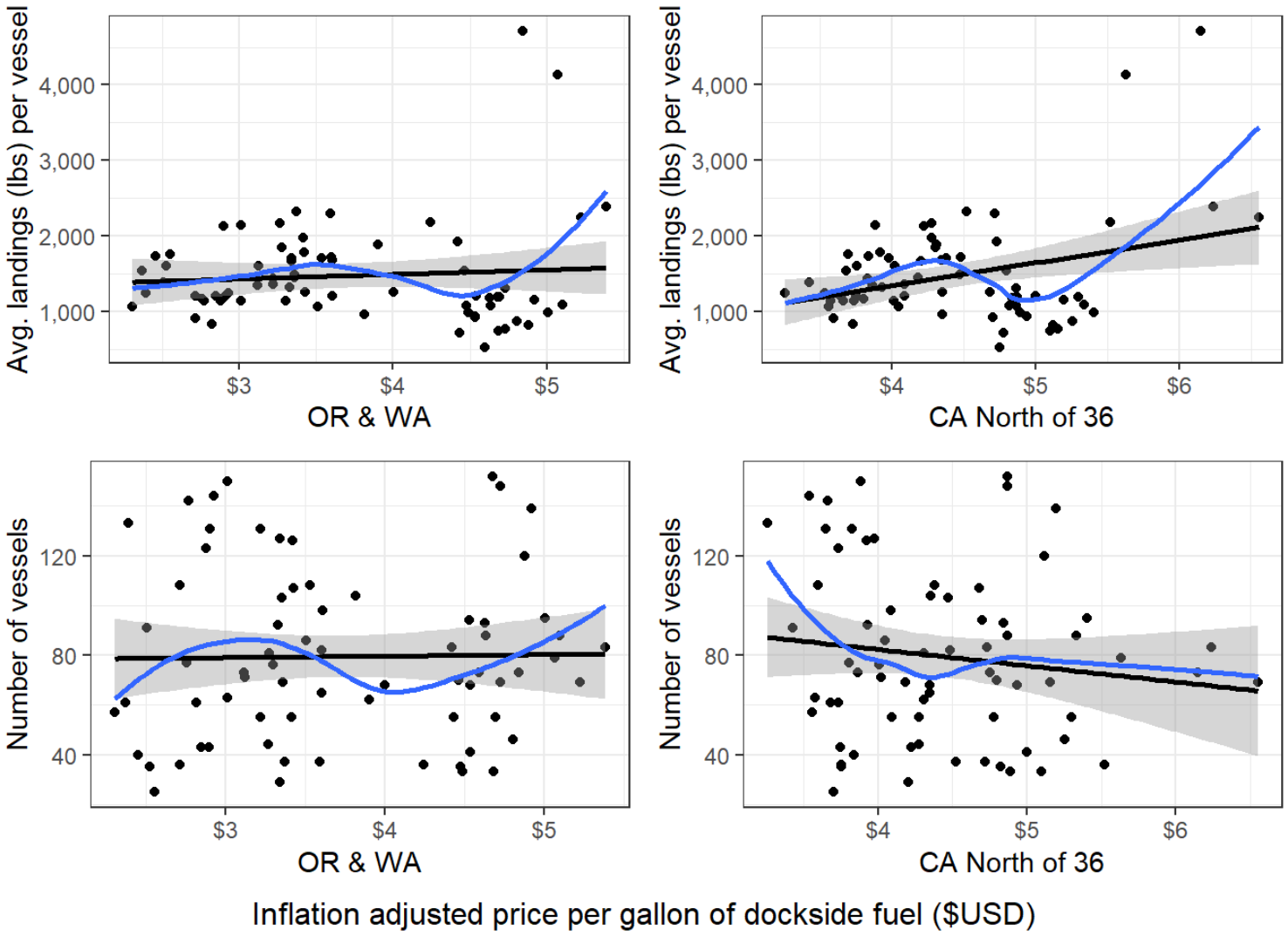


Log Transformation + Maximum D. Crab Price



OAN

Section 3.2.4 – Fuel Prices



OAN

Section 3.2.4 – Fuel Prices

Response variable = number of vessels

	SQ Model	Sable & Crab Prices	OR+WA Fuel	CA North Fuel	Sable & Crab & OR+WA Fuel	Sable & Crab & CA N. Fuel	Sable & Crab & OR+WA & CA N. Fuel
(Intercept)	28.34	61.77 **	119.39 ***	151.39 ***	86.37 **	107.97 ***	125.95 ***
	(16.35)	(22.02)	(17.02)	(19.17)	(26.98)	(30.47)	(33.32)
ADJ_PRICE	22.97 ***	19.61 ***			19.10 ***	16.65 **	12.90 *
	(4.90)	(5.01)			(4.97)	(5.07)	(5.81)
PER.4.PEAK	15.24 ***	13.39 ***	18.02 ***	19.05 ***	14.28 ***	14.84 ***	15.12 ***
	(3.03)	(3.07)	(3.52)	(3.36)	(3.09)	(3.07)	(3.06)
max_crab_price		-2.44 *			-2.66 *	-2.61 *	-2.38 *
		(1.11)			(1.11)	(1.09)	(1.10)
adj_fuel_OR_WA			-4.35		-4.88		11.85
			(3.70)		(3.15)		(9.12)
adj_fuel_CAN				-9.98 **		-6.94 *	-18.61
				(3.60)		(3.25)	(9.55)
N	70	70	70	70	70	70	70
R2	0.45	0.48	0.28	0.34	0.50	0.52	0.53

*** p < 0.001; ** p < 0.01; * p < 0.05.

Likelihood ratio test:
OR/WA + CA fuel
VS.
only CA fuel

#Df	LogLik	Df	Chisq	Pr(>Chisq)
7	-321			
6	-322	-1	1.82	0.177

Likelihood ratio test:
CA fuel
VS.
no fuel prices

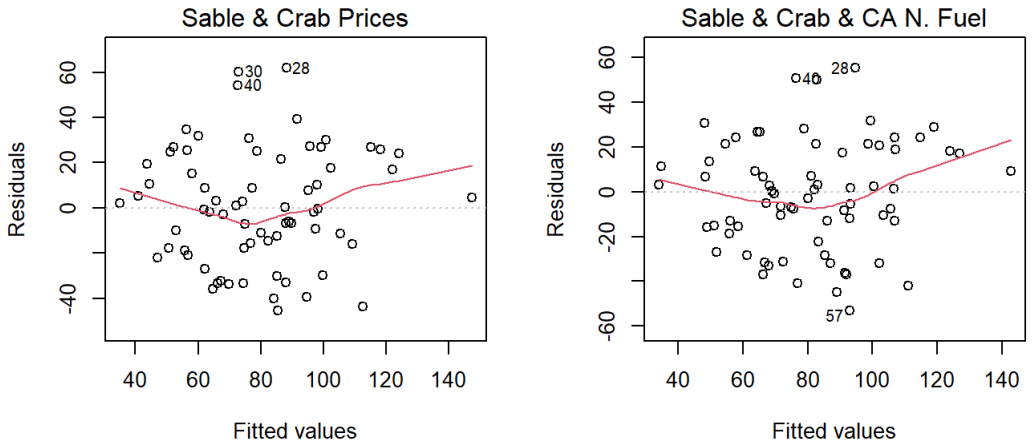
#Df	LogLik	Df	Chisq	Pr(>Chisq)
6	-322			
5	-324	-1	4.75	0.0294

OAN

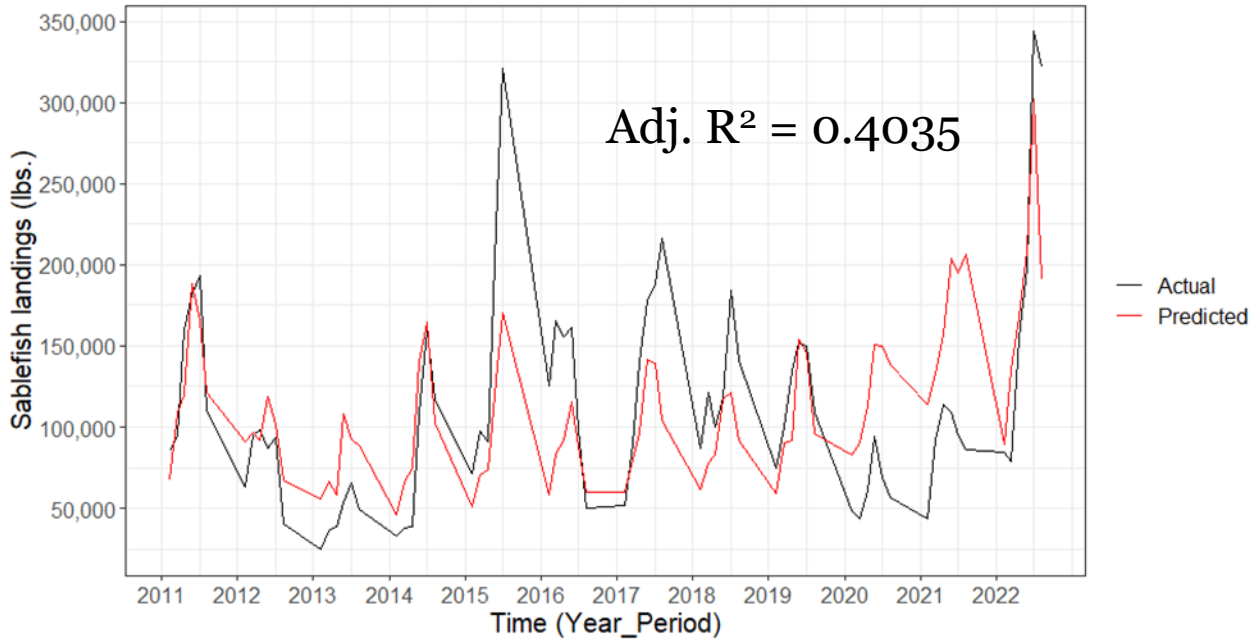
CA fuel prices are significant predictors but OR/WA fuel prices are not

Section 3.2.4 – Fuel Prices

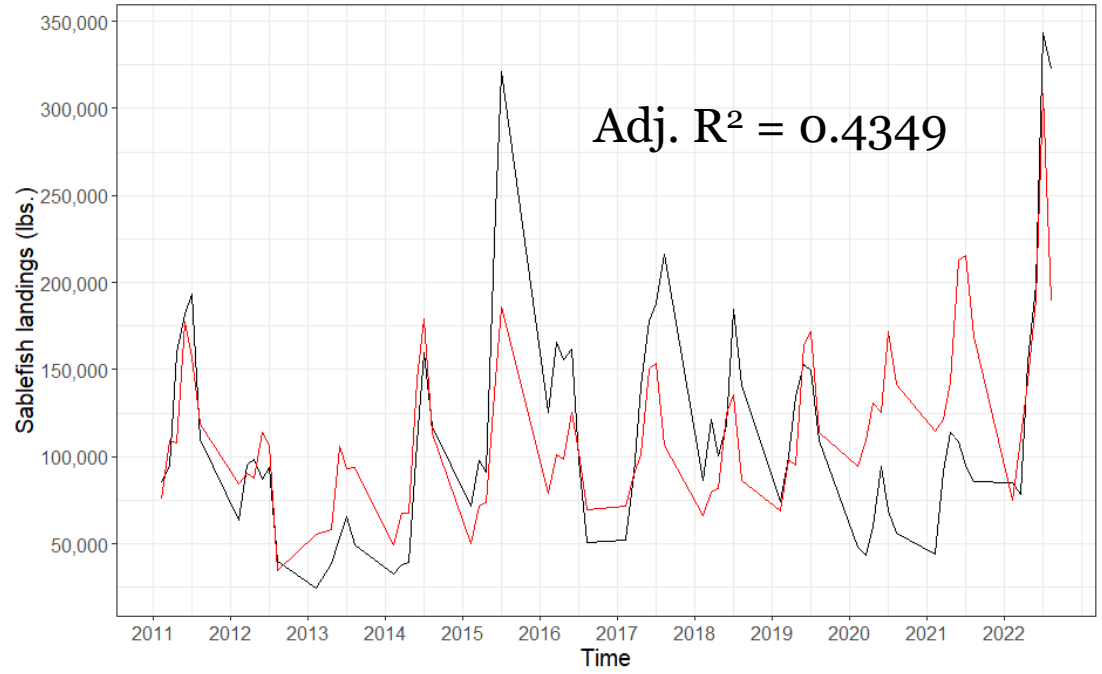
Response variable = number of vessels



Status Quo Model



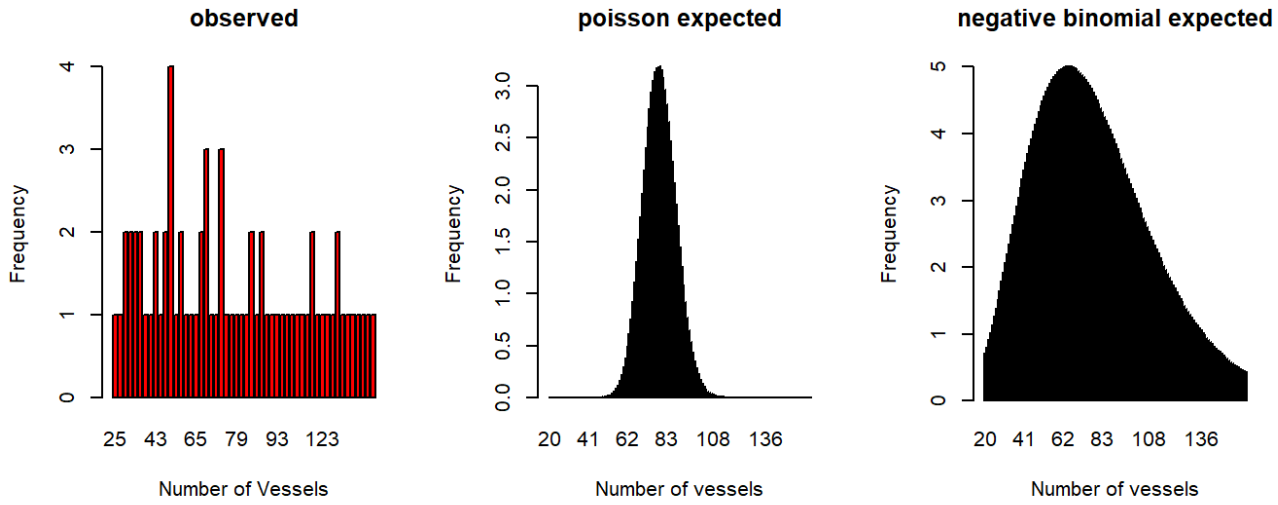
Log Transformation + Crab Prices + Northern CA Fuel Prices



OAN

Section 3.2.5 – Generalized Linear Model

- Ranked all GLM model variations using the following predictor variables based on AIC scores:
  - Average inflation-adjusted sablefish price
  - Median AFI sablefish price
  - Maximum AFI sablefish price
  - Period 4 Peak Adjuster (fixed effect)
  - Average inflation-adjusted Dungeness crab price
  - Maximum Dungeness crab price
  - OR/WA dockside fuel price
  - CA dockside fuel price in ports north of 36° N. lat.




```
model.full <- glm.nb(as.formula(
  paste("VES_NUM",
        paste(0, "+", paste(covars, collapse = " + ")),
        sep = " ~ ")),
  data = OAN,
  weights = WEIGHT,
  na.action = "na.fail")

model.suite <- MuMIn::dredge(model.full,
                             rank = "AIC",
                             fixed = c("PER.4.PEAK"))
```

OAN

Section 3.2.5 – Generalized Linear Model

	adj_crab_price	adj_fuel_CAN	adj_fuel_OR_WA	ADJ_PRICE	max_afi_price	max_crab_price	med_afi_price	PER.4.PEAK	df	logLik	AIC	delta	weight
1		-0.0514			0.218	-0.0159		+	8	-399	815	0	0.27375340025816
2			-0.0402		0.228	-0.016		+	8	-400	816	1.04	0.162470294713297
3					0.231	-0.0152		+	7	-401	816	1.25	0.146234313955052
		-0.0602			0.231	-0.0162	-0.0344	+	9	-399	816	1.28	0.1442526975406
		-0.0489			0.233			+	7	-401	816	1.36	0.138358796057569
		-0.0543		-0.0372	0.23	-0.0162		+	9	-399	816	1.41	0.134930497475322

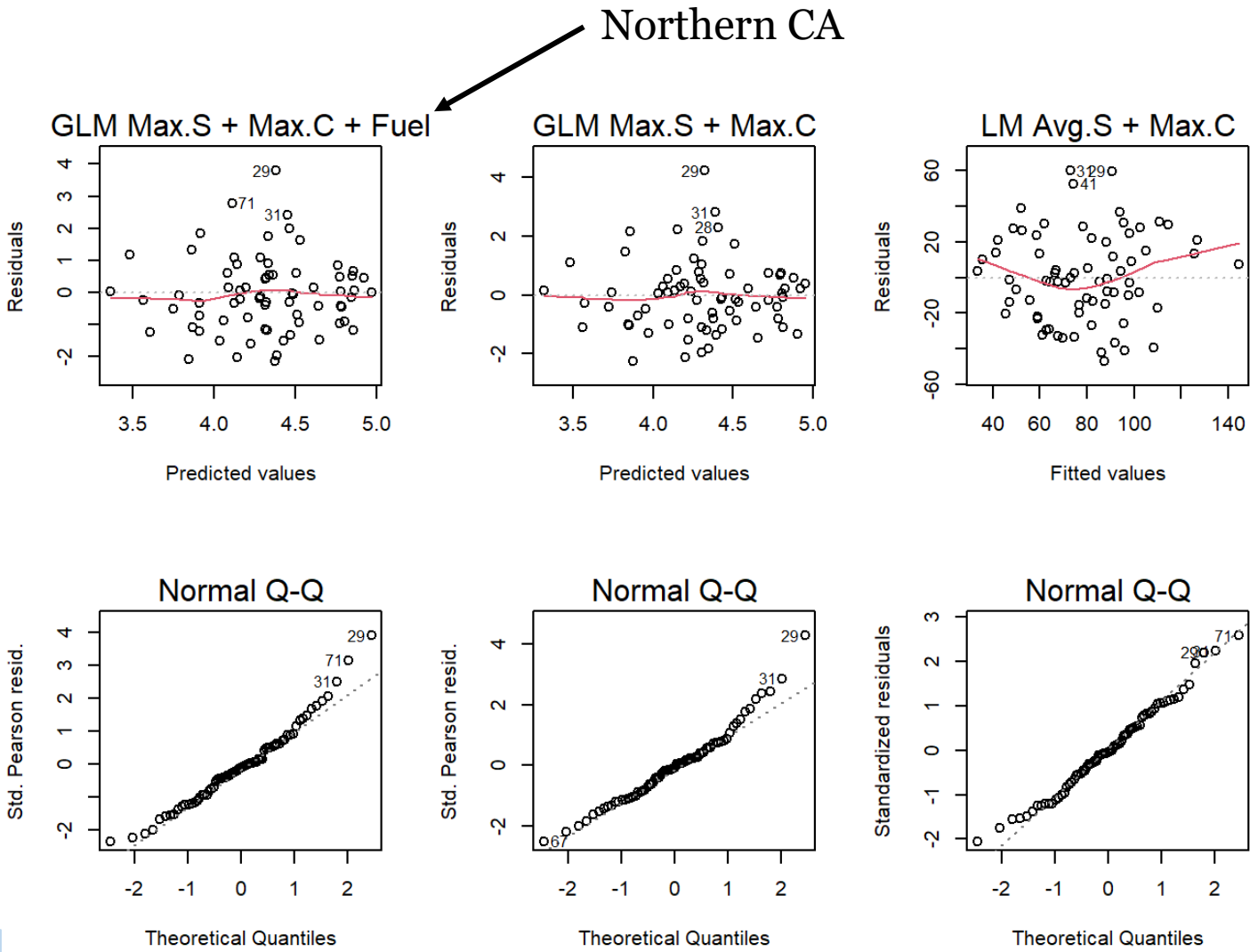
Likelihood ratio test results:

	Full Model		Nested Model	P-value
1	CA fuel + max sable price + max crab price	3	max sable price + max crab price	0.07125
2	OR/WA fuel + max sable price + max crab price	3	max sable price + max crab price	0.13710

OAN

Section 3.2.5 – Generalized Linear Model

Response variable = number of vessels



Including northern CA fuel prices in the GLM slightly improves the model diagnostics compared to a GLM with only sablefish and crab prices

OAN

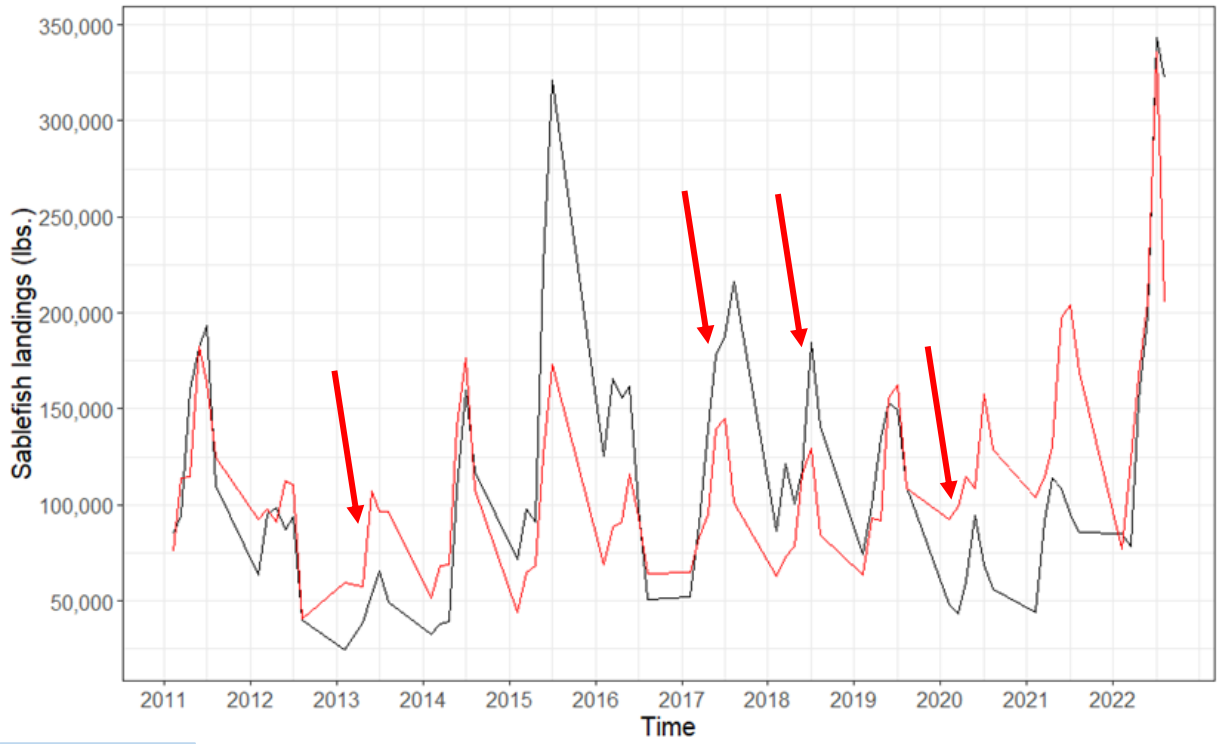
Section 3.2.5 – Generalized Linear Model

Both:

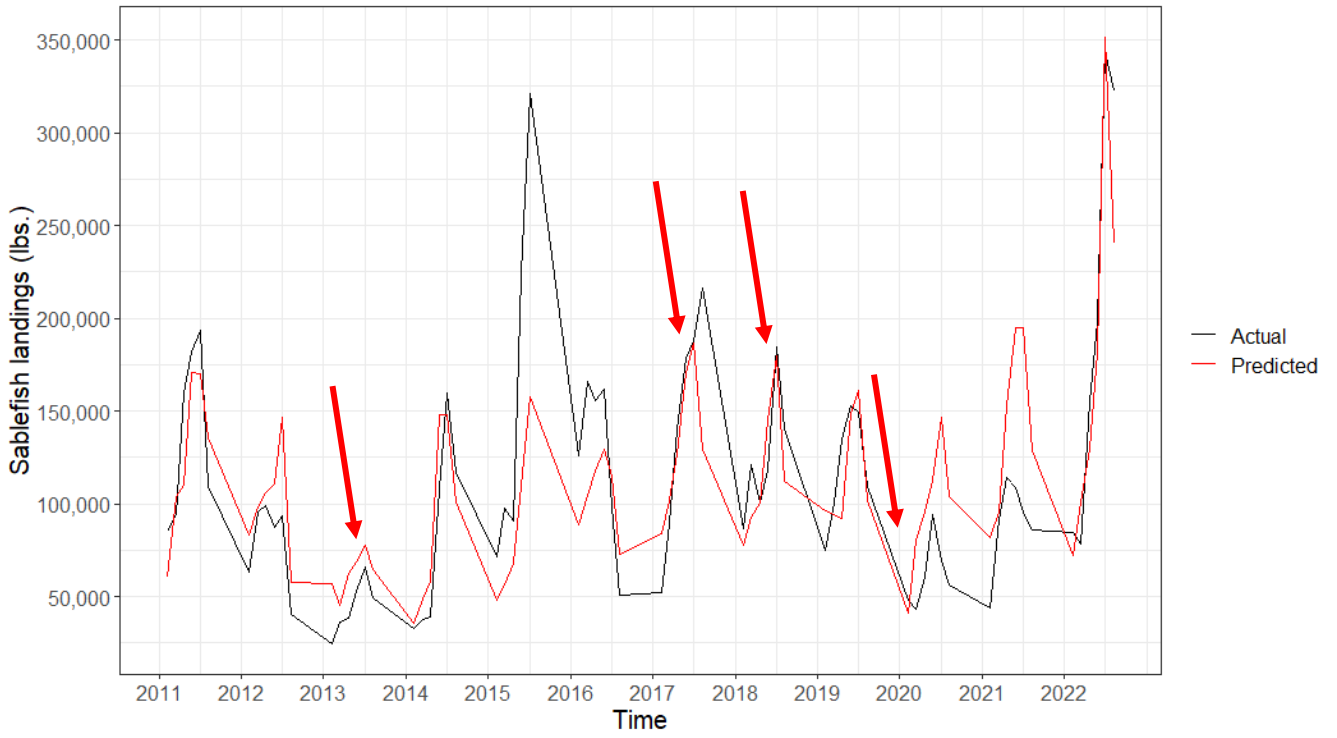
- Log-transformed average landings per vessel & weekly limit
- Maximum Dungeness crab prices
- Northern CA dockside fuel prices

GLM is better able to capture the OAN fleet's volatility

Linear Regression

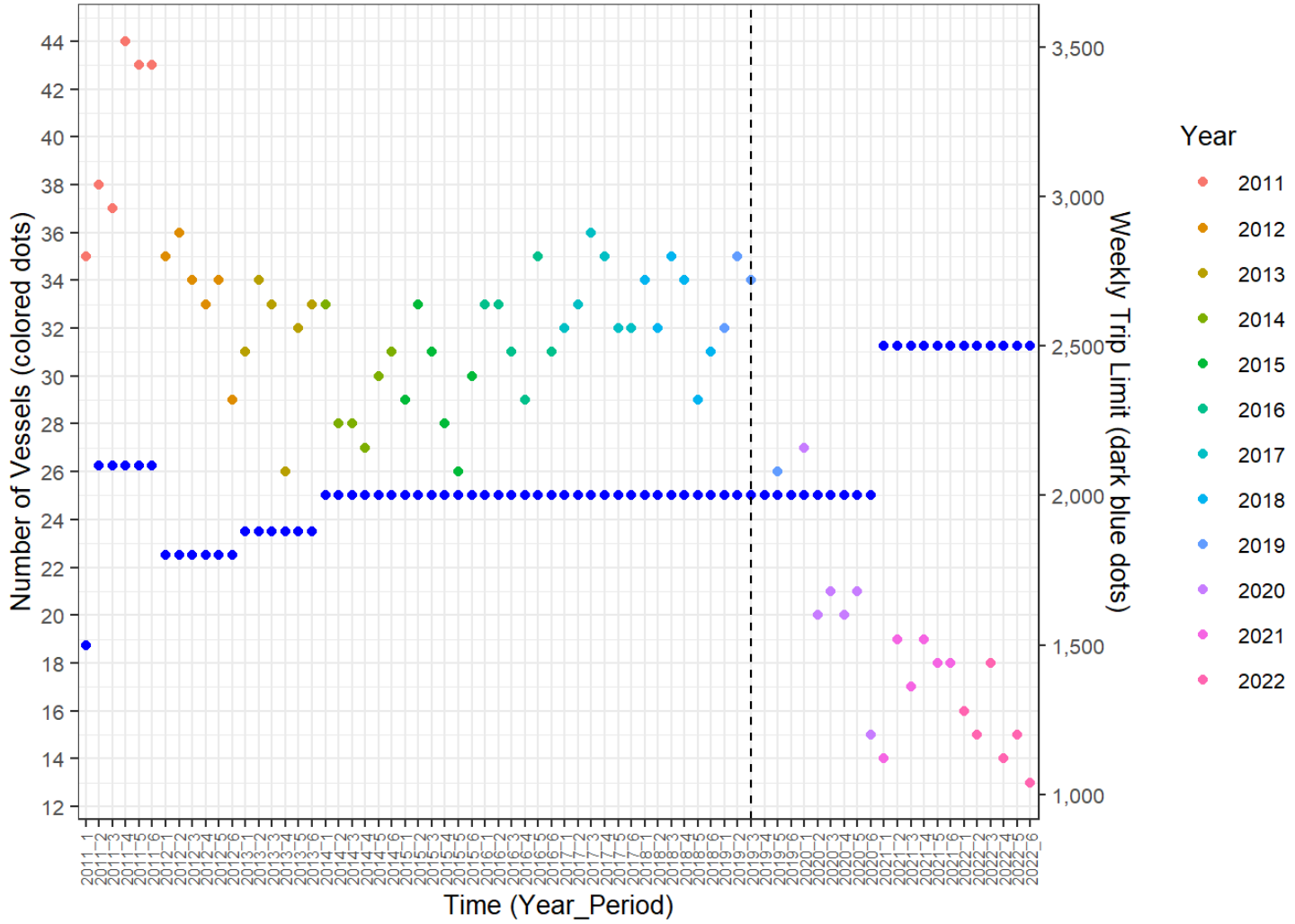


Generalized Linear Model

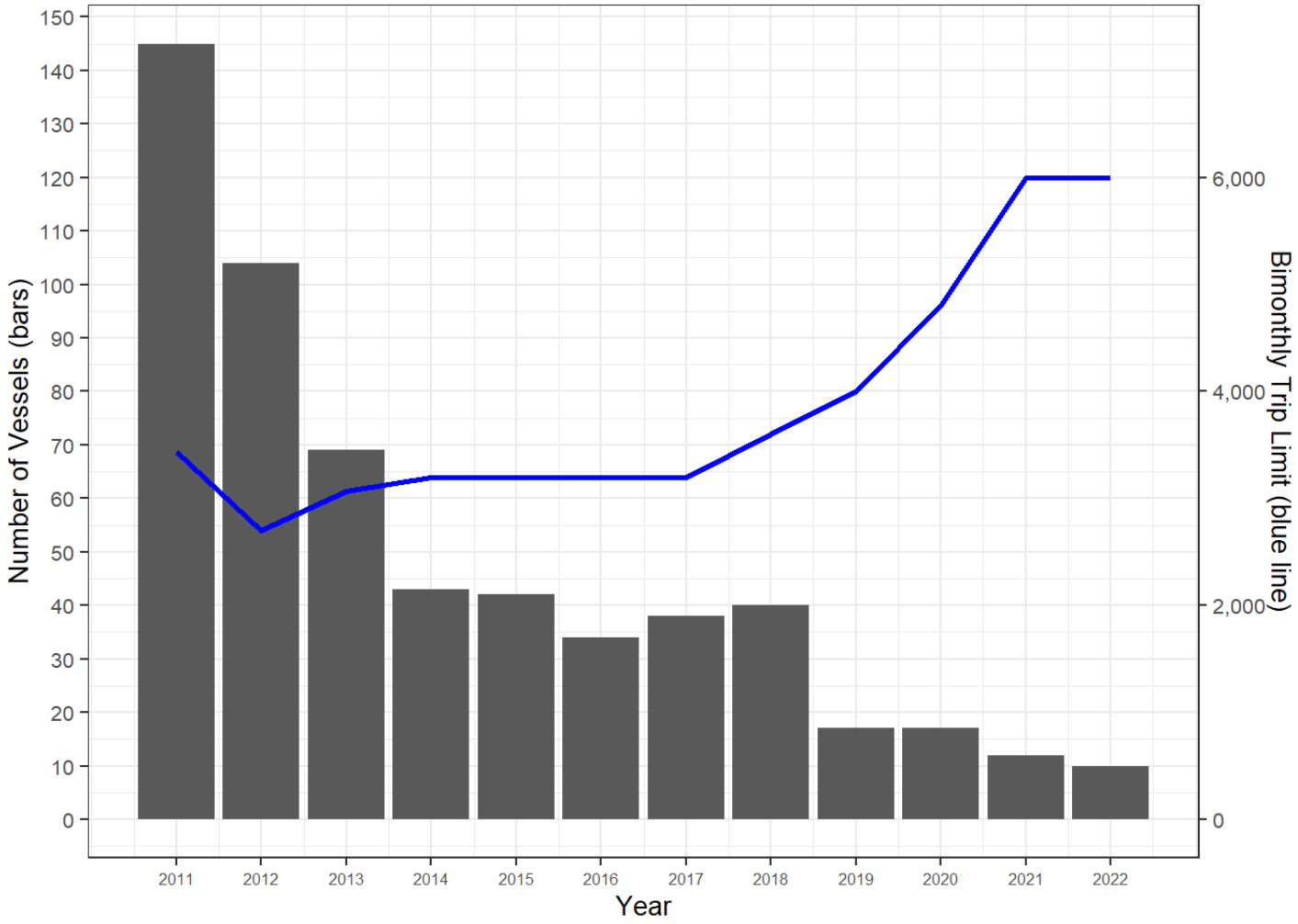


OAN

Limited Entry South (LES)



Open Access South (OAS)



Questions on OAN and anything else??