Standardized Catch Rates for Red Hind from the Commercial Diving, Trap, and Vertical Line Fisheries in Puerto Rico

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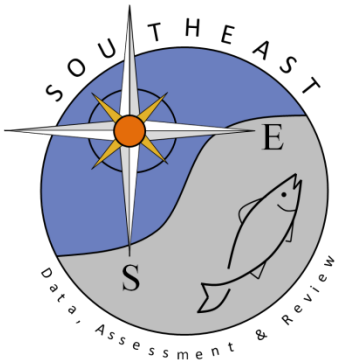

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Summary

Generalized Linear Models (GLM) were used to examine catch rates from commercial fisheries targeting Red Hind in Puerto Rico from 1990-2012. Catch rates were examined separately for the diving, trap, and vertical line gear types.

Methods

Data from self-reported fisher logbooks were used to characterize abundance trends of Red Hind in Puerto Rico. Catch per unit effort (CPUE) was calculated on an individual trip basis. CPUE was equal to the pounds of Red Hind landed on a given trip divided by the effort, where effort was the total hours on fishing grounds. Reported gears were grouped into gear types as follows:

Gear Type	Reported Gears
Diving	BY HAND, DIVING GEAR
Diving	SPEARS
Traps	FISH POTS AND TRAPS
Vertical Line	BOTTOM HOOK AND LINE

The following data filtering techniques were applied to the logbook data:

1. Records associated with more than one trip were excluded
2. Trips with more than one reported gear type were excluded
3. Trips with more than one reported value for number of gear were excluded
4. Trips with more than one reported value for number of hours were excluded
5. Trips associated with exactly duplicated records were removed
6. Trips associated with multiple reported coasts were removed

7. Outliers were removed from the data by looking at the following variables by gear type and removing trips where values in at least one of these variables fell above the 99.5 percentile: number of gear, and hours fished
8. Trips during the closed season for Red Hind (December to February, starting in December 2005) were excluded

The Stephens-MacCall approach (2004) was used to identify trips that targeted Red Hind. This approach uses the species composition of each trip in a logistic regression of species presence/absence to infer if effort on that trip occurred in similar habitat to Red Hind. If effort on a trip was determined to occur in similar habitat to Red Hind, or if a trip caught only Red Hind, then that trip was used in the analysis.

Delta-lognormal modeling methods were used to estimate relative indices of abundance (Lo et al. 1992). This modeling approach combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed red hind) and of the catch rates on successful trips to construct a single standardized CPUE index (Lo et al. 1992, Hinton and Maunder 2004, Maunder and Punt 2004).

The following factors were examined as possible influences on the proportion of positive trips, and on the catch rates of trips reporting the capture of Red Hind:

FACTOR	LEVELS	DESCRIPTION
YEAR	22	1990 – 2012
COAST	4	East, North, South, West
SEASON	4	Spring (March –May), Summer (June – August), Fall (September – November), Winter (December – February)

A stepwise approach was used to quantify the relative importance of the explanatory factors. Factors were screened and not added to the models if the reduction in deviance per degree of freedom was less than one percent. Two way interactions among significant main effects were examined and significant interactions were included in the models as random effects.

Results

The Stephens-MacCall approach was used to identify trips that targeted Red Hind. Stephens and MacCall regression coefficients for species occurring in at least 1% of trips for each gear are included in Tables 1-3. Model diagnostics for the logistic regression of species presence/absence are included in Figures 1-3.

The following models resulted from the standardization procedures where *Success* is a binomial indicating whether or not a fisher landed Red Hind, α represents the parameter estimate of each factor, μ represents the mean, and ε represents the error term.

The final models for the commercial diving fishery were:

$$Success = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + (Year * Coast)\alpha_3 + \epsilon$$

$$\ln(CPUE) = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + (Season)\alpha_3 + (Year * Coast)\alpha_4 + (Year * Season)\alpha_5 + \epsilon$$

The final models for the commercial trap fishery were:

$$Success = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + (Year * Coast)\alpha_3 + \epsilon$$

$$\ln(CPUE) = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + (Year * Coast)\alpha_3 + \epsilon$$

The final models for the commercial vertical line fishery were:

$$Success = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + \epsilon$$

$$\ln(CPUE) = \mu + (Year)\alpha_1 + (Coast)\alpha_2 + (Season)\alpha_3 + (Year * Coast)\alpha_4 + (Coast * Season)\alpha_5 + (Year * Season)\alpha_6 + \epsilon$$

Final deviance tables are included in Tables 4-6 and Tables 7-9 summarize number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance, and corresponding index statistics. The nominal CPUE and standardized indices for each index are plotted in Figures 4-6 and model diagnostics are included in Figures 7-9.

The standardized indices for Red Hind in Puerto Rico exhibit wide confidence intervals and show no overall directional trends in CPUE. However, similar trends across all three indices in the most recent years provide some support for a positive change in CPUE at the end of the time series.

Literature Cited

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Maunder, M. N. and A.E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70: 141-159.

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Tables and Figures

Table 1: Stephens and MacCall regression coefficients for species occurring in at least 1% of reported commercial diving trips in Puerto Rico.

Species	ITIS Code	Estimate	Std. Error	z value	P(<|z|)
BONY FISHES	161030	-3.16	0.18	-18.02	<0.0001
GROUPERS	167674	-2.55	0.09	-26.87	<0.0001
SNAPPERS	168845	0.41	0.04	11.34	<0.0001
MUTTON SNAPPER	168849	0.72	0.04	19.25	<0.0001
LANE SNAPPER	168860	-0.86	0.16	-5.30	<0.0001
HOGFISH	170566	0.39	0.02	15.74	<0.0001
PARROTFISHES	170809	0.18	0.04	4.46	<0.0001
QUEEN TRIGGERFISH	173139	1.33	0.03	49.66	<0.0001
BOXFISH	173235	0.67	0.03	21.15	<0.0001
QUEEN CONCH	72558	-0.63	0.03	-24.10	<0.0001
OCTOPUS	82595	-0.34	0.04	-9.50	<0.0001
OTHER SHELLFISH	83677	-0.64	0.16	-4.12	<0.0001
CARIBBEAN SPINY LOBSTER	97648	0.96	0.03	27.88	<0.0001
Intercept	Intercept	-3.63	0.04	-101.66	<0.0001

Table 2: Stephens and MacCall regression coefficients for species occurring in at least 1% of reported commercial trap trips in Puerto Rico.

Species	ITIS Code	Estimate	Std. Error	z value	P(<|z|)
BONY FISHES	161030	-2.70	0.12	-23.06	<0.0001
SQUIRRELFISHES	166170	0.06	0.05	1.32	0.1882
GROUPERS	167674	-0.45	0.05	-8.31	<0.0001
NASSAU GROUPER	167706	-0.30	0.12	-2.56	0.0105
CONEY	167740	1.67	0.05	36.15	<0.0001
BAR JACK	168614	0.19	0.07	2.75	0.0060
SNAPPERS	168845	0.18	0.04	4.19	<0.0001
MUTTON SNAPPER	168849	0.39	0.04	11.02	<0.0001
LANE SNAPPER	168860	-0.35	0.03	-10.85	<0.0001
SILK SNAPPER	168861	0.32	0.04	7.50	<0.0001
YELLOWTAIL SNAPPER	168907	0.95	0.03	27.35	<0.0001
VERMILION SNAPPER	168909	0.50	0.11	4.67	<0.0001
WHITE GRUNT	169059	0.16	0.03	4.75	<0.0001
PORGIES	169180	-0.24	0.04	-5.79	<0.0001
YELLOW GOATFISH	169408	0.54	0.07	7.78	<0.0001
SPOTTED GOATFISH	169421	-0.39	0.05	-7.80	<0.0001
HOGFISH	170566	0.79	0.04	20.25	<0.0001
PARROTFISHES	170809	0.09	0.04	2.05	0.0407
QUEEN TRIGGERFISH	173139	1.15	0.03	35.31	<0.0001
BOXFISH	173235	0.11	0.03	3.18	0.0015
TRUNKFISHES	173236	1.16	0.07	16.30	<0.0001
OCTOPUS	82595	0.28	0.10	2.90	0.0038
CRAB	95599	-0.30	0.09	-3.34	0.0008
CARIBBEAN SPINY LOBSTER	97648	0.09	0.03	3.02	0.0025
Intercept	Intercept	-3.41	0.03	-113.79	<0.0001

Table 3: Stephens and MacCall regression coefficients for species occurring in at least 1% of reported commercial vertical line trips in Puerto Rico.

Species	ITIS Code	Estimate	Std. Error	z value	P(<|z|)
REQUIEM SHARKS	160178	-0.02	0.07	-0.28	0.7786
BONY FISHES	161030	-2.45	0.14	-18.00	<0.0001
SQUIRRELFISHES	166170	0.82	0.05	18.02	<0.0001
GROUPERS	167674	-0.57	0.05	-12.42	<0.0001
MISTY GROUPER	167703	-0.31	0.16	-1.97	0.0487
NASSAU GROUPER	167706	-0.84	0.08	-10.31	<0.0001
CONEY	167740	2.26	0.04	53.44	<0.0001
JACKS	168584	-0.04	0.05	-0.86	0.3925
BAR JACK	168614	0.04	0.04	0.89	0.3719
DOLPHINS	168789	-1.07	0.13	-7.94	<0.0001
DOLPHIN	168791	-1.15	0.11	-10.07	<0.0001
SNAPPERS	168845	0.23	0.04	6.31	<0.0001
MUTTON SNAPPER	168849	-0.04	0.03	-1.28	0.2002
BLACKFIN SNAPPER	168852	1.09	0.07	15.13	<0.0001
LANE SNAPPER	168860	-0.75	0.03	-26.64	<0.0001
SILK SNAPPER	168861	-0.91	0.03	-28.76	<0.0001
QUEEN SNAPPER	168902	-1.96	0.08	-23.81	<0.0001
YELLOWTAIL SNAPPER	168907	-0.28	0.02	-12.37	<0.0001
VERMILION SNAPPER	168909	0.81	0.04	18.76	<0.0001
CARDINAL SNAPPER	168915	-1.24	0.20	-6.05	<0.0001
WHITE GRUNT	169059	0.46	0.03	14.13	<0.0001
PORGIES	169180	0.56	0.05	10.50	<0.0001
BARRACUDAS	170424	0.03	0.08	0.33	0.7450
ALBACORES	172398	-0.32	0.09	-3.77	0.0002
SKIPJACK TUNA	172401	-0.62	0.11	-5.51	<0.0001
BLACKFIN TUNA	172427	0.00	0.09	0.05	0.9563
KING MACKEREL	172435	-0.68	0.04	-17.41	<0.0001
CERO	172437	-0.50	0.05	-9.41	<0.0001
QUEEN TRIGGERFISH	173139	1.57	0.03	49.43	<0.0001
BOXFISH	173235	-0.22	0.08	-2.62	0.0087
Intercept	Intercept	-2.41	0.02	-124.18	<0.0001

Table 4. Final deviance tables for the Puerto Rico Red Hind regressions from the diving fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below.

Diving Binomial								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	8,234.5	6,345	8,234.5	8,236.4	-	-4,117.2	-
Coast	3	476.6	6,342	7,757.9	7,766.0	5.74	-3,879.0	476.4
Year	22	214.3	6,320	7,543.6	7,595.6	2.42	-3,771.8	214.4
Year*Coast	61	276.5	6,259	7,267.1	7,441.2	2.73	-3,633.6	276.4
Diving Log Normal								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood RatioTest**
Null	1	1,297.9	2,234	1,297.9	5,130.0	-	-2,564.0	-
Year	22	111.2	2,212	1,186.7	4,973.8	7.66	-2,463.9	200.2
Coast	3	43.7	2,209	1,143.0	4,896.0	3.55	-2,422.0	83.8
Season	3	24.9	2,206	1,118.1	4,852.6	2.05	-2,397.3	49.4
Year*Coast	45	103.7	2,161	1,014.4	4,725.2	7.39	-2,288.6	217.4
Year*Season	44	37.0	2,117	977.4	4,730.0	1.64	-2,247.0	83.2

Table 5. Final deviance tables for the Puerto Rico Red Hind regressions from the trap fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below.

Traps Binomial								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	7,496.6	5,562	7,496.6	7,498.6	-	-3,748.3	-
Coast	3	185.7	5,559	7,310.9	7,319.0	2.42	-3,655.5	185.6
Year	22	208.1	5,537	7,102.8	7,154.8	2.46	-3,551.4	208.2
Year*Coast	61	716.3	5,476	6,386.5	6,560.4	9.08	-3,193.2	716.4
Traps Log Normal								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	1,698.0	2,235	1,698.0	5,732.0	-	-2,865.0	-
Year	22	201.4	2,213	1,496.6	5,493.8	10.98	-2,723.9	282.2
Coast	3	38.5	2,210	1,458.1	5,441.6	2.44	-2,694.8	58.2
Year*Coast	53	154.0	2,157	1,304.1	5,298.0	8.36	-2,570.0	249.6

Table 6. Final deviance tables for the Puerto Rico Red Hind regressions from the vertical line fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below. Although the interaction term between year and coast (highlighted in gray) was significant in the binomial deviance analysis, it was not included in the final model since the GLM with this interaction would not converge.

Vertical Line Binomial								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	14,650.8	10,754	14,650.8	14,652.8	-	-7,325.4	-
Coast	3	459.2	10,751	14,191.6	14,199.6	3.11	-7,095.8	459.2
Year	22	229.6	10,729	13,962.0	14,014.0	1.42	-6,981.0	229.6
Year*Coast	66	601.5	10,663	13,360.5	13,544.4	3.72	-6,680.2	601.6
Vertical Line Log Normal								
Factor	**Df**	**Dev.**	**Resid. Df**	**Resid. Dev.**	**AIC**	**Dev/Df %Red.**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	4,238.6	4,544	4,238.6	12,583.0	-	-6,290.5	-
Coast	3	353.7	4,541	3,884.9	12,193.0	8.28	-6,092.5	396.0
Season	3	130.7	4,538	3,754.2	12,043.4	3.30	-6,014.7	155.6
Year	22	121.4	4,516	3,632.8	11,938.0	2.76	-5,940.0	149.4
Year*Coast	66	146.9	4,450	3,485.9	11,882.4	2.62	-5,846.2	187.6
Coast*Season	9	44.3	4,441	3,441.6	11,842.2	1.07	-5,817.1	58.2
Year*Season	59	79.6	4,382	3,362.0	11,853.8	1.00	-5,763.9	106.4

Table 7: Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for Red Hind from the diving fishery in Puerto Rico.

Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
1990	10	0.20	0.5781	1.2132	0.7440	0.3217	4.5753
1991	61	0.28	0.5170	1.2509	0.3384	0.6475	2.4164
1992	53	0.02	0.1346	0.2109	1.0756	0.0365	1.2176
1993	39	0.13	0.4217	0.1334	0.6303	0.0419	0.4240
1994	47	0.09	1.1454	1.1394	0.6412	0.3523	3.6849
1995	48	0.08	0.1800	0.3391	0.6323	0.1063	1.0817
1996	55	0.20	0.5498	0.8767	0.4231	0.3894	1.9739
1997	120	0.33	2.2352	1.8727	0.3170	1.0085	3.4773
1998	172	0.20	0.8809	1.0799	0.3476	0.5495	2.1221
1999	266	0.44	1.9207	1.8605	0.3174	1.0013	3.4571
2000	149	0.31	1.2195	1.3029	0.3487	0.6617	2.5655
2001	511	0.27	0.8058	0.8701	0.3400	0.4491	1.6858
2002	375	0.25	0.8771	0.8415	0.3582	0.4201	1.6858
2003	371	0.29	0.6369	0.6868	0.3598	0.3418	1.3800
2004	679	0.26	0.8904	1.4046	0.3623	0.6958	2.8354
2005	610	0.36	0.9787	0.9282	0.3575	0.4639	1.8571
2006	345	0.38	1.0296	0.4175	0.4667	0.1718	1.0145
2007	357	0.35	0.7899	0.6479	0.4762	0.2623	1.6001
2008	372	0.45	1.3710	0.7775	0.4483	0.3304	1.8299
2009	362	0.41	1.0381	1.0356	0.3445	0.5300	2.0235
2010	403	0.47	1.4155	1.0156	0.4996	0.3951	2.6105
2011	538	0.49	1.3320	0.7827	0.3630	0.3873	1.5818
2012	403	0.51	2.0520	2.3125	0.2711	1.3576	3.9390

Table 8: Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for Red Hind from the trap fishery in Puerto Rico.

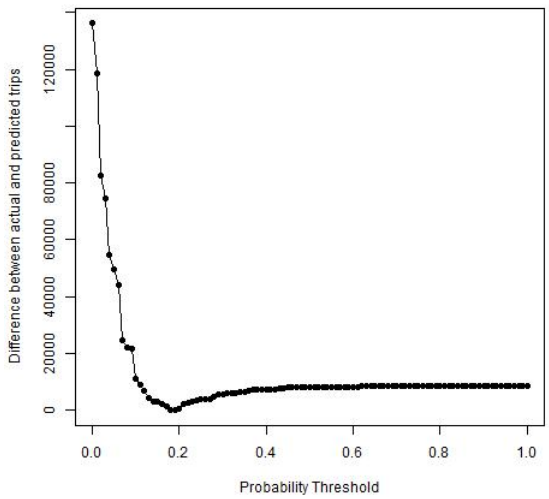
Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
1990	26	0.46	1.8243	1.3850	0.6225	0.4409	4.3507
1991	87	0.32	1.9830	1.3379	0.4417	0.5750	3.1126
1992	45	0.40	1.7891	1.4843	0.4921	0.5849	3.7670
1993	45	0.31	1.0015	1.1015	0.5066	0.4235	2.8652
1994	81	0.54	1.2644	1.8330	0.3509	0.9272	3.6239
1995	85	0.29	0.5987	0.8991	0.4876	0.3570	2.2643
1996	212	0.26	0.6747	0.6081	0.4843	0.2428	1.5230
1997	195	0.19	0.3730	0.5767	0.4552	0.2421	1.3735
1998	249	0.38	0.9858	0.9384	0.3493	0.4760	1.8496
1999	173	0.39	0.9510	0.8900	0.4041	0.4089	1.9373
2000	226	0.40	0.7572	1.3804	0.3660	0.6792	2.8055
2001	291	0.55	1.0286	1.1794	0.2997	0.6561	2.1204
2002	298	0.39	1.7137	1.4472	0.3261	0.7663	2.7332
2003	741	0.42	1.0963	1.1445	0.3087	0.6260	2.0926
2004	727	0.41	1.0543	1.0811	0.3648	0.5331	2.1925
2005	465	0.36	0.6880	0.8370	0.4224	0.3722	1.8821
2006	360	0.46	1.5375	1.0945	0.3930	0.5129	2.3356
2007	305	0.47	0.8050	1.0150	0.3870	0.4809	2.1425
2008	204	0.43	0.4033	0.3665	0.4603	0.1525	0.8806
2009	263	0.41	0.3423	0.2619	0.4964	0.1025	0.6697
2010	181	0.32	0.4017	0.3509	0.4796	0.1413	0.8717
2011	141	0.36	0.6605	0.5420	0.4684	0.2224	1.3208
2012	163	0.56	1.0662	1.2456	0.3090	0.6809	2.2787

Table 9: Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for Red Hind from the vertical line fishery in Puerto Rico.

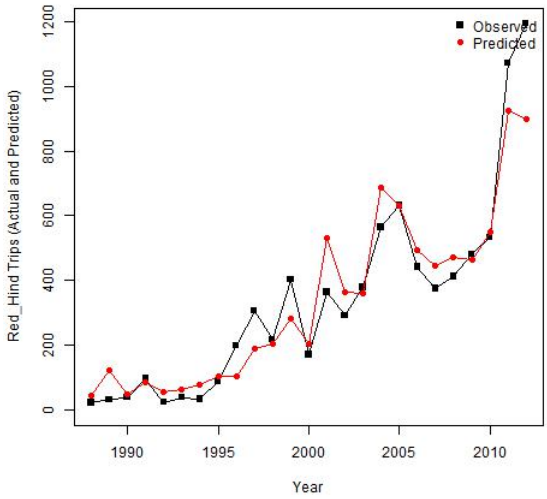
Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
1990	129	0.54	1.2840	1.2232	0.3125	0.6642	2.2524
1991	294	0.51	1.6762	1.8521	0.2150	1.2106	2.8336
1992	221	0.38	0.8007	1.0590	0.2859	0.6046	1.8550
1993	221	0.38	0.9282	1.0268	0.2896	0.5821	1.8112
1994	216	0.30	0.5030	0.5262	0.3537	0.2648	1.0456
1995	595	0.33	0.5827	0.7385	0.2191	0.4789	1.1389
1996	598	0.37	0.9674	0.9605	0.2132	0.6301	1.4641
1997	520	0.35	1.1324	1.0539	0.2291	0.6704	1.6565
1998	526	0.28	0.7328	0.6530	0.2577	0.3933	1.0843
1999	483	0.35	0.8286	0.8778	0.2325	0.5548	1.3889
2000	465	0.42	1.1045	0.9670	0.2239	0.6213	1.5049
2001	783	0.49	1.5652	1.2584	0.1755	0.8883	1.7829
2002	964	0.47	1.1573	1.1741	0.1671	0.8425	1.6364
2003	1,192	0.48	0.8981	0.9296	0.1621	0.6737	1.2829
2004	874	0.53	1.0502	1.0633	0.1692	0.7599	1.4877
2005	664	0.49	0.9801	1.0027	0.1927	0.6844	1.4691
2006	277	0.40	0.8498	0.8895	0.2836	0.5100	1.5514
2007	310	0.46	1.0279	1.1606	0.2538	0.7041	1.9132
2008	301	0.42	1.0812	1.1669	0.2748	0.6803	2.0016
2009	292	0.31	0.8094	0.8122	0.3320	0.4254	1.5508
2010	253	0.35	0.5221	0.7164	0.3127	0.3889	1.3196
2011	322	0.44	0.6649	0.7480	0.2436	0.4628	1.2091
2012	255	0.38	1.8533	1.1402	0.2757	0.6636	1.9592

Diving Puerto Rico Red Hind
Trip Selection Diagnostics

(a)



(b)



(c)

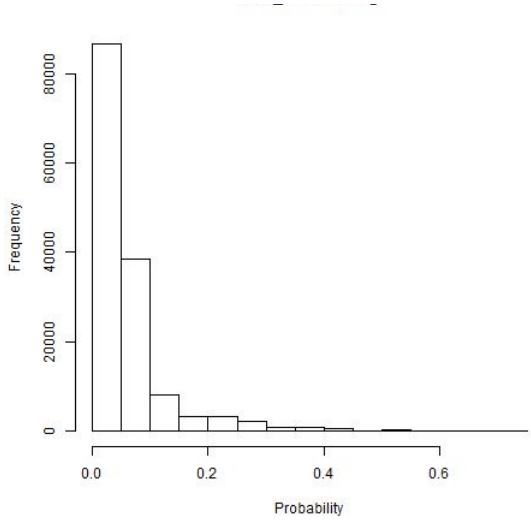
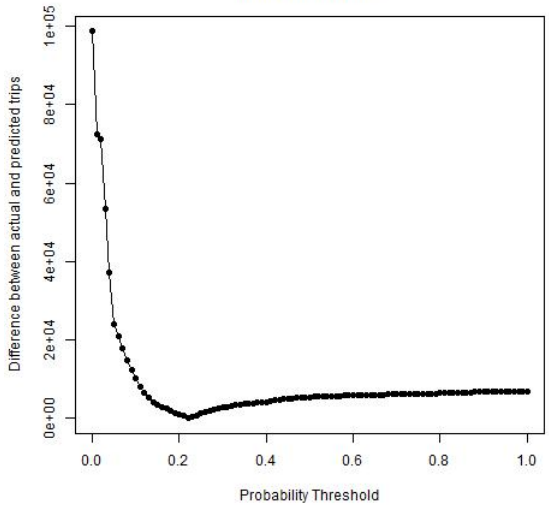


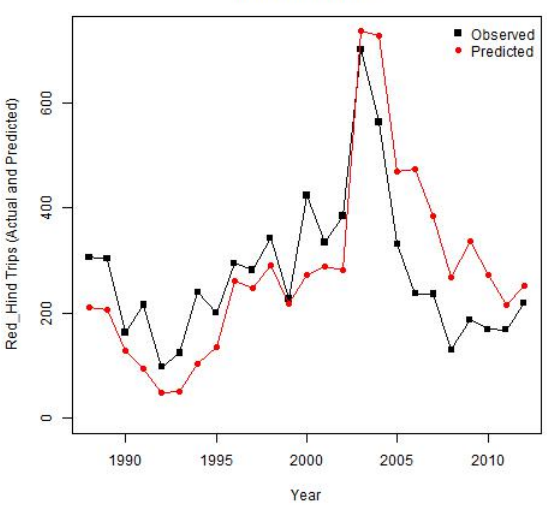
Figure 1. Stephens and MacCall (2004) model diagnostics for Red Hind from the diving fishery in Puerto Rico. a) Difference between the number of trips in which Red Hind were observed and the number in which they were predicted. b) Numbers of predicted and observed trips that caught Red Hind over time. c) Frequency of probabilities generated by the species regression.

Traps Puerto Rico Red Hind
Trip Selection Diagnostics

(a)



(b)



(c)

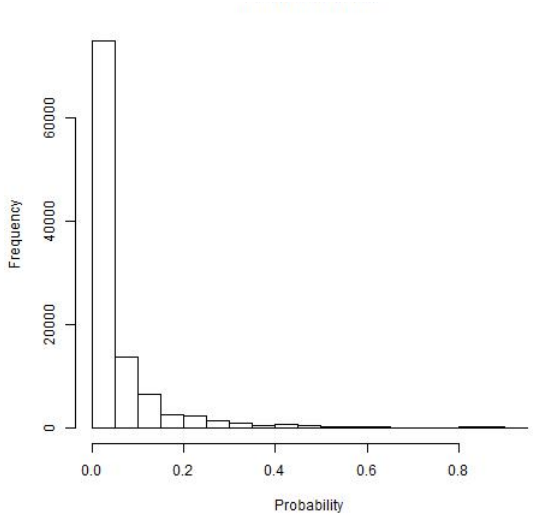


Figure 2. Stephens and MacCall (2004) model diagnostics for Red Hind from the trap fishery in Puerto Rico. a) Difference between the number of trips in which Red Hind were observed and the number in which they were predicted. b) Numbers of predicted and observed trips that caught Red Hind over time. c) Frequency of probabilities generated by the species regression.

Traps Puerto Rico Red Hind
Trip Selection Diagnostics

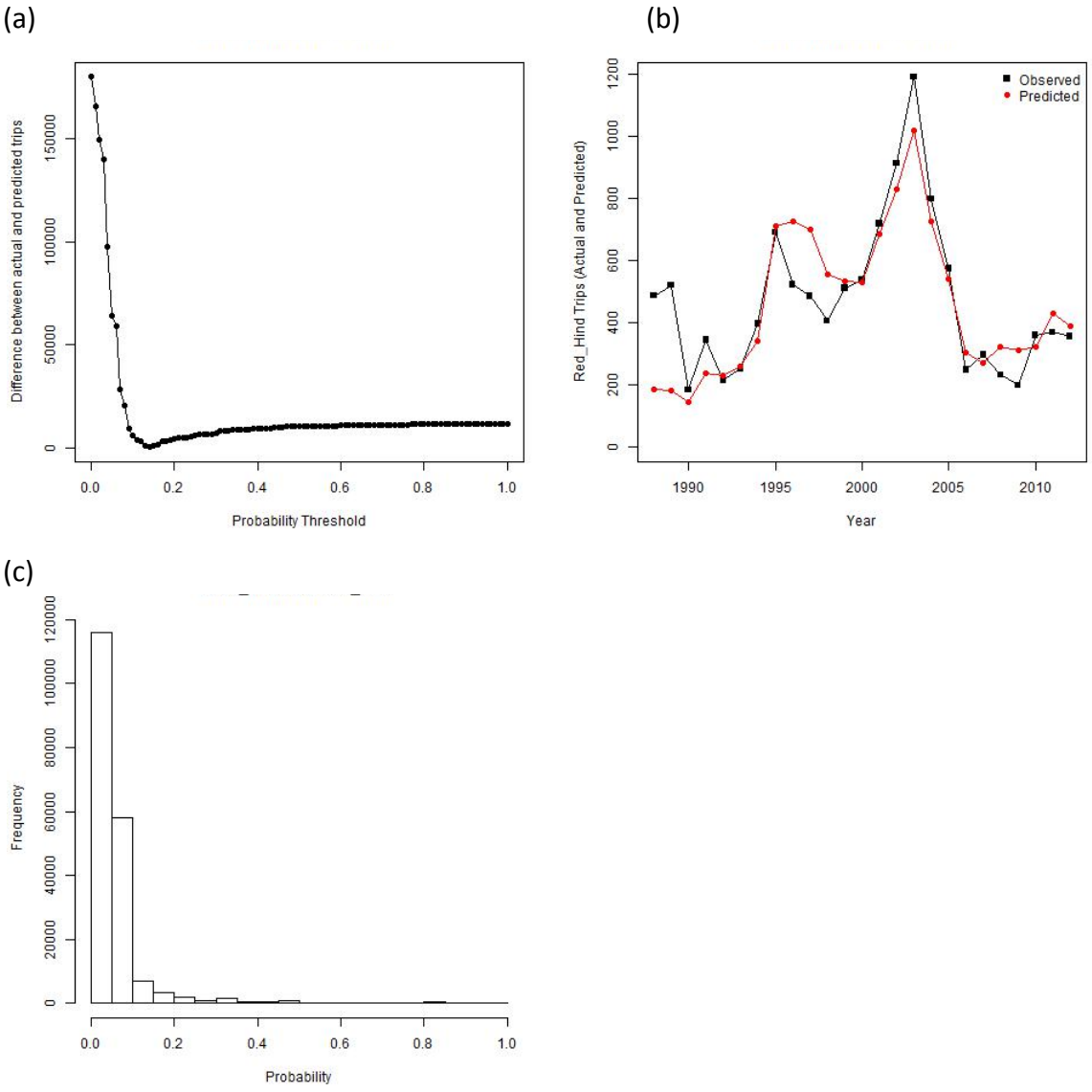


Figure 3. Stephens and MacCall (2004) model diagnostics for Red Hind from the trap fishery in Puerto Rico. a) Difference between the number of trips in which Red Hind were observed and the number in which they were predicted. b) Numbers of predicted and observed trips that caught Red Hind over time. c) Frequency of probabilities generated by the species regression.

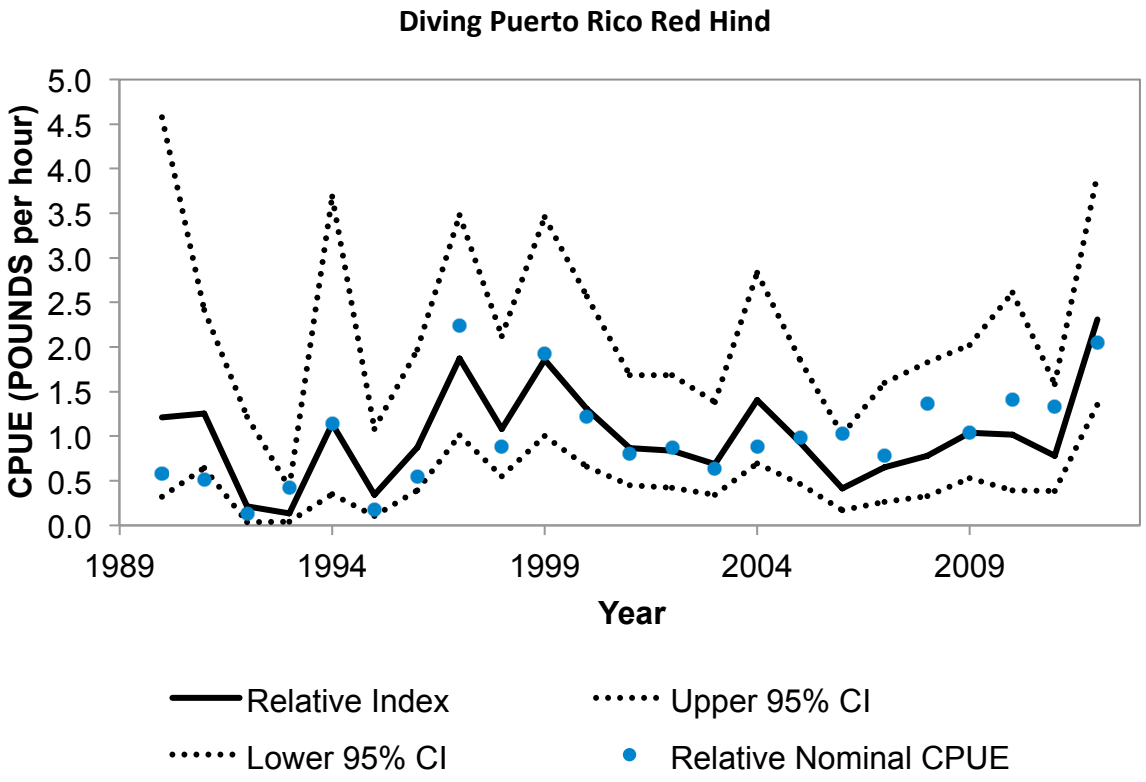


Figure 4. Nominal CPUE, standardized index, and the 95% confidence intervals for Puerto Rico Red Hind from the diving fishery. The standardized index and nominal CPUE values were normalized by their respective means over the time series.

Traps Puerto Rico Red Hind

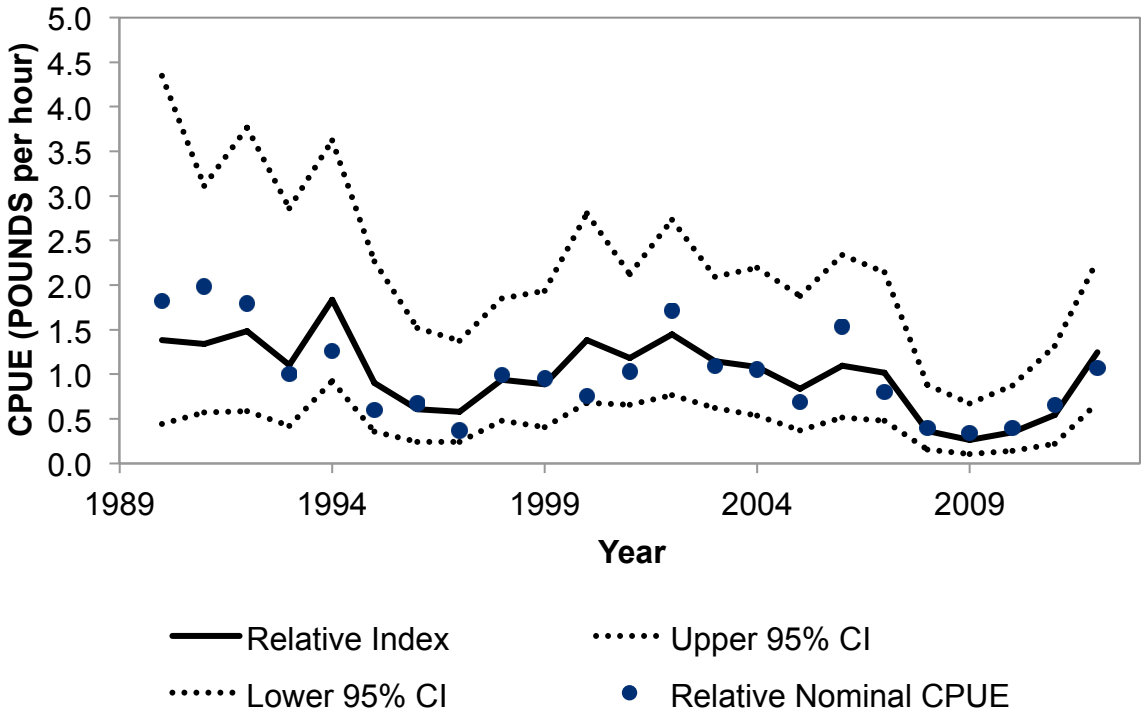


Figure 5. Nominal CPUE, standardized index, and the 95% confidence intervals for Puerto Rico Red Hind from the trap fishery. The standardized index and nominal CPUE values were normalized by their respective means over the time series.

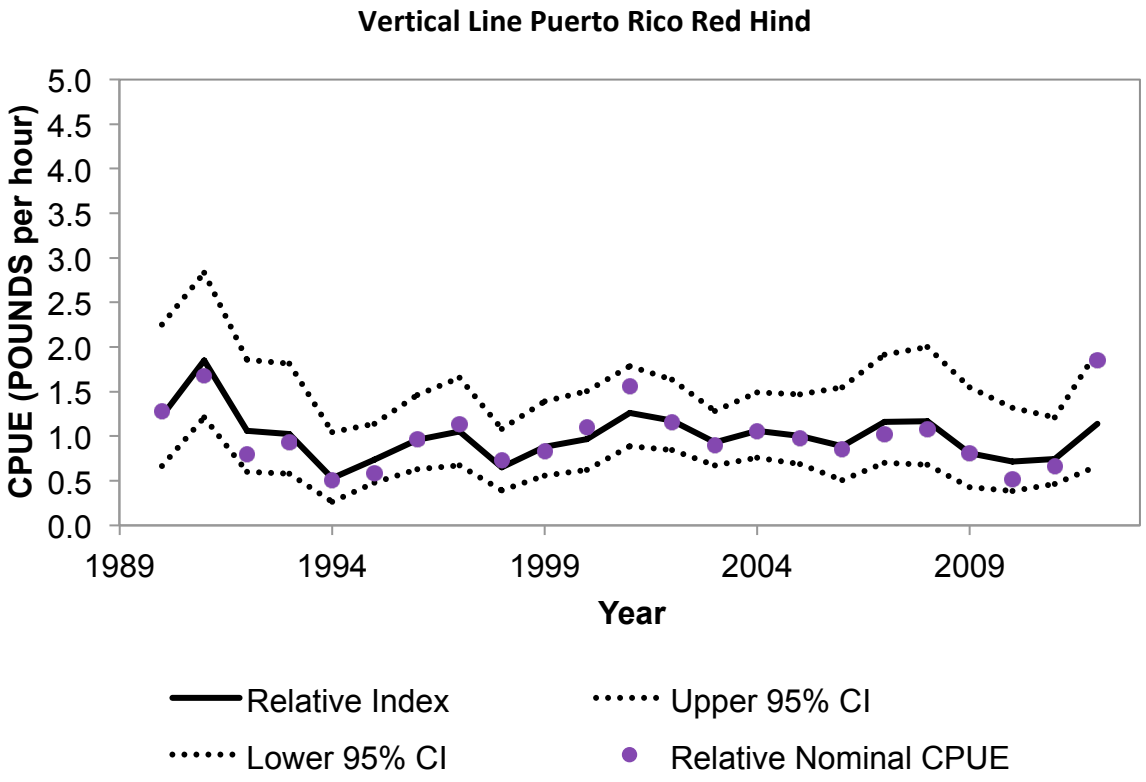
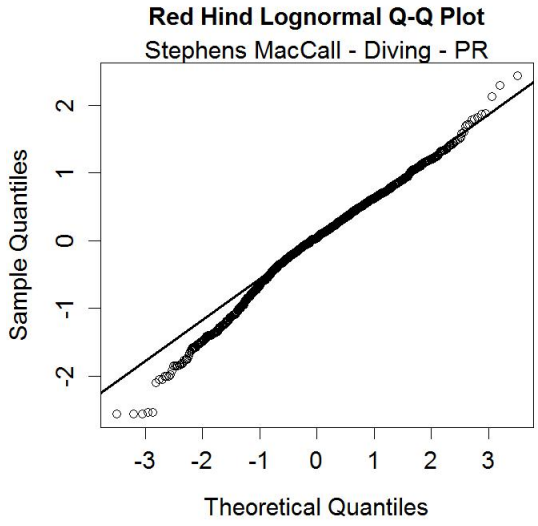


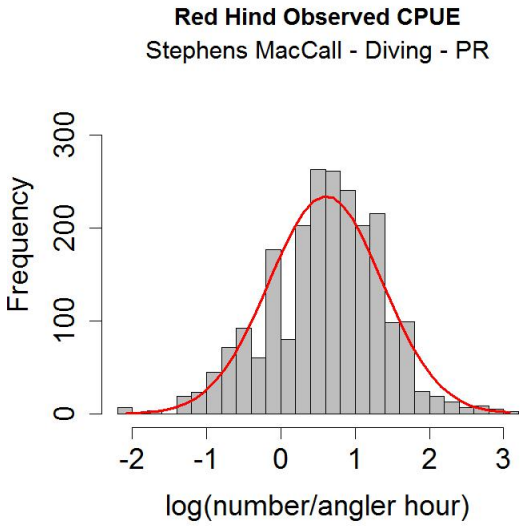
Figure 6. Nominal CPUE, standardized index, and the 95% confidence intervals for Puerto Rico Red Hind from the vertical line fishery. The standardized index and nominal CPUE values were normalized by their respective means over the time series.

Diving Puerto Rico Red Hind
Standardized Index Diagnostics

(a)



(b)



(c)

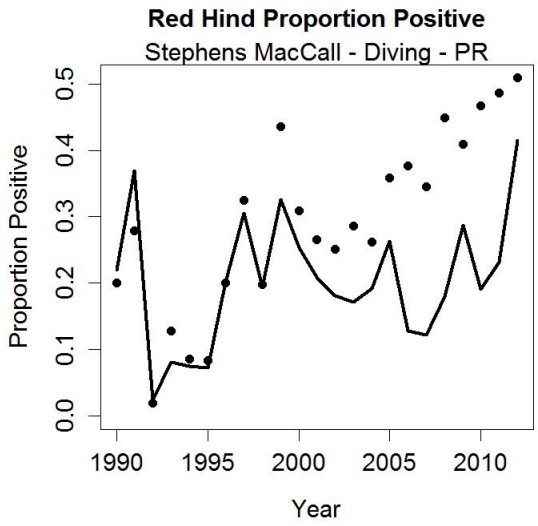
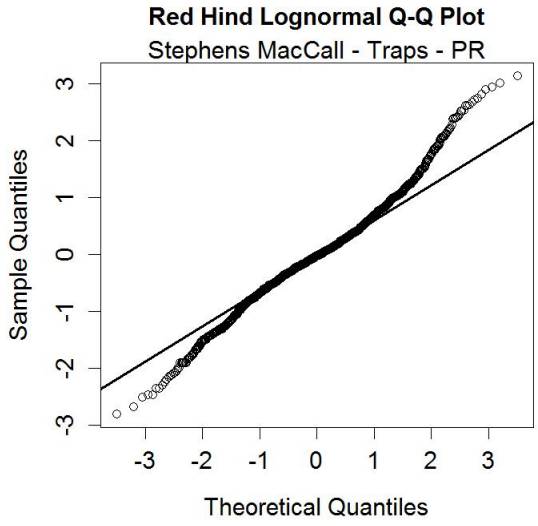


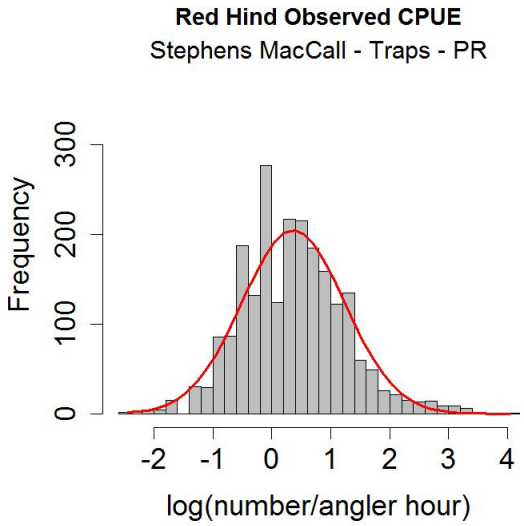
Figure 7. Diagnostic plots for the standardized diving index. a) QQ-Plot of CPUE. b) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution. c) Fit of the binomial proportion positive model to the observed proportion positive values.

Trap Puerto Rico Red Hind
Standardized Index Diagnostics

(a)



(b)



(c)

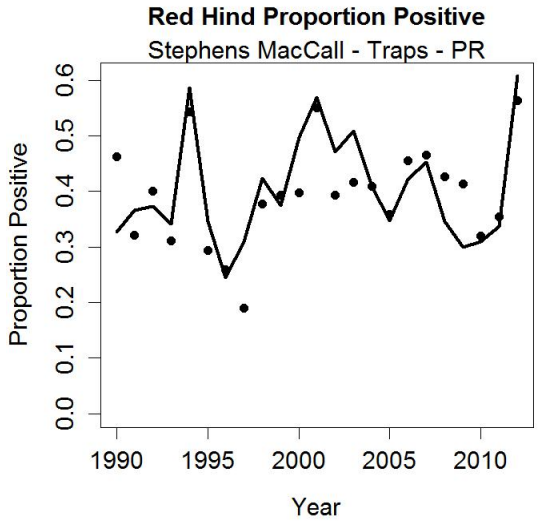
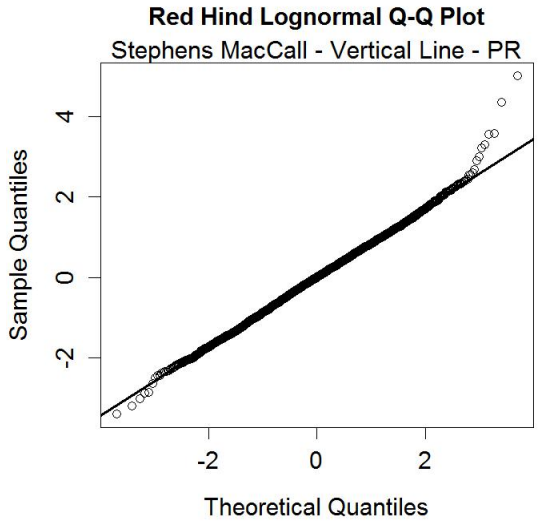


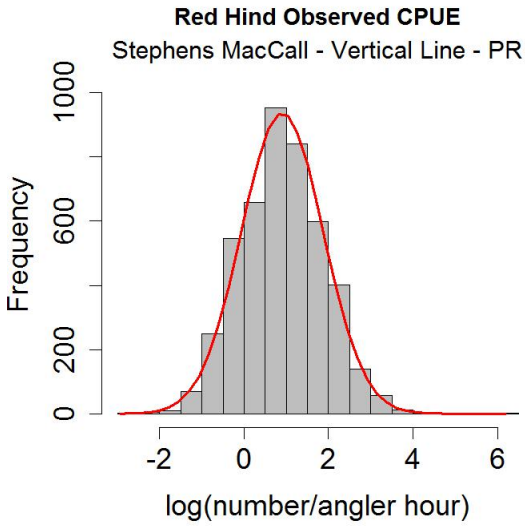
Figure 8. Diagnostic plots for the standardized trap index. a) QQ-Plot of CPUE. b) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution. c) Fit of the binomial proportion positive model to the observed proportion positive values.

Vertical Line Puerto Rico Red Hind
Standardized Index Diagnostics

(a)



(b)



(c)

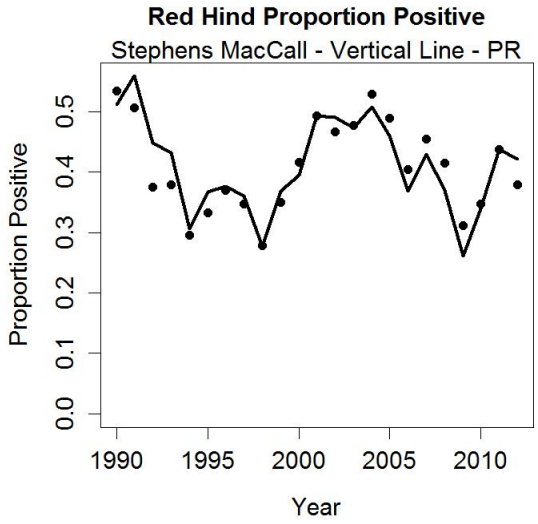


Figure 9. Diagnostic plots for the standardized vertical line index. a) QQ-Plot of CPUE. b) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution. c) Fit of the binomial proportion positive model to the observed proportion positive values.