Riley's Hump Visual Census Survey, Tortugas South Ecological Reserve 2002-2015

Robert Muller

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Robert Muller
Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
St. Petersburg, FL

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Introduction

NOAA began the visual census at Riley's Hump in July 2001 with the objective of evaluating the effectiveness of the Tortugas South Ecological Reserves on the numbers of snappers and groupers (Burton *et al.*, 2005). Riley's Hump (Fig.1) was selected because fishers had reported obtaining large catches of Mutton Snapper (muttons) there during their spawning season. Riley's Hump is located approximately 20 km southwest of Fort Jefferson. Feeley *et al.*(2018) used acoustic tagging of muttons to determine their movements to Riley's Hump from other banks in the Tortugas. This index and its associated length frequencies provides a fishery independent index of Mutton Snapper and was previously used in SEDAR 15AU.

Sampling

Riley's Hump is a moderately deep reef with the top of the reef at approximately 30 m with some variation in height of up to 5 m (Mallinson *et al.* 2003). Initially 10 stations were selected on Riley's Hump by dividing the top of Riley's Hump into 0.40 km^2 grids and then scanning the grids with the ship's depth sounder for areas of hard bottom at depths where divers could sample (Burton *et al.* 2005). Another five stations were added in 2002 based on the recommendation of a fisher whose boat NOAA chartered in 2002. The plan was to sample all stations every year.

According to Burton and Ingram (2005), the sampling procedure was to drop a descent line at a station's GPS numbers, have divers descend along the line to the bottom where they then swam a pre-determined number of kicks along pre-determined compass course. At that point, they extended a 30 m transect tape and identified and tallied the fish observed while swimming the transect. Upon completing a transect, the divers return to the transect' s starting point and repeat the process of swimming a pre-determined distance (number of kicks) along a pre-determined compass course. The number of transects per station depends upon the divers' bottom time (divers usually complete between two and four transects per station). In 2001 the transects were usually 50 m but they were standardized at 30 m in 2002. In 2011, divers began to estimate the lengths of fish using a camera equipped with two parallel laser pointers (Burton pers. comm.).

Analysis

Prior to analyses, the observation data were filtered. Data from 2001 were omitted because the divers used transects that were 50 m long which were shortened to 30 m beginning 2002. The longest time series came from stations that were frequently sampled during the 2002 – 2015 period. Data from Station 13 were omitted because Station 13 was only sampled in 2013 and 2015, similarly the data from Station 14 were omitted because Station 14 was only sampled in 2002, Stations 16 and 17 were not sampled according to the data supplied by Mike Burton. Data from 2010 were omitted because sampling in 2010 was only conducted in April at 2 stations. Feeley et al. (2018) identified the months of April through August as the mutton spawning season at Riley's Hump. Very few stations were sampled outside of the spawning season and these observations were omitted, there were only two stations sampled in April and none in August; therefore, the analyses only included data from stations sampled in May through July. The final working data set contained 285 stations records and muttons were observed on 199 stations (70%).

Following the method In the SEDAR 15A update, the count data from the transects at a station on a given day were added across transects to obtain the total number of muttons observed and the number of transects conducted at that station on that day.

Burton and ingram (2005) used a delta-log-normal modeling approach (Lo et al 1992) to develop an index of the average number observed per year. As the name implies, a delta-lognormal model combines two generalized linear models, with one submodel estimating the probability of seeing a Mutton Snapper at a station and this submodel used a binomial distribution with a logit link and a second submodel estimating the mean number of muttons observed on positive stations using a normal distribution on the log transformed number of muttons. The two estimates are transformed back from their linear scales and multiplied together to form the index. This approach is also called a hurdle model (Cragg 1971).

O'Hop (SEDAR 15AU) also used a delta-log-normal model although he configured the model differently instead of nesting transects in a station (Burton and Ingram 2005), he used the number of muttons observed per station per day as the response variable and included the number of transects at the station on that day as a covariate. The response variable in the first submodel that estimated the probability of observing muttons was 1.0 if a mutton was observed at the station on that day or a 0.0 if not, and the response variable for the second submodel was the number of muttons observed per station per day. Potential explanatory variables included year, month, station, visibility (in 10 foot intervals) and the number of transects. Month was either included as a factor or it was nested in station which means that it explained some of the variability at a station, without being considered a factor. The criteria for including a variable in the final submodel was whether including the variable was statistically significant at the 0.05 level and whether adding the variable reduced the mean deviance (a measure of uncertainty) by at least 0.5%. The idea of having a deviance reduction threshold is to avoid over-parameterizing the model with variables that are statistically significant but do not reduce the deviance. The uncertainty in the annual estimates was derived from a Monte Carlo approach using the least square means (LS means) and their standard errors from the two submodels. In each iteration, a random normal deviate from $N(\mu = 0, \sigma = 1)$ was drawn and multiplied by the standard error and this error term was added to the LSmeans and then back transformed to the arithmetic scale. This was done for both submodels and the resulting back transformed LSmeans from each submodel were multiplied and the process was repeated 5000 times for each year.

Instead of just fitting a single delta-log-normal model, I also developed alternative configurations that included delta-gamma and delta-Poisson hurdle models, and Poisson and negative binomial models which used single distributions. Hence, there were five candidate models. Because the hurdle models used two submodels with different distributions while the Poisson model and the negative binomial model had single distributions, to evaluate the different models, it was necessary to use a statistic common to all configurations. The initial step was to identify for each observation the number of muttons observed per station and then to retrieve from the residuals, the predicted number of muttons also in the number per station, i.e., in the original units. For the hurdle models the predicted values from the positive submodel were substituted for those observations in the binomial submodel. With this data set, it was straight-forward to calculate the root mean square error for each configuration. The final model was the configuration with the lowest root mean square error.

Results and discussion

There were 285 stations included in the final data set and, of those stations, divers observed muttons at 199 stations (70%). The highest number of muttons observed at a station were 116 muttons (2004) and 105 muttons (2006) both at Station 12 and most of the station counts (95%) were 27 muttons or fewer.

The nominal catch rates were quite variable without any trend although few Mutton Snapper were observed in 2002, 2003, 2008, and 2013 (Fig. 2, Table 1). The binomial submodel was the same for the three hurdle models, and the selected variables for the final submodel were: station, year, month, and visibility and those variables explained 11.9% of the deviance in the probability of observing a Mutton Snapper at a station. The standard residuals in the binomial submodel were balanced (Fig. 3a and b). The three hurdle submodels for the number of Mutton Snapper observed per station used different distributions. The log-normal submodel selected station and year and those variables explained 38.3% of the deviance in the positive data set with one outlier. The Poisson submodel selected station, year, month, and visibility and those variables explained 57.0% of the deviance with six standard residual outliers and there were more positive standard residuals (Fig. 3d and e). The gamma submodel selected station, year, and visibility and those variables explained 55.1% of the deviance with six standard residual outliers. The Poisson model selected station, year, visibility, month nested in station, and the number of transects per station for the reduced model which reduced the deviance 58.4% but this is for the entire data set not just the positive dives. The standard residuals were balanced and there were 8 outliers. The negative binomial model selected station and year for the reduced model which reduced the deviance 50.5% and, like the Poisson model, this is for the entire data set. The standard residuals were more negative and there were 5 outliers.

The configuration with the lowest root mean square error was the delta-Poisson (RMSE = 8.75, Table 1). The delta-log-normal configuration had the highest root mean square error (RMSE = 11.80). The standardized index, like the nominal catch rates was variable without any trend (Fig. 4) and had low values in 2002, 2006, and 22013 but not in 2003 the CVs of the annual index values were all less than 0.22. (Table 1). When the index from SEDAR 15AU is compared to the current index, the patterns overlay with the current estimate except for 2004, 2005, and 2011 being higher and 2008 being lower in the current index; however, the SEDAR 15AU and SEDAR 79 indices were correlated ($r = 0.83$, $df = 7$, $P < 0.01$; Fig. 5).

Beginning in 2011, the divers began to photograph muttons to estimate their total lengths using two parallel lasers mounted on the camera, only five fish had lengths that were estimated to 1 cm while the remainder were estimated to 5 cm increments. Figure 6 contains the unweighted (a) and the weighted by the delta-Poisson index (b) length frequencies of 130 Mutton Snapper from the years 2011, 2013, and 2015 with a length range of 30-90 cm total length. The FWC-NOAA Fisheries program during this same general period was examining the use of Riley's Hump by Mutton Snapper as a spawning site. (Feeley et al. 2018) measured the total length of the muttons that were tagged (n = 54, range = 48-89 cm). The tagged fish were larger, on average, than the fish observed by survey divers (maximum difference in cumulative proportions was 0.47 and for n = 130 and 54 the test difference was 0.22, Kolmogorov-Smirnov Two sample test, Fig. 7b). Although the survey divers observed fish over wide range of sizes, selectivity can be described by a double logistic (dome shaped) curve. The equation for Riley's Hump length-based selectivity is:

$$Sel = \left[\left(\frac{1}{1 + \exp\left(\frac{Infl1 - l}{slope1}\right)} \right) * \left(1 - \left(\frac{1}{1 + \exp\left(\frac{InflP2 - l}{slope2}\right)} \right) \right) \right] * \frac{1}{x}$$

where *Sel* is the selectivity, *Infl1* is the inflection point, *l* is the fish length, *slope1* is the slope of the ascending limb of the curve, *Infl2* is the inflection point, *slope2* is the slope of the descending limb of the curve, and x is a scalar such that at least one length is fully selected (Quinn and Deriso 1999). The ascending inflection point was 38.4 (SE = 2.36) cm, the ascending slope was 5.44 (SE =2.70) cm, the descending inflection point was 67.8 (SE = 2.41) cm, the descending slope was 6.10 (SE = 2.33) cm, and *x* was 0.861 in the 50-54.99 cm length bin (Fig. 8).

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Table 1. Comparison of alternate standardization model configurations for the Riley's Hump index; all configurations used the same data: counts of Mutton Snapper from 285 stations sampled from 2002-2015. The configuration with the lowest mean square error is highlighted.

Model	Model degrees of freedom	Error sum of squares	Mean square error	Root mean square error	Mean absolute error	Deviance reduction positive data %
Delta-Poisson	32	19302	76.60	8.75	3.33	57.0
Poisson	46	20669	86.84	9.32	3.47	
Delta - log normal	24	36232	139.35	11.80	3.69	38.3
Delta-gamma	30	28653	112.81	10.62	3.67	55.1
Negative binomial	24	32024	123.17	11.10	4.02	

Table 2. The number of stations sampled per year, the number of positive stations where Mutton Snapper were observed, the nominal and standardized Riley's Hump index, their coefficients of variation (CV), and the annual indices scaled to the overall mean.

Year	Number of stations	Number of positive stations	Nominal index	CV	Delta-Poisson index	CV	Index scaled to mean
2002	52	26	0.77	0.244	0.84	0.171	0.33
2003	24	13	1.63	0.303	2.20	0.188	0.87
2004	16	12	10.13	0.643	6.97	0.108	2.76
2005	19	16	6.47	0.387	4.61	0.120	1.82
2006	21	17	10.52	0.517	4.20	0.107	1.66
2007	24	19	4.83	0.342	2.98	0.116	1.18
2008	30	20	1.77	0.218	0.51	0.176	0.20
2009	33	28	5.67	0.407	2.67	0.105	1.05
2010							
2011	25	19	7.24	0.509	3.87	0.115	1.53
2012							
2013	24	15	1.42	0.208	0.42	0.215	0.16
2014							
2015	17	14	7.53	0.432	3.28	0.128	1.30
Total	285	199					

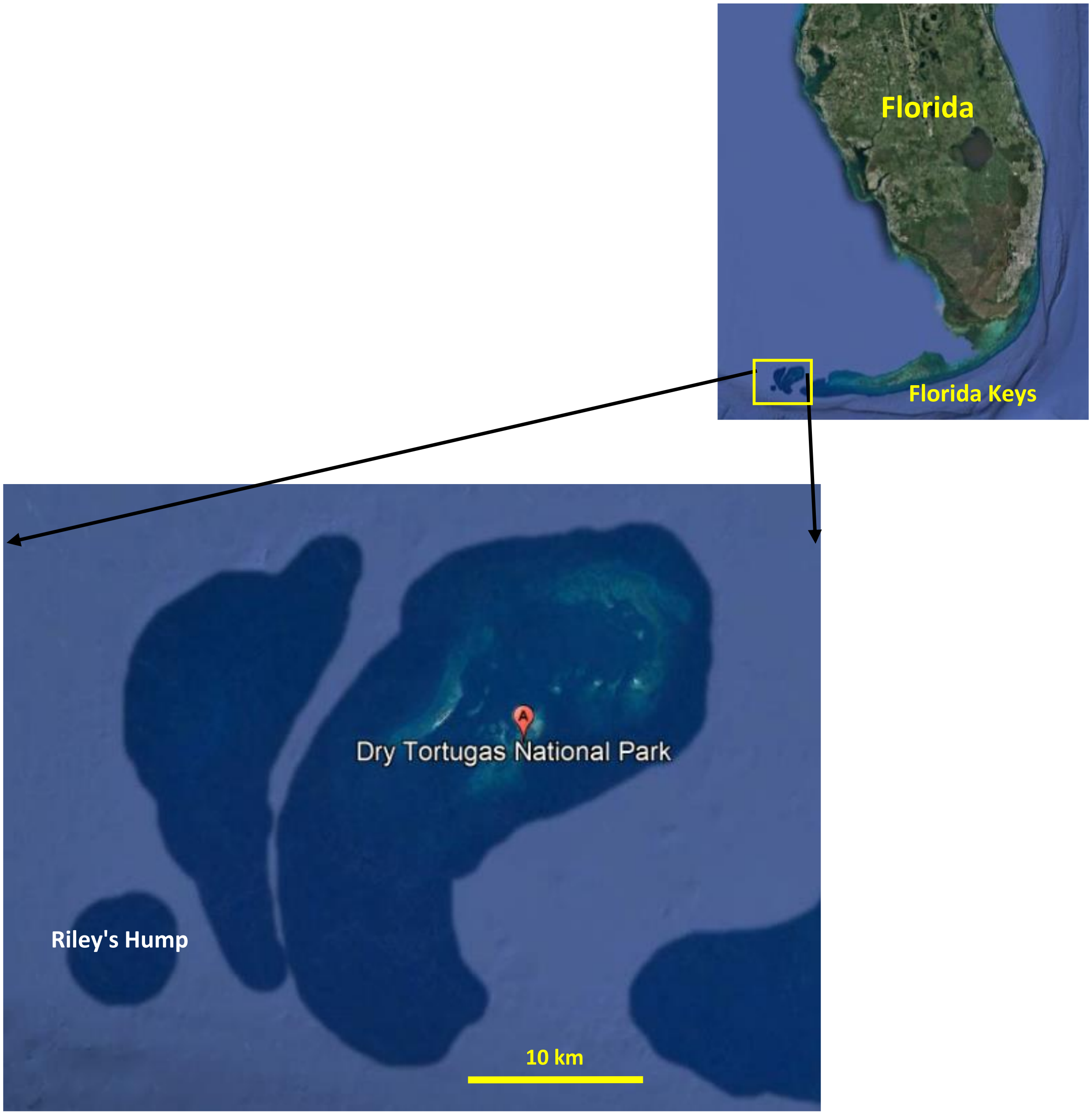


Figure 1. Riley's Hump in relation to the Dry Tortugas National Park and to Florida (inset above, Google Earth images).

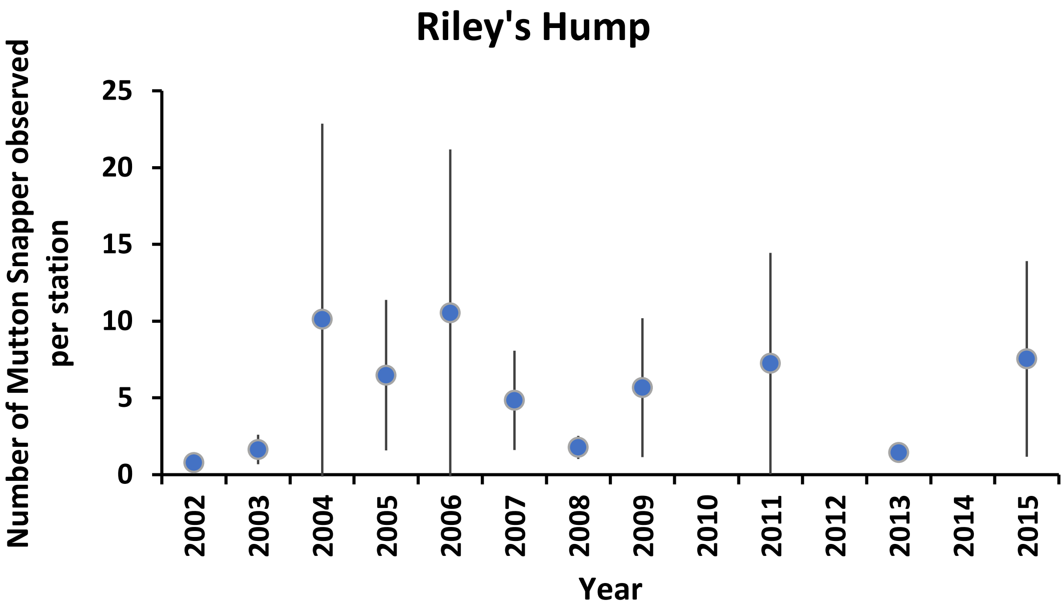


Figure 2. Annual, nominal catch rates of Mutton Snapper at Riley's Hump during the spawning season.

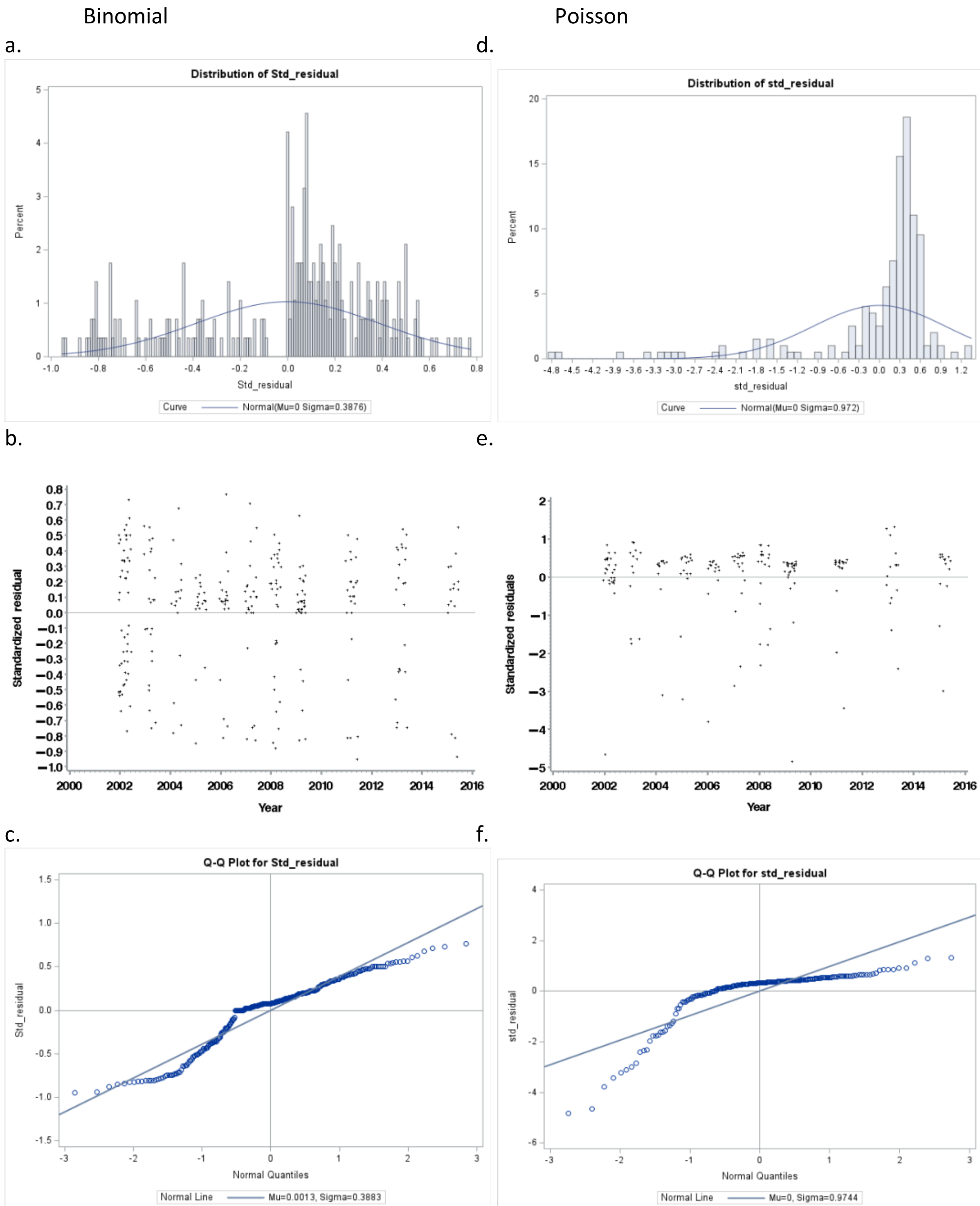


Figure 3. Distribution of standard residuals from the binomial submodel (a b) and a QQ plot of the standard residuals and the normal quantiles (c) and similar plots for the Poisson submodel (d-f).

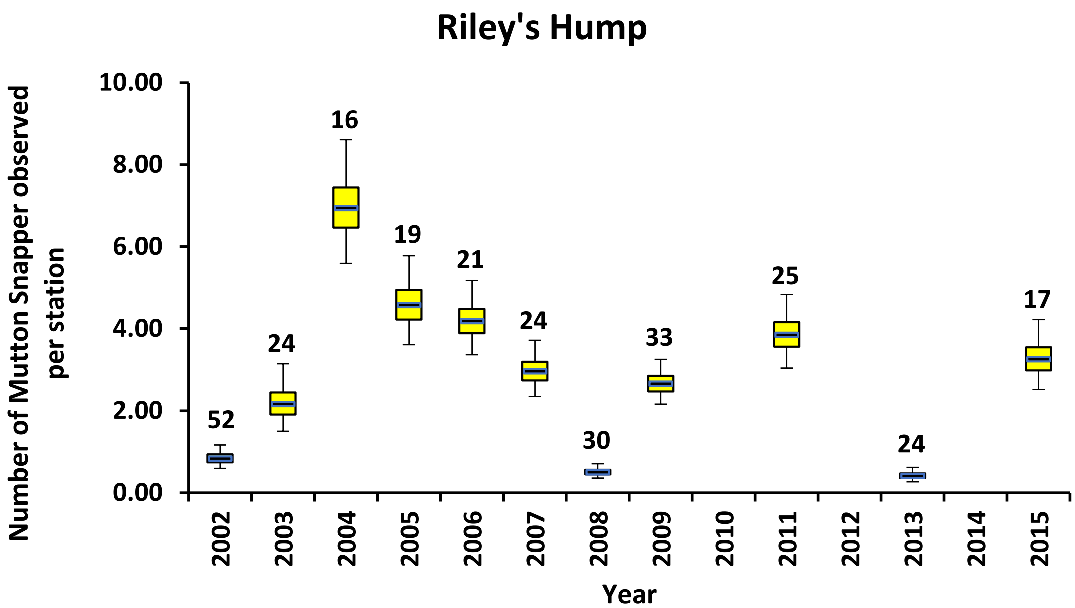


Figure 4. Standardized catch rates at Riley's Hump.

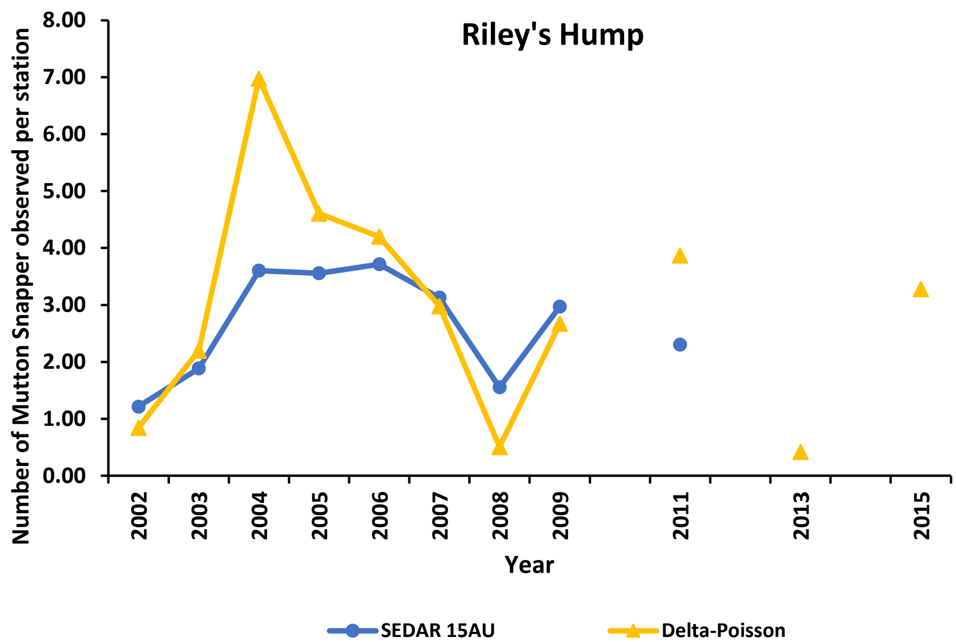
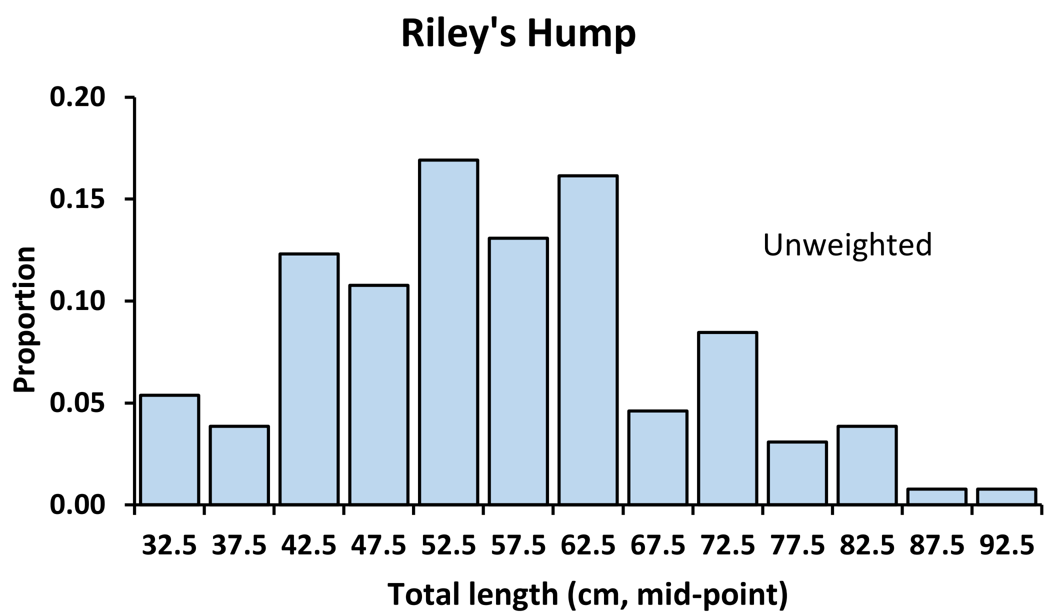


Figure 5. Comparing the delta-Poisson index (SEDSAR 79) with the delta-log-normal index from SEDAR 15AU.

a.



b.

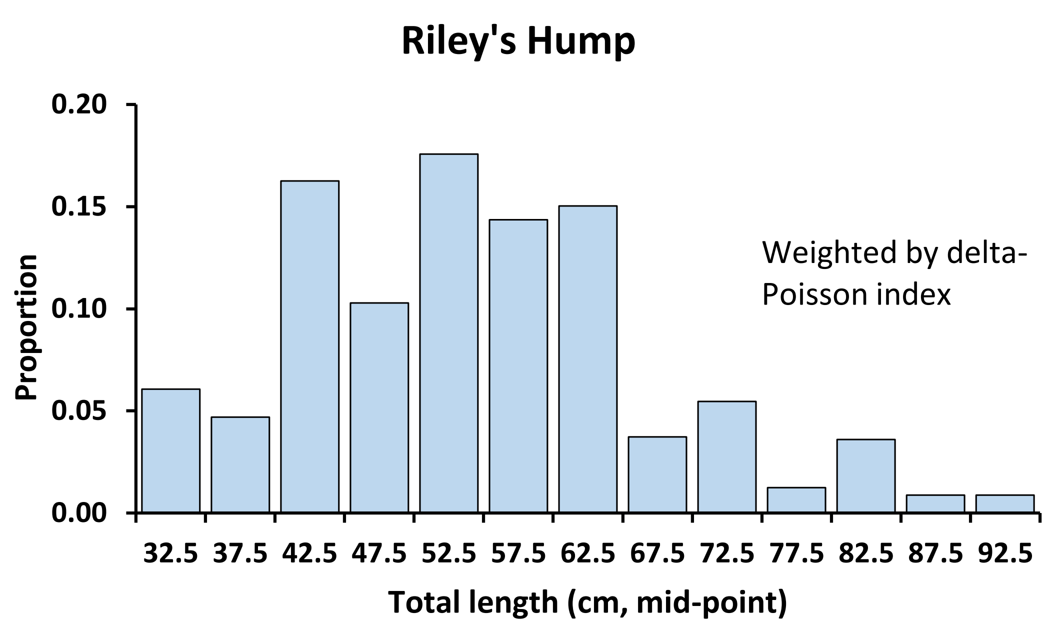
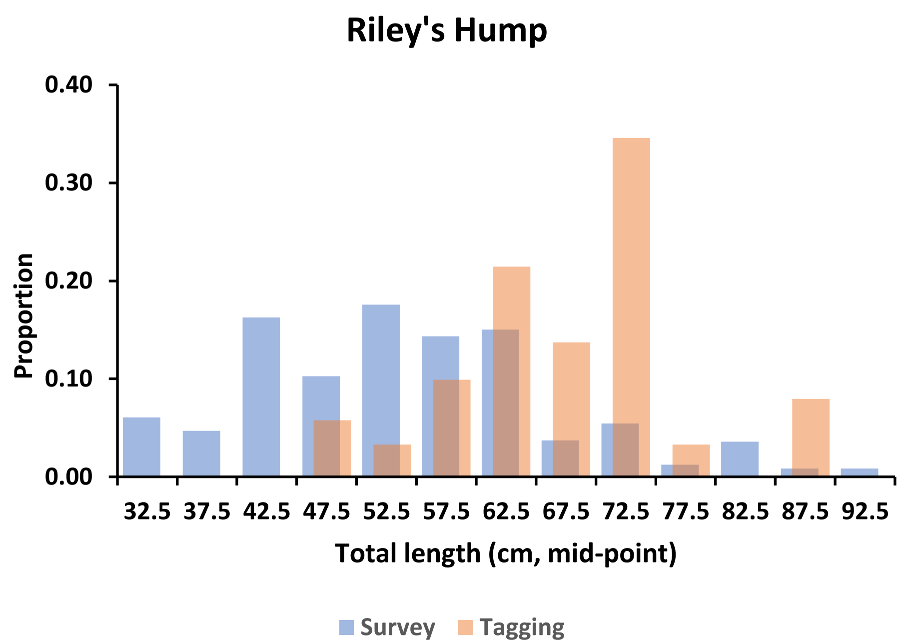


Figure 6. Unweighted (a) and weighted by index (b) length frequencies of Mutton Snapper at Riley's Hump.

a.



b.

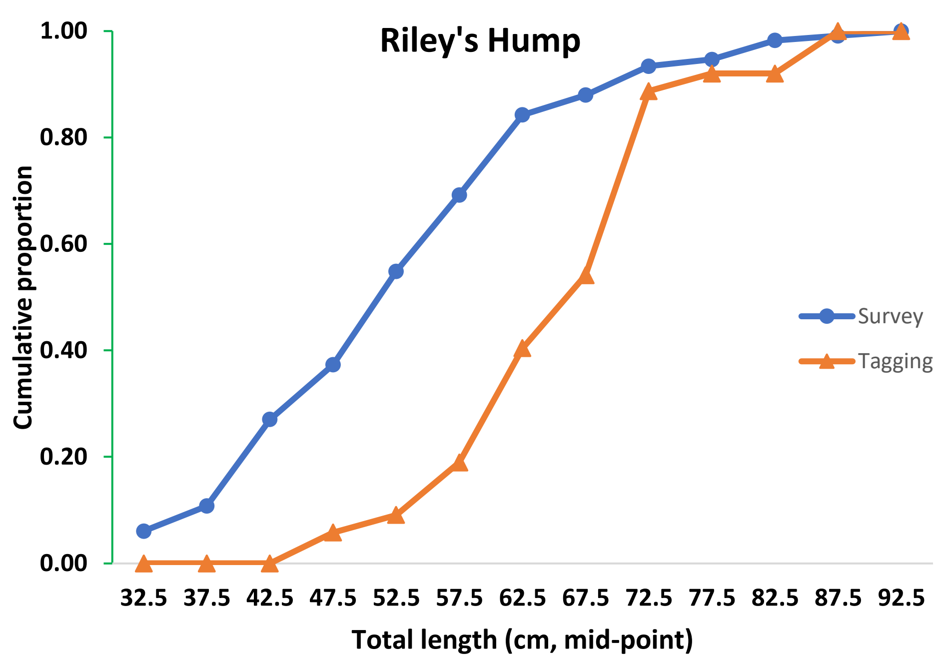


Figure 7. Comparing the length distributions of survey fish to tagged fish weighted by the delta-Poisson index (a length histogram and b cumulative length distributions).

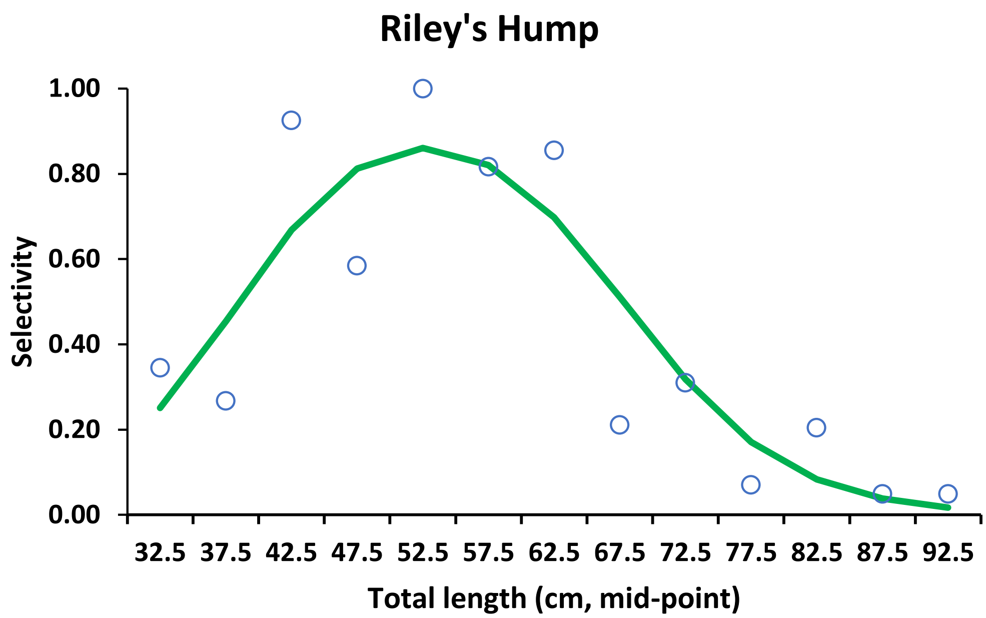


Figure 8. Selectivity of Mutton Snapper in Riley's Hump survey.