Update of Vermilion Snapper, *Rhomboplites aurorubens*, Reproductive Life History from the MARMAP/SERFS Program

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SEDAR55-WP03

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**** ADDEDDUM ADDED TO REFLECT CHANGES MADE DURING THE ASSESSMENT PROCESS. THE FINAL BATCH FECUNDITY RECOMMENDATION IS FOUND IN THE ADDENDUM (PDF PAGE 21).****

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Update of Vermilion Snapper, *Rhomboplites aurorubens*, Reproductive Life History from the MARMAP/SERFS program.

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Background

In the most recent benchmark assessment (SEDAR, 2008) and the subsequent update assessment (SEDAR, 2012) for Vermilion Snapper (*Rhomboplites aurorubens*), reproductive parameter selection was constrained due to limited samples of immature fish for maturity schedules and actively spawning fish for fecundity estimates. Since reproductive parameters were last provided for an assessment (SEDAR, 2008), there are nine additional years of samples, including an increase in the annual number of collections since 2009. There has also been a completion of ageing of historic samples between 1995 and 1998 that were not included previously. Since the last benchmark assessment, this continuation of sampling, additional numbers of samples collected annually, and completion of age estimates from historic samples have identified more immature individuals which allows for a modeling approach that could not be applied for SEDAR-17 or the subsequent update in characterizing maturity schedules. These analyses, as well as a more recent estimates of sex ratio and fecundity, including an examination of number of batches per year by age, provide an improved characterization of the reproductive potential of Vermilion Snapper in the Atlantic waters off the southeastern United States.

The Marine Resources Monitoring, Assessment and Prediction program (MARMAP) has conducted fishery-independent and fishery dependent research on reef fish species off the continental shelf and shelf edge between Cape Hatteras, North Carolina, and St. Lucie Inlet, Florida, since 1972. In 2008, with a first field season in 2009, the Southeast Area Monitoring and Assessment Program, South Atlantic Region (SEAMAP-SA) provided funding to a project called the "Reef Fish Complement" to assist with the expansion of the geographical sampling coverage of the MARMAP fishery-independent chevron trap survey. Again in 2010, with the formation of the Southeast Fishery-Independent Survey (SEFIS), located at the Southeast Fisheries Science Center in Beaufort, NC, the geographical coverage and sampling intensity of the MARMAP fishery-independent chevron trap survey was expanded. Collectively, we now refer to these three surveys combined reef fish monitoring efforts as the Southeast Reef Fish Survey (SERFS).

Objective

This report presents maturity schedule, sex ratio, and fecundity estimates of female Vermilion Snapper derived from MARMAP/SERFS collections from 1977-2016, unless otherwise noted. These data are critical inputs informing the reproductive potential of the stock and provide a more complete picture compared to previous assessments of Vermilion Snapper. Data presented in this report are based on the combined SERFS database accessed on September 14, 2017.

Methods

Survey Design and Gear

(see Smart et al. 2015 for full description of MARMAP/SERFS survey design)

Sampling area

- Cape Hatteras, NC, to St. Lucie Inlet, FL
  - General increase in sampling intensity (# of annual chevron trap deployments) through time
  - Gradual shift regarding the spatial coverage of samples through time
    - More geographic coverage in southern and northern latitudes in later years

- Sampling depths range from 13 to 218 m
  - Generally less than 100 m

Sampling season

- May through September
  - Limited earlier and later sampling in some years

Survey Design

- Simple random sample survey design
  - Annually, randomly selected stations from a chevron trap universe of confirmed live-bottom and/or hard-bottom habitat stations
  - No two stations are randomly selected that are closer than 200 m from each other
    - Minimum distance is typically closer to 400 m

Sampling Gear – Chevron Traps

(see Collins 1990 for descriptions that are more complete)

- Arrowhead shaped, with a total interior volume of 0.91 m^3
- Constructed of 35 x 35 mm square mesh plastic-coated wire with a single entrance funnel ("horse neck")
- Baited with a combination of whole or cut clupeids (*Brevoortia* or *Alosa* spp., family Clupeidae), with *Brevoortia* spp. most often used
  - Four whole clupeids on each of four stringers suspended within the trap
  - Approximately 8 clupeids placed loose in the trap
- Soak time of approximately 90 minutes

Data Filtering/Inclusion

- Projects coordinated by MARMAP/SERFS (Table 1)
  - P05/T59/T60 – MARMAP/SEAMAP-SA/SEFIS
  - P50 – Port Sampling (Fishery-Dependent)
  - T46 – CRP life history comparison
  - T42 – Trap comparison
- Gear (Table 2)
  - 014 - Hook and line
  - 022 - Yankee trawl
  - 043 - Snapper Reel
  - 053 - Blackfish trap
  - 061 - SBLL
  - 070 - 40/54 fly net
  - 073 - Experimental trap
  - 074 - Florida Antillean trap
  - 086 - Kali pole
  - 324 - Chevron trap
  - 540 - Lionfish chevron trap

Summary tables were generated for fish collected and aged per project and gear type by year (Tables 1 and 2). Data analyses were performed using R statistical program unless otherwise noted (R Core Team 2013).

Age Data

The left sagittal otolith and, when possible, the right sagittal otolith were removed from all Vermilion Snapper and stored dry prior to processing. In the laboratory, the left otolith was embedded in West System 105 epoxy resin, sectioned dorsoventrally to a thickness of 0.4 mm, and mounted on glass microscope slides using Accu-mount 60 mounting medium (Baxter Scientific Products). One to three otolith sections were examined with transmitted light under a dissecting microscope. Counts were made from the core of each otolith to the outer edge of each opaque zone and to the edge of the otolith. Sections were examined independently without reference to specimen length, collection date, and location and re-examined jointly when differences in age estimation occurred. If disagreement persisted, the specimen was eliminated from age analyses. In addition, quality and edge type was recorded.

Due to the volume of otoliths to be read that were not included in the previous assessment (n = 13,336), decisions were made to age the full range of years. This was accomplished by two methods. The first was to have 30% overlap between readers. Consistency between readers was maintained throughout by reader comparisons every 1,000 otoliths read, which consisted of calculations of average percent error (APE) and coefficients of variation (CV) to assess precision and bias plots to examine potential bias between the readers. There was also a random 50% subsample of life history samples collected in 2016 (both otoliths and gonads) that were read due to the large number of samples collected in that year (4,367), which was more than double the next highest annual number and greater than 5 times the average number kept for life history analysis.

Age data used for SEDAR-55 included calendar age using criteria from previous assessments of Vermilion Snapper. Fractional age was also calculated for Vermilion Snapper for use in modeling maturity schedules.

- Calendar age calculation (Edge code >2 is equivalent to a wide translucent edge)
  - Fish collected September or after: calendar age = increment count
  - Fish collected before September with a narrow translucent edge: calendar age = increment count
  - Fish collected before September with a wide translucent edge: calendar age = increment count +1

- Fractional age calculation
    - Calendar age adjusted to the fraction of the year in which the fish was caught based on month of peak spawn (July for Vermilion Snapper)
        - The fractional age was calculated by adding or subtracting fractions of a year, corresponding to the month of capture from the calendar age, using a July 1 birth date (during the peak of the spawning season).
            - Fractional Age = Calendar_Age + ((Month_Capture - Month_Spawn)/12)

Reproductive data

The information presented in this report on maturity schedule and sex ratio is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes. A sample from the posterior portion of the gonad was fixed in 10% seawater formalin solution for 7-14 days and transferred to 50% isopropanol for 7-14 days. Tissue samples were vacuum infiltrated in a Leica ASP300 Tissue Processor and blocked in paraffin. Three transverse sections (6-8 µm) were cut from each sample with a rotary microtome, mounted on glass slides, stained with double-strength Gill hematoxylin, and counterstained with eosin-y.

Two readers independently determined sex and reproductive state using standard histological criteria (Table 1) without reference to specimen age and length, collection date, and location. When assignments differed, the readers re-examined the section simultaneously to determine reproductive phase. To ensure that females were correctly assigned to the immature and regenerating categories, the length frequency histogram of females that were definitely mature (i.e., those that were developing, spawning or regressing) was compared with histograms of immature and regenerating/cortical alveolar oocyte females.

Specimens with developing, spawning, regressing, or regenerating gonads were considered sexually mature. For females, this definition of maturity included specimens with oocyte development at or beyond the cortical alveolar stage and specimens with beta, gamma, or delta stages of atresia (Hunter and Macewicz 1985). Maturity schedules were developed with a modeling approach using the glm function in the R stats package (R core team 2013) using a logistic equation with one of four different links (Probit, Logit, Cauchy, and clog-log). The final model selection of the links was based on the lowest AIC value. Age at 50% maturity (A_{50}) was calculated from the output of the model runs. Fractional ages were used for this analysis due to the early onset of maturation in Vermilion Snapper and the need for greater resolution as the majority of fish mature before age 1. Any individuals missing

data required to assign a fractional age (date of capture, increments, or edge types) were removed from the analysis. The lower and upper confidence intervals around A_{50} were individually calculated from the error estimates of the model parameters obtained during the fitting procedure using functions in the R stats package (R Core Team 2013).

A total of 45 gonads was utilized for the fecundity analysis. Whole gonads from 24 actively spawning (oocyte maturation, but pre-ovulation) females were preserved in 10% seawater formalin; maturation is the final stage of oocyte development, beginning with oil droplet coalescence/displacement of nucleus and ending with hydration. Fresh and preserved gonad weights were obtained for those ovaries and a regression equation (Preserved wt (g) = fresh wt (g) * 0.7906 – 0.271; adj. r^2=0.976) was developed to convert fresh weight to preserved weight thereafter. To reduce the amount of formalin handled at sea and stored in lab spaces, a longitudinal strip of tissue (3 cm x 10 cm) from one ovarian lobe, representing the anterior through posterior portions, was preserved for the remaining specimens (n=21).

A previous study in the region revealed that Vermilion snapper exhibit indeterminate fecundity (Cuellar et al. 1996); therefore, batch fecundity and spawning frequency were estimated to calculate potential annual fecundity. The hydrated oocyte method (Hunter and Goldberg 1980; Hunter et al. 1985) was modified and used to determine batch fecundity. Two 75-mg samples were removed from random locations (anterior, middle, or posterior) in ovaries, weighed on a digital balance (±0.00001 g), and immersed in a 1-5% formalin solution to count the oocytes with evidence of nucleus migration and/or hydration (see Hunter et al. (1992)). The counts were extrapolated to preserved gonad weight to estimate batch fecundity; if preserved gonad weight was not measured, it was calculated using the conversion equation above.

The relationship between batch fecundity vs. maximum total length, fork length, whole fish weight, ovary-free weight, and calendar age was calculated using simple linear regression. All fecundity based statistical analyses were performed in SAS (SAS Institute, Inc. 1989), and the results were considered significant at P-values less than 0.05.

Because the terminology associated with reproductive activity can be confusing, we define those terms here, based on the summary in Lowerre-Barbieri et al. (2011), and present formulae for the calculations:

Spawning fraction: proportion of mature females spawning daily. If duration of spawning indicators is > 24 hr, the fraction of active spawners is proportionally reduced to reflect a 24-hr period.

Spawning interval: time (in days) between spawning events and at the population level is estimated as the reciprocal of the spawning fraction.

Spawning frequency: number of spawning events within a spawning season and has been historically calculated by dividing the number of days in spawning season by the spawning interval; an alternative method is to multiply the spawning fraction by the spawning season duration.

To estimate spawning frequency by calendar age class, adult specimens collected during the spawning season were classified as actively spawning or non-spawning based on the presence or absence of spawning indicators (oocyte maturation, ovulation, and postovulatory follicle complexes) in histological sections. The spawning season duration was defined as the time between the first and last occurrence of spawning indicators in specimens. Individuals with one or more spawning indicators were classified as actively spawning. The duration of spawning indicators in individual fish was estimated to be 48 hr (oocyte maturation=12 hr and postovulatory follicle complexes=36 hr) based on Hunter et al. (1986) and Fitzhugh et al. (1993). Vermilion Snapper spawn at a mean bottom temperature (23.4^{o}C; Sedberry et al. 2006, Farmer et al. 2017) that is within the range of temperature (23-24^{o}C) in the laboratory study of spawning in Skipjack Tuna (*Katsuwonus pelamis*) by Hunter et al. (1986). To calculate spawning fraction, the fraction of active spawners was proportionally reduced from 48 hr to 24 hr. Potential annual fecundity for each calendar age was calculated by multiplying batch fecundity and spawning frequency.

Only data from 1988-2016 were used to determine sex-ratio in accordance with decisions made during SEDAR-17. These decisions dealt with gear change and potential differences in selectivity patterns due to this. Data for sex ratio analysis were filtered to include only known sex fish.

- Data filtering to include only known sex fish
    - Exclude fish with unknown sex (sexcode = 9) or the germ cells were undifferentiated (sexcode = 0).
    - Exclude fish with an unknown reproductive phase (Matcode = 9) or the gonads were inactive and a reproductive phase could not be assessed (Matcode = 0).

Sex ratio was calculated from known sex fish over three time blocks: The entire time series included (1988-2016), since the most recent update of the sex ratio parameter (2007-2016), and those

years included in the previous assessment (1988-2006). A Chi-square goodness of fit test was used to determine if the overall (1988-2016) and most recent (2007-2016) ratios differed from an expected 1:1 (Zar, 1984). The mean annual proportion of the most recent sex ratios since SEDAR-17 compared to those from the years examined during SEDAR-17 were tested using an ANOVA to determine if there were differences.

Results

Vermilion Snapper included in consideration for the analyses for SEDAR-55 were captured between latitude 27.23° and 34.87° N and at a depth range of 14 to 187 meters, from fishery-independent and fishery-dependent sources, between 1977 and 2016 (n=29,127). Specimens ranged in size from 100 to 615 mm maximum TL. Increment counts in sagittal otoliths ranged from 0-15 (0-16 for calculated calendar age).

Reproduction ****FINAL BATCH FECUNDITY RECOMMENDATION FOUND IN ADDENDUM (PDF PAGE 21)****

There was less overlap in the length distributions of immature and regenerating Vermilion Snapper compared to the substantial overlap of regenerating and definitely mature individuals, indicating that maturity stages were assigned correctly (Figure 1). All fishes staged for maturity with age estimates were included in the maturity schedule analyses, regardless of project, gear, or source (fishery-independent and dependent). The logistic regression with the Cauchy link had the lowest AIC value of the four. Age for females at 50% maturity (A_{50}) was 0.85 yr (Cauchy link; 95% confidence intervals (CI) = 0.57-1.26 yr) (Figure 2). The oldest immature fish were 3 years of age, while the youngest observed mature fish were less than 1 year of age (Table 4).

The relationship between batch fecundity in Vermilion Snapper and TL (maximum), FL, ovary-free body weight, and whole body weight was highly significant ($P < 0.001$), whereas the relationship with age was not significant (P=0.1942) due to the high level of variation in size at age. Adjusted R^2 values ranged from 0.74 for whole body weight to 0.04 for calendar age (Table 5). The analysis to estimate spawning frequency revealed that the number of batches (N_{bi}) per spawning season increased from Age 0 (N_{bi} = 29) to Age 2 and was essentially constant (N_{bi} = 41-49) at Ages 2+ (Table 6). Vermilion Snapper spawn on average every 3 to 4 days. Estimates of batch size relative to the base length for the assessment (maximum TL) ranged from 22,641 to 160,755 oocytes for Vermilion Snapper 209-507 mm TL. Previous assessments of Vermilion Snapper utilized the batch fecundity equation of Cuellar et al.

(1996). We recommend using the equations in the present report because the specimens examined represent a wider range of size.

Of the 24,210 Vermilion Snapper with a known sex, 16,557 (68%) were females. The analysis indicated that the proportion of females to males in the population for Vermilion Snapper was significantly different from the expected 1:1 ($\chi^2 = 3274.74$; df = 1; $p < 0.0001$). There were no differences between annual sex ratio in years included in SEDAR-17 (proportion female = 0.67) and those following SEDAR-17 (2007-2016) (proportion female = 0.70) (ANOVA; df = 1,27; F-value = 2.72; p = 0.11).

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Table 1. The annual number of Vermilion Snapper collected by MARMAP/SERFS available for life history analysis based on project. See above for project code descriptions.

Year	P05	P50	T42	T46	T59	T60	Total
1978	12						12
1979	121						121
1980	114	32					146
1981	225	64					289
1982	37						37
1983	174						174
1984	189						189
1985	180						180
1986	141						141
1987	92						92
1988	202						202
1989	176						176
1990	111						111
1991	497						497
1992	214	248					462
1993	395	160					555
1994	567						567
1995	493						493
1996	717						717
1997	597						597
1998	538						538
1999	397	276					673
2000	1,020						1,020
2001	622						622
2002	768	69					837
2003	215	72					287
2004	306	7					313
2005	514			599			1,113
2006	344		3	794			1,141
2007	538			316			854
2008	693						693
2009	989						989
2010	321				15	284	620
2011	611				23	402	1,036
2012	250	9			19	265	543
2013	195					278	473
2014	340				3	764	1,107
2015	1,093					989	2,082
2016	1,239					1,135	2,374
Total	**16,247**	**937**	**3**	**1,709**	**60**	**4,117**	**23,073**

Table 2. The annual number of Vermilion Snapper collected by MARMAP/SERFS available for life history analysis based on gear type. See above for gear code descriptions.

Year	014	022	043	053	061	070	073	074	086	324	540	Total
1978		1	11									12
1979		105	14	2								121
1980			66			80						146
1981			249	5		27	1	7				289
1982			8	1		24		4				37
1983			13					142	19			174
1984			62	10		57		60				189
1985	10		31	2		89		48				180
1986			38			31		72				141
1987	3		24	1		15		49				92
1988			79	13				50		60		202
1989			54	9				56		57		176
1990			9							102		111
1991	7		7							483		497
1992	19		252							191		462
1993	2		172							381		555
1994	1		28							538		567
1995			9							484		493
1996	1									716		717
1997			9							588		597
1998			3							535		538
1999			276							397		673
2000			2							1,018		1,020
2001	6		4							612		622
2002			71							766		837
2003			72							215		287
2004	7									306		313
2005	20		599							494		1,113
2006	72		794							275		1,141
2007	1		316							537		854
2008	17									676		693
2009	16									973		989
2010	1				1					617	1	620
2011	64									972		1,036
2012	19		12							512		543
2013										473		473
2014										1,107		1,107
2015	8									2,074		2,082
2016										2,374		2,374
Total	**274**	**106**	**3,284**	**43**	**1**	**323**	**1**	**488**	**19**	**18,533**	**1**	**23,073**

Table 3. Histological criteria used to determine reproductive state in Vermilion Snapper (modified from Wallace and Selman (1981); Hunter and Macewicz (1985); Hunter et al. (1986); Wenner et al. (1986); West (1990); Davis and West (1993)).

Reproductive Stage	Male	Female
1-Immature	Small transverse section compared to resting male; spermatogonia & little or no spermatocyte development	Oogonia & primary growth oocytes only (< 60 m), no evidence of atresia. Relative to resting female, area of transverse section of ovary is smaller, lamellae lack muscle and connective tissue bundles are not as elongate, oogonia are abundant along margin of lamellae, ovarian wall is thinner. See below
2-Developing	Development of cysts containing primary and secondary spermatocytes through some accumulation of spermatozoa in lobular lumina and ducts.	See below (2B, 2C, 2D, 2E, 2F, & 2G)
3-Migratory Nucleus oocytes & Hydrated oocytes (Spawning)	Predominance of spermatozoa in lobules and ducts; little or no occurrence of spermatogenesis.	Completion of yolk coalescence and hydration in most advanced
4-Regressing	No spermatogenesis; some residual spermatozoa in shrunken lobules or ducts.	More than 50% of vitellogenic oocytes undergoing alpha or beta atresia.
5-Regenerating	Large transverse section compared to immature male; little or no spermatocyte development; empty lobules and ducts; some recrudescence (spermatagonia through primary spermatocytes) possible at end of stage.	Oogonia & primary growth oocytes only (> 60 m), traces of all stages of atresia. Relative to immature female, area of transverse section of ovary is larger, lamellae more elongate, oogonia are less abundant along margin of lamellae, bundles of connective and muscle tissue present, ovarian wall is thicker.
2B-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs (postovulatory complex) <12 h old (sensu Hunter et al.1986).
2C-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs 12-24 h old (sensu Hunter et al.1986).
2D-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs >24 h old (sensu Hunter et al. 1986)
2E-Early developing, cortical alveolar (CAO)		Most advanced oocytes in cortical-alveolar stage. Cortical form in peripheral cytoplasm. Oil droplets form around germinal vesicle.
2F-Developing, vitellogenesis		Most advanced oocytes in yolk-granule or yolk-globule stage.
2G-Oocyte maturation		Most advanced oocytes in migratory-nucleus stage. Partial coalescence of yolk globules. Nucleus has moved away from center of cell, being replaced by coalescing oil droplets. By the time of ovulation, one large oil droplet is present.

Table 4. The number by maturity status and calendar age of female Vermilion Snapper from which the maturity schedules were derived. The observed proportion of mature individuals and predicted proportion of mature individuals based on the model outputs are also included.

Age (yr)	Immature	Mature	Total	Observed Proportion Mature	Predicted Proportion Mature
0	2	5	7	0.71	0.02
1	57	285	342	0.83	0.91
2	65	2,592	2,657	0.98	0.99
3	12	3,173	3,185	1.00	0.99
4	0	2,788	2,788	1.00	1.00
5	0	2,240	2,240	1.00	1.00
6	0	1,380	1,380	1.00	1.00
7	0	971	971	1.00	1.00
8	0	727	727	1.00	1.00
9	0	370	370	1.00	1.00
10	0	140	140	1.00	1.00
11	0	59	59	1.00	1.00
12	0	20	20	1.00	1.00
13	0	9	9	1.00	1.00
14	0	2	2	1.00	1.00
Total	136	14,761	14,897		

Table 5. The range of dependent variables used and the parameters obtained for modeled length, weight, and age based batch fecundity for Vermilion Snapper using the equation: Batch fecundity = a+b(x). Also included is the standard error (SE_x) for the parameters, the R^2 values of the regression, the F-value by dependent variable, and the sample size (n).

Dependent Variable	Range	Intercept (a)	SE_a	slope (b)	SE_b	Adj. R2	F	n
TL (mm)	209-507	-74224	13871	463.047	45.059	0.70	105.6	45
FL (mm)	187-457	-72422	13985	509.779	50.657	0.70	101.3	45
Whole Wt (g)	117-1614	20319	4893	112.184	9.967	0.74	126.7	45
Ovary-free wt (g)	112-1574	21323	4937	114.280	10.422	0.73	120.2	45
Calendar age (yr)	1-6	36580	15576	5655.106	4192.974	0.04	1.8	20

Table 6. The average annual number of batches of eggs spawned per fish in the population by calendar age.

Cal. age (yr)	Annual # Batches/ind.fish
0	28.9
1	34.0
2	45.7
3	46.7
4	48.7
5	40.8
6	42.0
7	44.7
8+	42.0

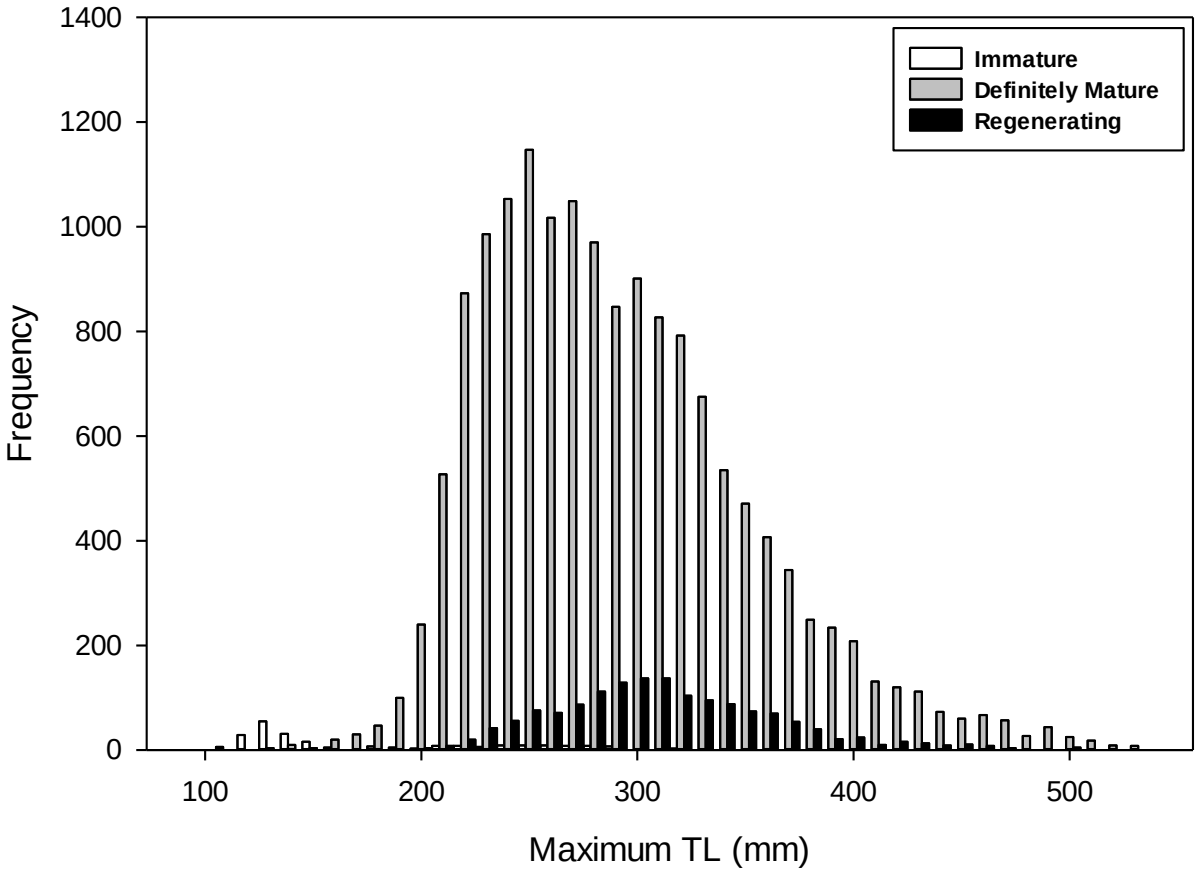


Figure 1. The frequency of fish by reproductive phase (immature, definitely mature, or regenerating/cortical alveolar stage) in 10 mm size bins of maximum total length.

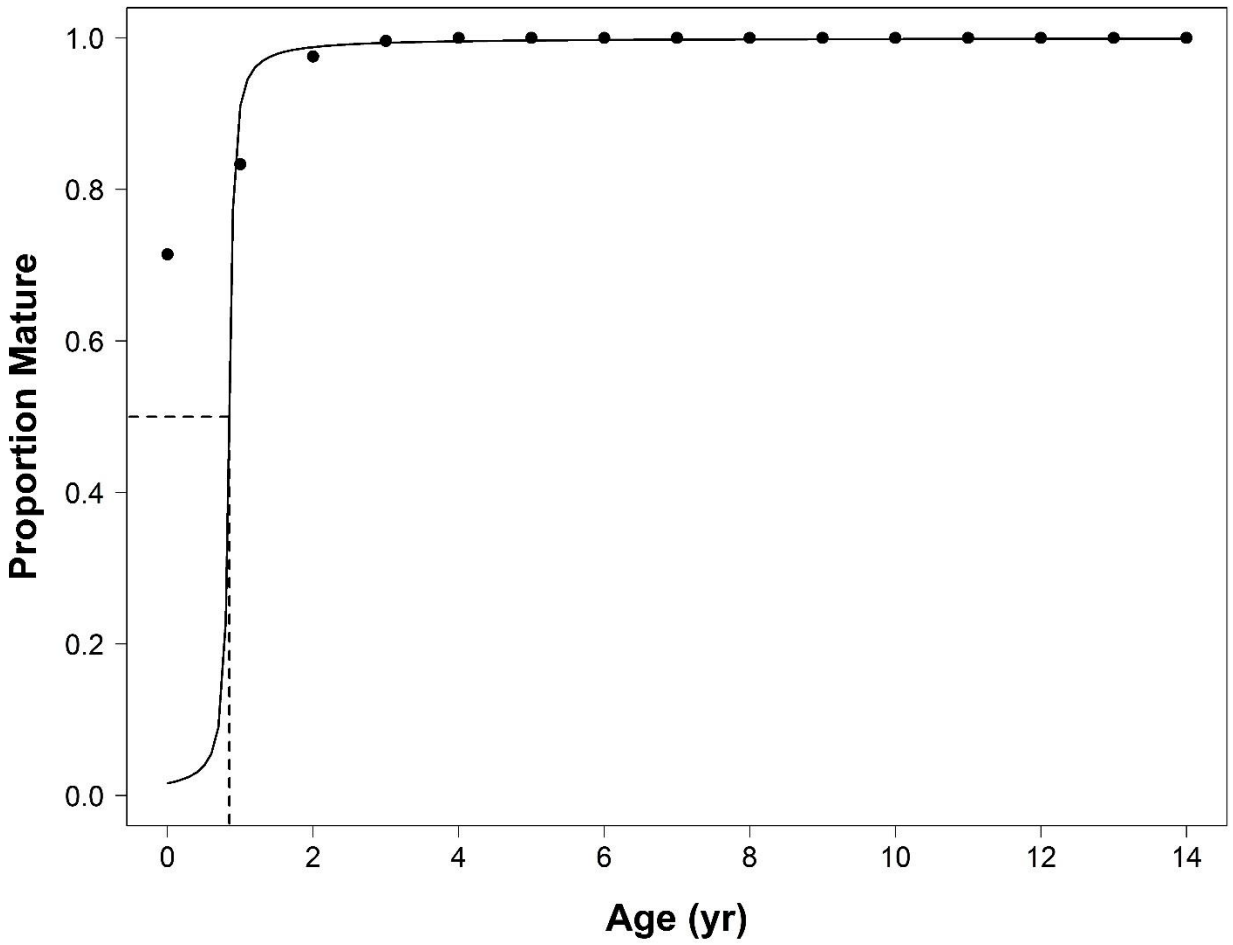


Figure 2. The observed (•) and modeled (–) proportion of mature female Vermilion Snapper as calendar and fractional age, respectively. Age at 50% maturity (----) was 0.85 years.

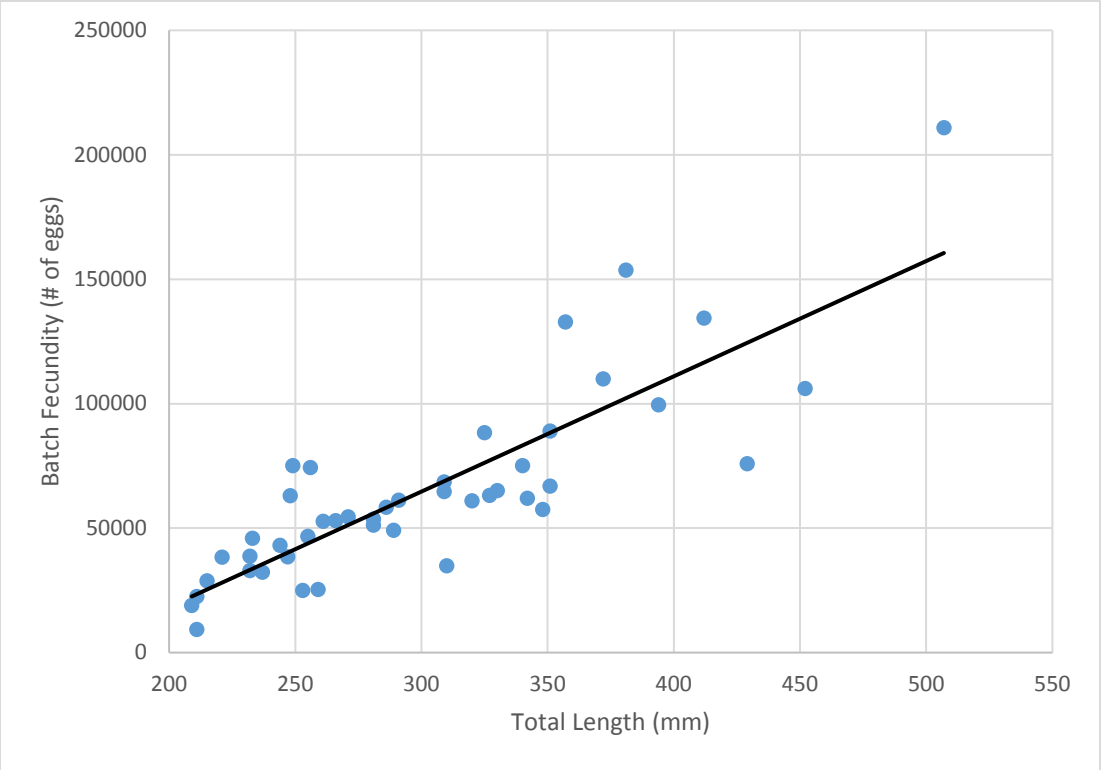
ADDENDUM

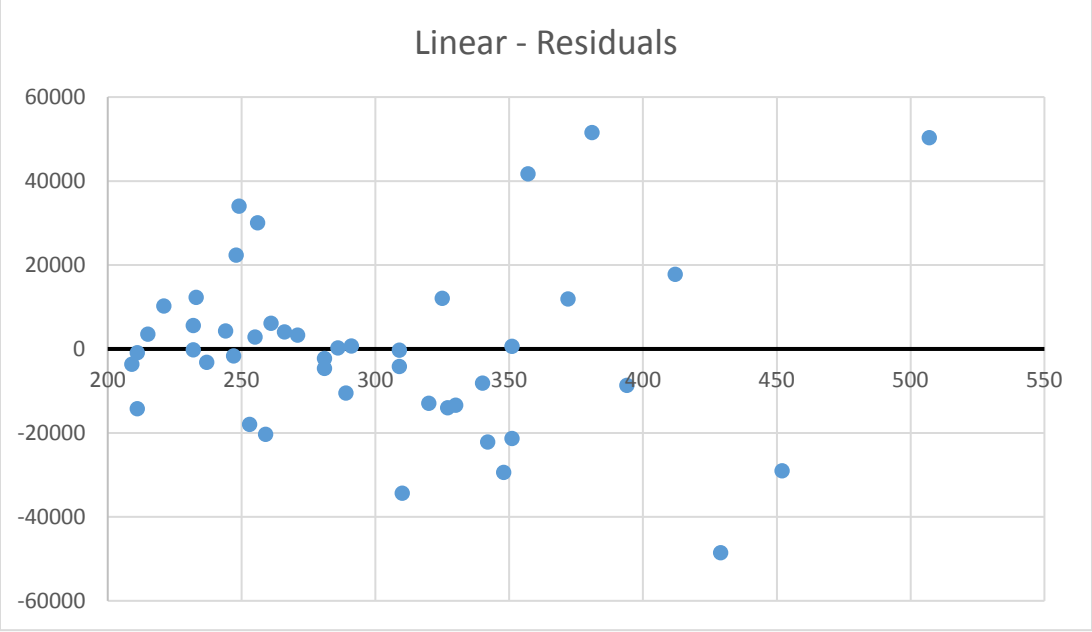
Addendum added January 16, 2018 to reflect changes made during the assessment process. The final batch fecundity recommendation is found in the addendum.

Batch Fecundity v TL for Vermilion Snapper – SEDAR 55

Linear

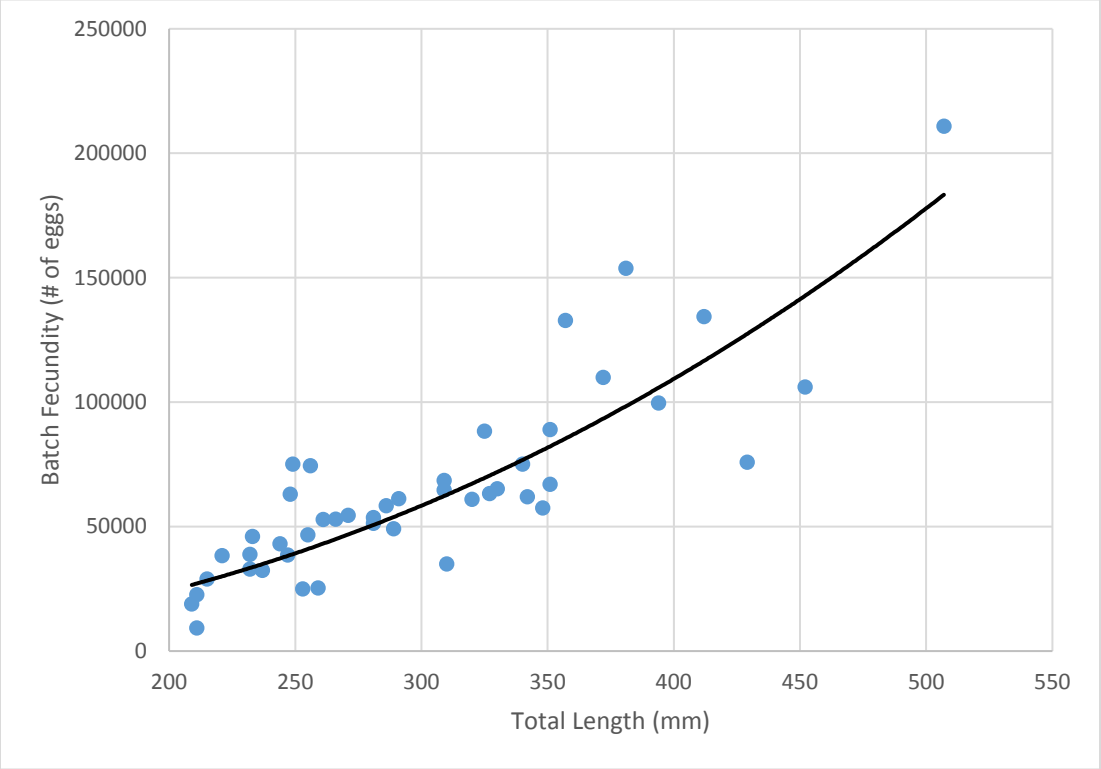
Equation: y = 463.05*TL – 74224

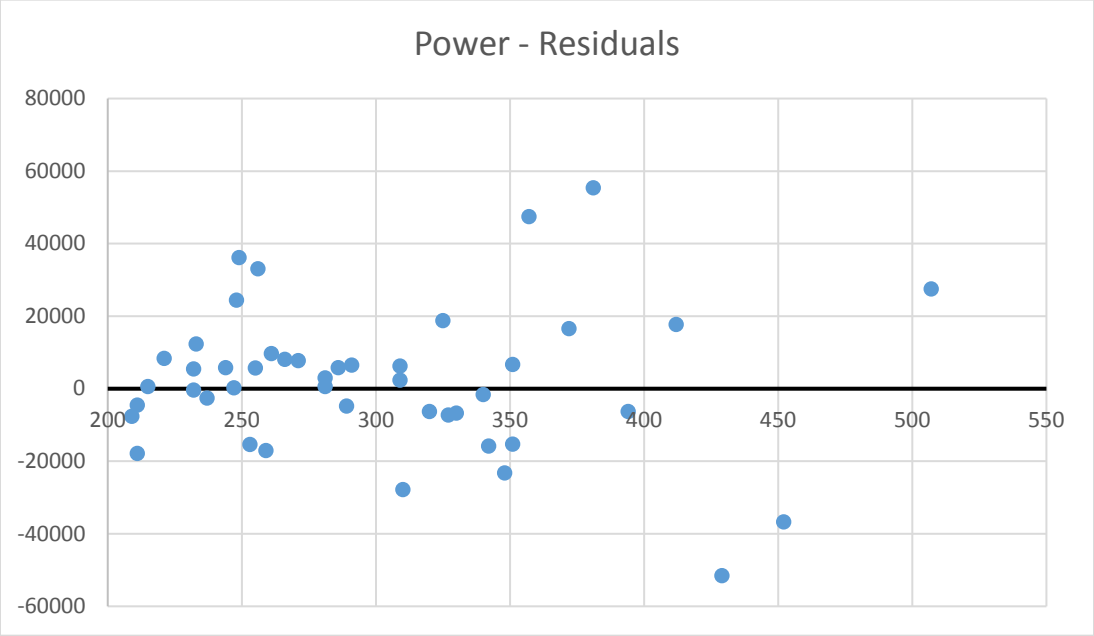




Power Function

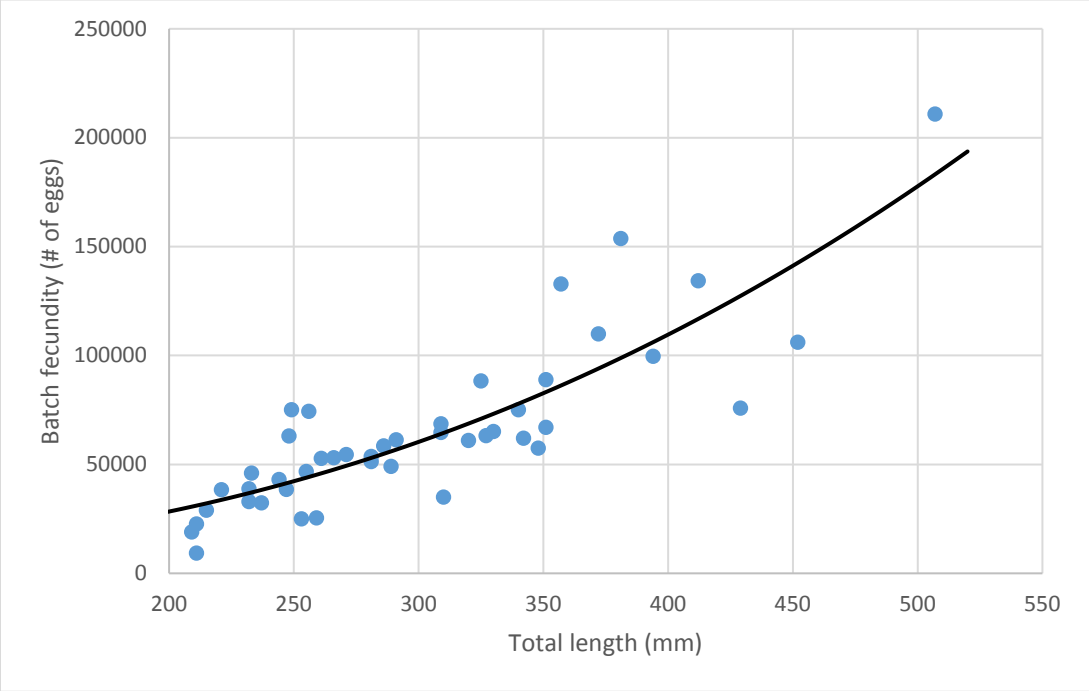
Equation: $y = 0.2338*TL^{2.1791}$

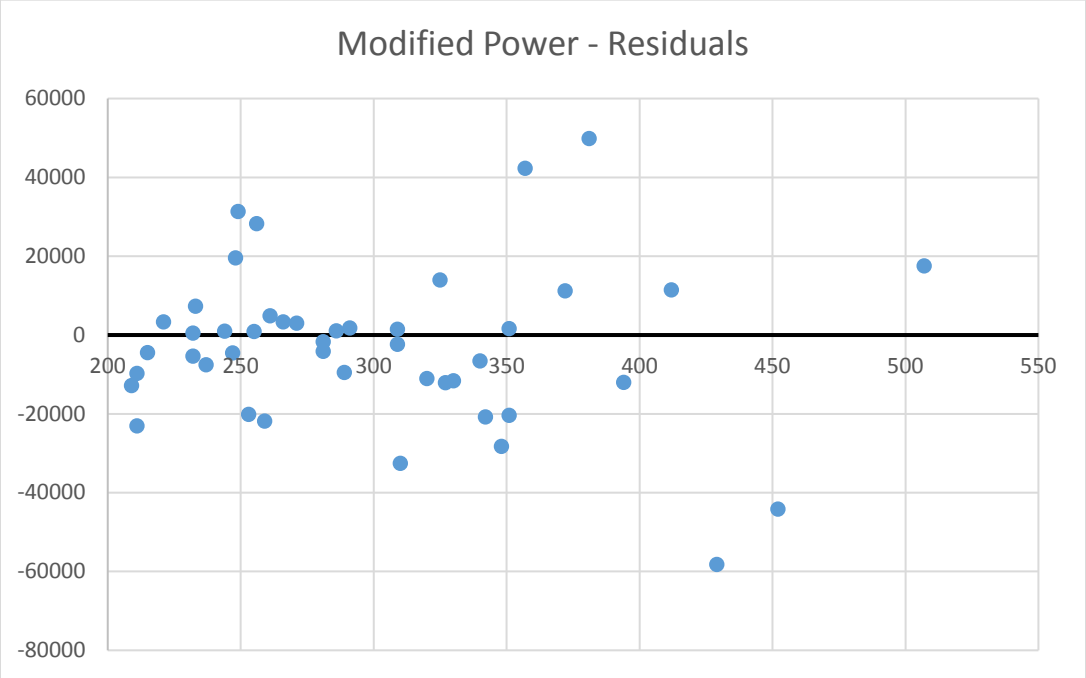




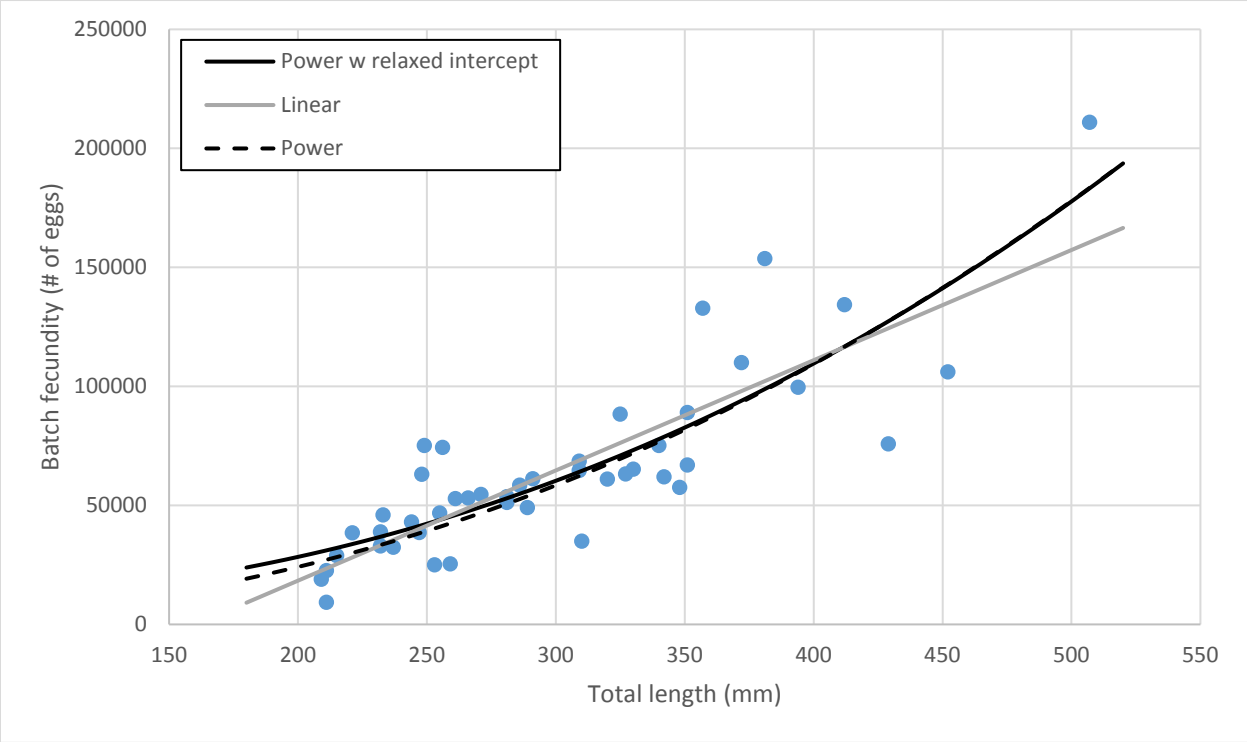
Modified Power Function with Relaxed Intercept

Equation: $y = 7473.432 + 0.113*TL^{2.289}$





Combined



Background:

Initially, the linear regression for batch fecundity by size was chosen as it had a better fit than a power function, especially at the lower end of the length range (250-300 mm TL). Because the majority of Vermilion Snapper caught in the chevron trap survey were in the 2-4 year old range which coincides with that length range, the linear model was deemed most appropriate. There was nothing that stood out in the residuals to indicate one method over the other.

Upon further investigation, we modified the power equation by adding a variable to relax the intercept requirement of going through the origin:

Modified Power Function: Batch Fecundity = $a + b*TL^z$

We felt this was appropriate because biologically, once the fish reaches maturity, the batch fecundity instantly jumps from 0 to some higher level. By this reasoning, it didn't make sense to have batch fecundity be required to smoothly go through the origin. By relaxing this requirement, it changes the earlier portion of the curve to provide a closer fit to the observed values.

Recommendation:

Based on the evidence provided above, as well as a precedence set in previous Vermilion Snapper stock assessments of using a power equation to fit batch fecundity, we are recommending that batch fecundity as a function of length be modelled as:

$$\text{Batch Fecundity} = a + b*TL^{z}$$

with: a = 7473.432

b = 0.113

z = 2.289