Updated Estimates of Batch Fecundity vs. Total Length, Total Weight, and Calendar Age for South Atlantic Red Snapper in Support of the SEDAR 73 Operational Assessment

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SEDAR73-WP07

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Background

Red Snapper, *Lutjanus campechanus*, is a large, long-lived, member of the family Lutjanidae, with a maximum reported age of 51 yr (SEDAR41, 2017) . Red Snappers are distributed in marine waters throughout the Gulf of Mexico south to the Yucatan Peninsula and in United States (U.S.) Atlantic waters north to North Carolina (Nelson and Manooch, 1982; Manooch and Potts, 1997). Along the southeastern U.S., adult Red Snapper are associated with structured habitats such as coral reefs, wrecks, gas and oil platforms, rocky outcroppings, and live-bottom (Moseley, 1966; Nelson and Manooch, 1982; Barans and Henry, 1984; Sedberry and Van Dolah, 1984). Red Snapper are gonochorists with indeterminate fecundity (Woods, 2003; Brulé et al., 2010) that spawn during April through October in the Atlantic waters of the southeastern U.S. (White and Palmer, 2004; Lowerre-Barbieri et al. 2015).

The objective of this report is to present updated batch fecundity (BF) equations for the SEDAR73 Operational Assessment. Additional specimens (n=28) were processed by staff of the SouthEast Reef Fish Survey and the data were added to the dataset analyzed for SEDAR41. The dataset from SEDAR41 included data from Lowerre-Barbieri et al. (2015).

Methods

Survey Design and Gear

(see Smart et al. 2015 for full description)

Sampling area

• Cape Hatteras, NC, to St. Lucie Inlet, FL

Sampling season

• May through September
    o Limited earlier and later sampling in some years

Survey Design

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

• Video traps deployed on suspected live-bottom and/or hard-bottom in a given year (reconnaissance) are evaluated based on catch and/or video or photographic evidence of bottom type for inclusion in the universe in subsequent years
    o If added to the known habitat universe, data from the reconnaissance deployment is included in index development

Sampling Gear – Chevron Video Traps (video camera(s) added in 2010)

(see Collins 1990 and MARMAP 2009 for more detailed descriptions)

• Arrowhead shaped, with a total interior volume of 0.91 m3

• 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), most often Brevoortia spp.

- Four whole clupeids on each of four stringers suspended within the video trap
  - Approximately 8 clupeids placed loose in the video trap
- Soak time of approximately 90 minutes
- Daylight hours

Oceanographic Data

- Hydrographic data collected via CTD during soaking of a "set" (typically 6 video traps, but may be less) of chevron video traps deployed at the same time and same reef patch
  - Bottom temperature (°C) is defined as the temperature of the deepest recording within 5 m of the bottom

Data Filtering/Inclusion

Projects coordinated by MARMAP/SERFS

- P05/T59/T60 – MARMAP/SEAMAP-SA/SEFIS
- P50 – Port Sampling (Fishery-Dependent)

Gear

- 043 - Snapper reel
- 061 - SBLL
- 324 - Chevron trap

Specimen processing

Fish were kept on ice until they were processed on the vessel or in the laboratory, generally within 24 h of capture. Maximum total length (±1 mm), total weight (±1 g), and gonad weight (± 1 g; ± 0.1 g for smaller gonads) were measured and usually both sagittal otoliths were removed and stored dry. A sample of gonad tissue was removed and fixed for histological processing and an additional sample of ovarian tissue was fixed to estimate batch fecundity if there was macroscopic evidence of oocyte hydration but no ovulation.

Fecundity

Histological samples were processed and examined to assess reproductive phase and search for evidence that ovulation had begun (i.e., postovulatory follicle complexes (POC)). All specimens with new POCs were not used for the estimation of batch fecundity. Batch fecundity was estimated gravimetrically by MARMAP/SERFS and Lowerre-Barbieri et al. (2015) using the hydrated oocyte method (see Hunter et al., 1985; Murua et al., 2003). The protocols for processing Red Snapper ovarian tissue were similar, except for the methods of fixing tissue and separating oocytes. Lowerre-Barbieri et al. (2015) hydraulically separated the oocytes prior to fixation in 2% neutrally-buffered formalin and then weighed subsamples, whereas MARMAP/SERFS fixed the tissue in 10% seawater-buffered formalin, weighed subsamples, transferred subsamples to 5% seawater-buffered formalin, and then separated oocytes. MARMAP/SERFS investigators obtained 2 or 3 subsamples per specimen that weighed 75-175 mg, versus 2 subsamples weighing 100 mg in Lowerre-Barbieri et al. (2015).

The count of hydrated oocytes in each subsample was extrapolated to gonad weight to compute batch fecundity. For MARMAP/SERFS subsamples, it was necessary to develop a regression equation to

convert fresh gonad weight to preserved (i.e., fixed) gonad weight because only a portion of most large gonads was preserved to reduce the amount of formalin utilized. For Red Snapper, the equation to estimate preserved weight was: preserved wt (g) = fresh wt (g) * 0.886218 – 1.61585, with the range of fresh gonad wt = 4 to 275 g, adj. r^2=0.99, n=15.
The relationship between batch fecundity vs. maximum total length, total weight, and calendar age was estimated using simple linear and non-linear (power function; BF = bX^z) regression analyses. In the most recent Vermilion Snapper assessment, the power function was recommended (Bubley and Wyanski, 2017) because fecundity tends to exhibit a non-linear relationship with fish length due to body cavity volume increasing in a non-linear manner with fish length (Wooten, 1979). Two power function models (with and without intercept) were utilized, the latter to relax forcing the intercept through the origin. Simple linear regression analyses were performed with EXCEL software and non-linear analyses were performed with Statistical Analysis System (SAS) software, vers. 9.4 (SAS Institute Inc, 1989).

Ageing
Otoliths were embedded and sectioned following standard protocols and assigned increment counts and edge codes by two readers independently (Smart et al., 2015). Calendar ages were determined from consensus ages via the rule that if the edge code was 3 or 4 and month of capture was January through July, then calendar age was increment count + 1. For all other edge codes and months, the calendar age was increment count.

Results
A total of 97 Red Snapper were collected during 1999-2019 to assess batch fecundity, including 28 specimens collected by MARMAP/SERFS during 2007-2019 that were added to the dataset (n=69) analyzed for SEDAR41. The dataset from SEDAR41 was composed of data from Lowerre-Barbieri et al. (2015; n=44) and 25 specimens processed by MARMAP/SERFS. The specimens processed by Lowerre-Barbieri et al. (2015) were collected with hooked gear (longlines, rod and reel) during April through August in 2012 off the upper half of Florida's east coast, whereas the 53 specimens from MARMAP/SERFS were collected throughout the sampling area (28.3 to 34.9 ^{o}N), nearly all (94%) with chevron traps.

The 97 specimens ranged in length from 360 to 958 mm TL and in calendar age from 2 to 16 yr. Although the fits of the linear regression equations were good (Table 1; Adj. R^2 = 0.50-0.62), the power function model was applied to the data because batch fecundity exhibited a non-linear relationship with total length (TL) and total weight (TW), and to a lesser degree with calendar age (Fig. 1). The power function with no intercept parameter (2-parameter) tended to overestimate batch fecundity at smaller sizes (length and weight) due to the model forcing the intercept through the origin (Fig. 2); therefore the 3-parameter model is recommended equations for predicting batch fecundity versus TL and TW (Table 2). The drawback to the 3-parameter model is that the predicted values are negative at TL < 378 mm and TW < 728 g (Tables 3 and 4). For smaller fish, it is recommended that the mean observed batch fecundity be used at sizes < 400 mm TL (= 55523 eggs) or < 1000 g TW (=61808 eggs). The 2-parameter power function is the recommended equation for predicting batch fecundity versus calendar age (Tables 2 and 5) because the 3-parameter function underestimated batch fecundity at younger ages (Age 2) and potentially at the oldest ages (Fig. 3)

Literature Cited

Barans, C.A., and V.J. Henry, Jr. 1984. A description of the shelf edge groundfish habitat along the southeastern United States. Northeast Gulf Sci. 7:77-96.

Brown-Peterson, N.J., D. M. Wyanski, F. Saborido-Rey, B. J. Macewicz, and S. K. Lowerre-Barbieri. 2011. A standardized terminology for describing reproductive development in fishes. Mar. Coast. Fish. [online serial] 3:52–70. DOI: 10.1080/19425120.2011.555724

Brulé, T., T. Colás-Marrufo, E. Pérez-Díaz, J.C. Sámano-Zapata. 2010. Red snapper reproductive biology in the southern Gulf of Mexico. Trans. Am. Fish. Soc. 139:957−968.

Bubley, W.J., and D.M. Wyanski. 2017. Update of Vermilion Snapper, *Rhomboplites aurorubens*, reproductive life history from the MARMAP/SERFS Program. SEDAR55-WP03. SEDAR, North Charleston, SC. 26 pp.

Collins, M.R. 1990. A comparison of three fish trap designs. Fisheries Research 9: 325-332.

Hunter, J.R., N.C.H. Lo, and J.H. Leong. 1985. Batch fecundity in multiple spawning fishes. NOAA Technical Report NMFS 36:67–77.

Lowerre-Barbieri, S., L. Crabtree, T. Switzer, S.W. Burnsed, and C. Guenther. 2015. Assessing reproductive resilience: an example with South Atlantic red snapper *Lutjanus campechanus*. Mar. Ecol. Progr. Ser. 526:125-141.

Manooch III, C.S. and J.C. Potts. 1997. Age and growth of Red Snapper, *Lutjanus campechanus*, Lutjanidae, collected along the southeastern United States from North Carolina through the East Coast of Florida. J. Elisha Mitchell 113:111-122.

MARMAP. 2009. Overview of sampling gear and vessels used by MARMAP. (Brief descriptions and sampling protocol). Marine Resources Research Institute, South Carolina Department of Natural Resources, Charleston, SC. 20 pp.

Moseley, F.N. 1966. Biology of the Red Snapper, *Lutjanus aya* Bloch, of the Northwestern Gulf of Mexico. Publs. Inst. Mar. Sci. Univ. Tex. 11:90-101.

Murua, H., G. Kraus, F. Saborido-Rey, P.R. Witthames, A. Thorsen, and S. Junquera. 2003. Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. J. Northwest Atl. Fish. Sci. 33: 33−54.

Nelson, R.S. and C.S. Manooch, III. 1982. Growth and mortality of Red Snapper, *Lutjanus campechanus,* in the west central Atlantic Ocean and the northern Gulf of Mexico. Trans. Am. Fish. Soc. 111:465-475.

SAS Institute, Inc. 1989. SAS/STAT User's Guide, Version 6, 4th edition, Volume 2. SAS Institute, Cary, North Carolina. 846 p.

SEDAR. 2017. SEDAR 41 – South Atlantic Red Snapper Assessment Report – Revision 1. SEDAR, North Charleston SC. 805 pp. available online at: http://sedarweb.org/sedar-41.

Sedberry, G.R., and R.F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the U.S.A. Environ. Biol. Fish. 11:241-258.

Smart, T.I., M.J.M. Reichert, J.C. Ballenger, W.J. Bubley, and D.M. Wyanski. 2015. Overview of sampling gears and standard protocols used by the Southeast Reef Fish Survey and its partners. SEDAR41-RD58.

White, D. B. and S. M. Palmer. 2004. Age, growth, and reproduction of the Red Snapper, *Lutjanus campechanus*, from the Atlantic waters of the southeastern U.S. Bulletin of Marine Science 75:335-360.

Woods, M.K. 2003. Demographic differences in reproductive biology of female red snapper (*Lutjanus campechanus*) in the northern Gulf of Mexico. M.S. Thesis. University of South Alabama, Mobile,

Alabama. 129 pp.
Wootton, R. J. 1979. Energy costs of egg production and environmental determinants of fecundity in teleost fishes. Symposium of the Zoological Society of London 44:133-159.

Table 1. Simple linear regression equations (BF= a +bX) for Red Snapper batch fecundity (BF) versus total length (TL), Total weight (g), and calendar age. Red Snapper (n=97) were collected in 1999-2019 primarily during fishery-independent sampling off the Atlantic coast of the southeastern United States by Florida's Fish & Wildlife Research Institute and the SouthEast Reef Fish Survey at S. Carolina Department of Natural Resources.

X	Range of X	a	SE_a	b	SE_b	n	Adj. R^2
TL (mm)	360-958	-1833719	210224	4479.011	355.3476	97	0.62
Total wt (g)	630-11,830	-180964	84244.44	257.0033	18.73116	97	0.66
Cal. Age (yr)	2-16	2.934978	0.253587	2.14E-06	2.21E-07	94	0.50

Table 2. Recommended power function equations relating batch fecundity (BF) to total length (TL), total weight, and calendar age for Red Snapper off the Atlantic coast of the southeastern United States.

Independent Variable (X)	Range	a	SE_a	b	SE_b	Z	SE_z	n	Model	Notes
TL (mm)	360-958	-271137	246741	0.0235	0.1126	2.7404	0.7030	97	BF = a+(b*X^Z)	Due to negative predicted value at TL < 378, let BF for females < 400 mm TL = mean obs. BF for TL < 400 (= 55523).
Total Weight (g)	630-11,830	-198789	211224	317.0	704.7	0.9775	0.2380	97	BF = a+(b*X^Z)	Due to negative predicted value at WW < 728, let BF for females < 1000 g WW = mean obs. BF for WW < 1000 (= 61808).
Calendar Age (yr)	2-16	n/a	n/a	137936.0	37942.3	1.1382	0.1301	94	BF = b*X^Z	

Table 3. Predicted batch fecundity versus total length (TL; mm) for Red Snapper off the Atlantic coast of the southeastern United States using the equation in Table 2.

TL (mm)	**Batch Fecundity (# of eggs)**
360	-33256
370	-14708
380	4734
390	25088
400	46370
410	68598
420	91791
430	115964
440	141137
450	167324
460	194545
470	222815
480	252152
490	282572
500	314091
510	346727
520	380497
530	415415
540	451499
550	488765
560	527230
570	566908
580	607817
590	649971
600	693388
610	738083
620	784071
630	831368
640	879991
650	929953
660	981272
670	1033961
680	1088038
690	1143516
700	1200411
710	1258739
720	1318514
730	1379752
740	1442467
750	1506675
760	1572390
770	1639627
780	1708401
790	1778727
800	1850620
810	1924094
820	1999163
830	2075843
840	2154148
850	2234092
860	2315690
870	2398956
880	2483905
890	2570550
900	2658906
910	2748988
920	2840809
930	2934383
940	3029725
950	3126849
960	3225769

Table 4. Predicted batch fecundity versus total weight (g) for Red Snapper off the Atlantic coast of the southeastern United States using the equation in Table 2.

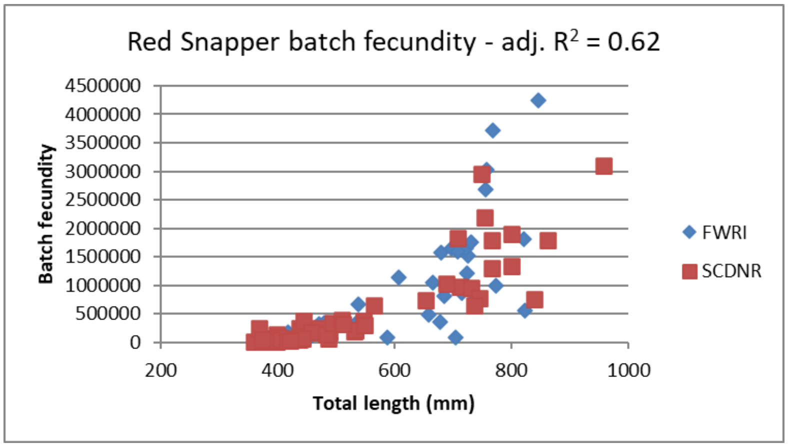
Total Weight (g)	**Batch Fecundity (# of eggs)**
500	-60972
1000	72579
1500	204567
2000	335549
2500	465788
3000	595439
3500	724602
4000	853349
4500	981734
5000	1109798
5500	1237573
6000	1365086
6500	1492361
7000	1619415
7500	1746265
8000	1872925
8500	1999406
9000	2125720
9500	2251877
10000	2377884
10500	2503749
11000	2629479
11500	2755081
12000	2880560

Table 5. Predicted batch fecundity versus calendar age (yr) for Red Snapper off the Atlantic coast of the southeastern United States using the equation in Table 2.

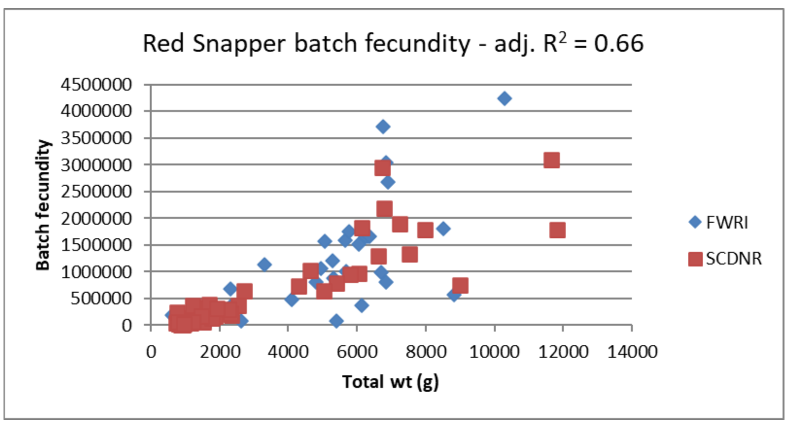
Calendar Age (yr)	**Batch Fecundity (# of eggs)**
2	303606
3	481656
4	668255
5	861480
6	1060155
7	1263480
8	1470871
9	1681886
10	1896172
11	2113444
12	2333467
13	2556042
14	2780997
15	3008186
16	3237479

Figure 1. Simple linear regression of batch fecundity versus A) total length, B) total weight, and C) calendar age in Red Snapper (n=97) collected in 1999-2019 primarily during fishery-independent sampling off the Atlantic coast of the southeastern United States by Florida's Fish & Wildlife Research Institute (FWRI) and the SouthEast Reef Fish Survey at S. Carolina Dept. of Natural Resources (SCDNR).

A)



B)



C)

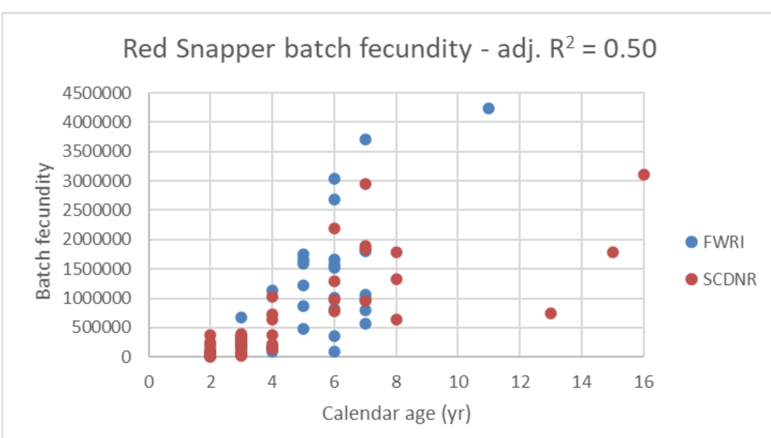
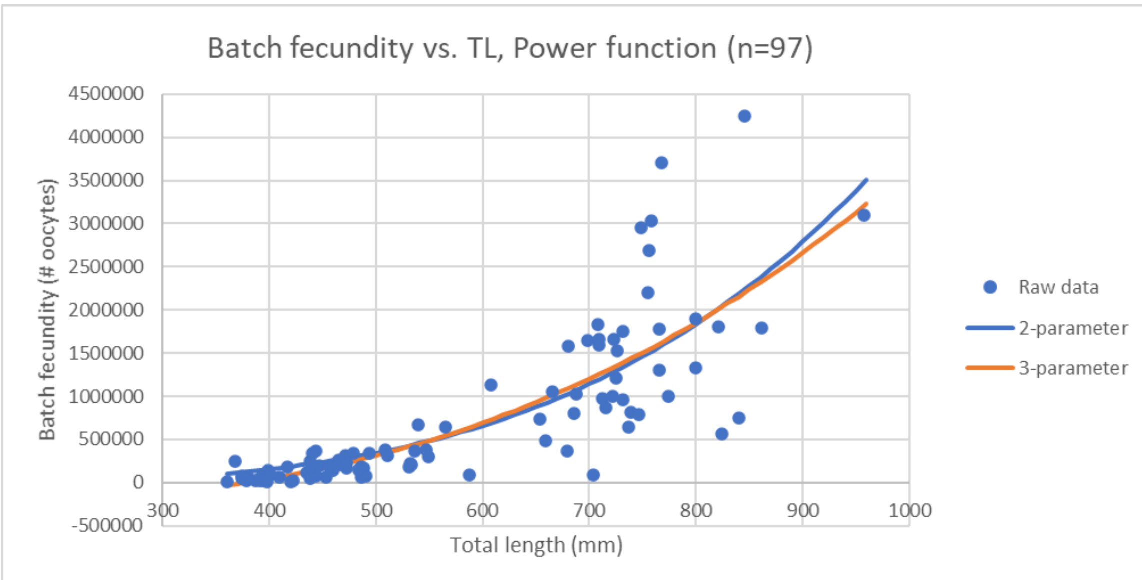


Figure 2. Non-linear regression analysis of batch fecundity (BF) versus A) total length and B) total weight in Red Snapper using the power function ($BF = bX^z$). The 3-parameter model included an estimate of the intercept ($BF = a + bX^z$). The Red Snapper (n=97) were collected in 1999-2019 primarily during fishery-independent sampling off the Atlantic coast of the southeastern United States by Florida's Fish & Wildlife Research Institute (FWRI) and the SouthEast Reef Fish Survey at S. Carolina Department of Natural Resources (SCDNR).

A)



B)

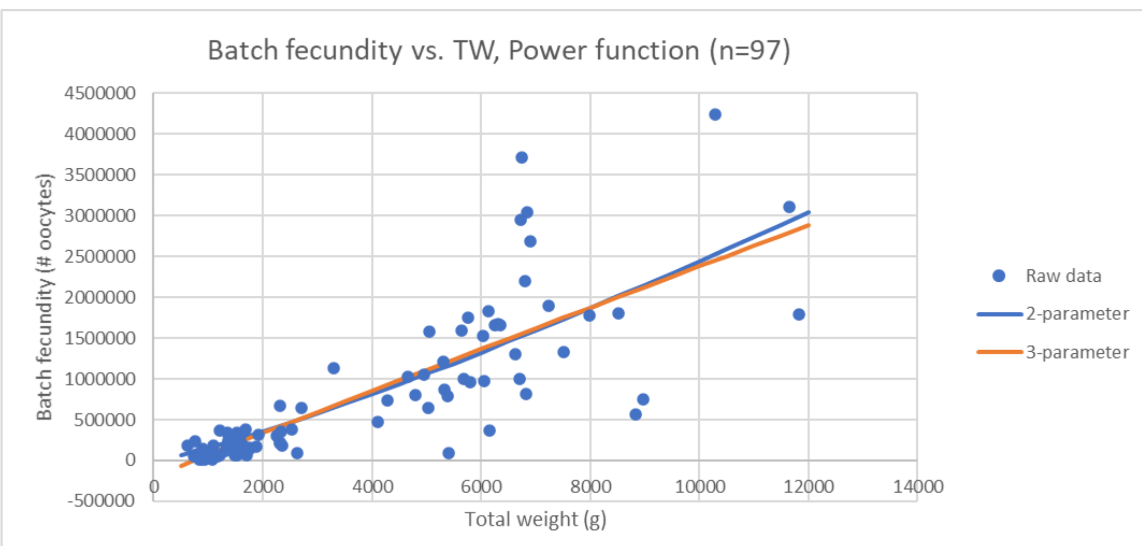


Figure 3. Non-linear regression analysis of batch fecundity (BF) versus calendar age in Red Snapper using the power function ($BF = bX^z$). The 3-parameter model included an estimate of the intercept ($BF = a + bX^z$). The Red Snapper (n=94) were collected in 1999-2019 primarily during fishery-independent sampling off the Atlantic coast of the southeastern United States by Florida's Fish & Wildlife Research Institute (FWRI) and the SouthEast Reef Fish Survey at S. Carolina Department of Natural Resources (SCDNR).