U.S. Caribbean Yellowtail Snapper Population Demographics, Growth, and Reproductive Biology: Addressing Critical Life History Gaps

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U.S. Caribbean Yellowtail Snapper Population Demographics, Growth, and Reproductive Biology: Addressing Critical Life History Gaps

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Highlights of Relevant Background

Habitat Use - Adults

- Adults inhabit shelf waters mostly associate with hard substrates including coral reefs
- Commonly form large pelagic aggregations and exhibit high site fidelity (Grimes 1977, Lindholm et al. 2005)
- Unlike many snapper species, adult yellowtail snapper are a more pelagic, (sometimes referred to as "semi-pelagic") often occurring above the substrate (McClellan and Cummings 1998, Lindholm et al. 2005)
- Yellowtail snapper occurs at depths up to 120 m (McClellan and Cummings 1998) with adults commonly found between 20 – 50 m (GMFMC, 2013; Thompson and Munro, 1974)

Diet/foraging

- Yellowtail snapper is a generalist carnivore, consuming a wide array of smaller fishes and invertebrates from pelagic and benthic habitat (Piedra 1969, Barbieri and Colvocoresses 2003)
- This species feeds during the day and at night; U.S. Caribbean fishers often target feeding aggregations of large yellowtail snapper at night (G Martinez, St. Croix fisher, and J Magras, St. Thomas fisher, personal communications)
- Seasonal variability in feeding has been observed in yellowtail snapper; a study conducted in Cuba noted that the frequency of individuals with full stomachs increased outside of spawning season (Carrillo de Albornoz and Ramiro 1988)
- Similar observations were reported of yellowtail snapper off south Florida by Collins and Finucane (1989)
- Interestingly, according to STFA (2013), commercial fishing of yellowtail snapper in the U.S. Caribbean often occurs at night, probably because fishers understand the nocturnal feeding behavior of this species

Reproductive Biology and Population Demographic Patterns

- Yellowtail snapper may form spawning aggregations of 25 to 30 individuals, although these aggregations are not well defined spatially or temporally (Claro et al. 2009, Trejo-Martínez et al. 2011).
- Studies from Florida documented yellowtail snapper spawning occurred mainly in the

spring and summer, with a peak from May – July; year-round spawning has been reported in the southern Florida Keys (Collins and Finucane 1989, Muller et al. 2003).

- Yellowtail snapper populations occurring at lower latitudes such as in the Caribbean and southern Gulf of Mexico (GOM) appear to have more protracted spawning seasons: A study from Jamaican waters observed that yellowtail snapper spawn year-round with a peak in March – April, and a secondary minor peak in September (Munro et al. 1973); A study on yellowtail snapper reproduction in waters of Campeche Bank, off the Yucatan Peninsula, observed that female yellowtail snapper in spawning condition occurred in all months of the year (Trejo-Martínez et al. 2011)

- Energetic investment of year-round spawning exhibited by low latitude populations may be a contributor to observed differences in regional growth rates of yellowtail snapper.

- A few studies have reported on yellowtail snapper age and growth, but this information is limited spatially and temporally.

    - Johnson (1983) collected 807 fish from southeastern Florida waters from 1979-1980 and reported a maximum estimated age of 14 years. Garcia et al. (2003) sampled 1528 fish from southeastern Florida, during the years of 1994-1999 and documented a maximum age of 13 y.

    - Allman et al. (2005) collected 6679 yellowtail snapper samples from waters of the east coast of Florida from 1980-2002 and reported a maximum age of 17 y.

    - The mean maximum length (von Bertalanffy growth model parameter L_{∞}) of fish from these three Florida studies ranged from 410-484 mm FL, the Brody growth coefficient (K) ranged from 0.17-0.30, and the age at which size would equal zero (t_0) ranged from -2.03 to -0.36 (Table 1)

- A study from U.S. Caribbean waters collected 468 yellowtail snapper in 1983-1984 and reported a maximum age of 17, L_{∞}= 503 mm FL, K = 0.14, and t_0 = -0.96 (Manooch and Drennon 1987). The U.S. Caribbean study noted that yellowtail snapper increments were relatively difficult to discern (Manooch and Drennon 1987)

- Prior to the current study, more recent information (post-1984) did not exist on age and growth for yellowtail snapper from waters of the U.S. Caribbean.

Table 1. Summary of yellowtail snapper studies focused on estimating growth parameters. *indicates that a fixed t_0 value of -0.96 was used so that other growth parameter results from the current study could be compared to results from Manooch and Drennon (1987). **indicates that a fixed t_0 value of -1.93 was used so that other growth parameter results from the current study could be compared to results from Florida (SEDAR 2020).

Study Area **Study Citation**	**Time period (n)** **sample source**	**Size range** **(mean) mm**	**Age range** **(mean) y**	**L_∞/K/t_0** **Opaque zone formation**	**Comments**
U.S. Caribbean Current study	2013-2023 (1554) FI + FD	FL: 28-572 (291)	0-26 (5)	FL: 508/0.12/-2.73 424/0.23/-0.96* 467/0.16/-1.93** Mar-Jun	Age validation via radiocarbon
U.S. Caribbean Manooch and Drennon 1987	1983-1984 (468) FD	FL: 140-590	1-17	FL: 503/0.14/-0.96 Mar-May	Used back-calculated size-at-age
Cuba Claro 1983	1972-1974 (3593) FD	FL: 160-460	0-6	FL: 681/0.16/-0.85 Mar-Jun	No validation of age estimates; otoliths read whole
FL east coast Allman et al. 2005	1980-2002 (6679) FI + FD	FL: 115-605 (312)	1-17 (4)	FL: 410/0.27/-2.03 Feb-May	
Southeast FL Garcia et al. 2003	1994-1999 (1528) FD	FL: 220-561	1-13	FL: 484/0.17/-1.87 Mar-May	
Southeast FL Johnson 1983	1979-1980 (807) FD	FL: 134-567	1-14	FL: 451/0.28/-0.36	
Florida SEDAR 2020	1980-2017 (42,985) FD (<1% FI)	FL: 100-600*	0-28	FL: 426/0.20/-1.93 Mar-Jun	Growth model accounted for truncated size-at-age

OVERALL GOAL AND SPECIFIC OBJECTIVES

- The overall goal of this study was to provide essential life history information in support of more effective fishery management for an important reef fish fisheries species in the U.S. Caribbean, yellowtail snapper

- **Utilization of region-specific and current information on life history information is key for assessing the local stock of yellowtail snapper**

- Age and growth estimates are fundamental to reliably estimating biological reference points and are required to facilitate the transition to age-based stock assessments.

The specific objectives of this study were:

1) Document length-length and length-weight relationships for yellowtail snapper from the U.S. Caribbean

2) Characterize attributes of population size and age structure

3) Determine reproductive patterns and describe reproductive seasonality

4) Document size and age at sexual maturity for yellowtail snapper in the U.S. Caribbean

5) Briefly compare results to selected studies from other regions and time periods to emphasize the importance of local and current information on U.S. Caribbean species in conducting stock assessments

Methods

Sample Collection

- Monthly; 2009-2023
- Fisheries-dependent (FD) samples were obtained directly from fishers in USVI and Puerto Rico (2013-2023) and divided into two FD sample types:
  - FD-random were collected by randomly selecting all triggerfish from one side of a cooler containing the day's catch or by purchasing all yellowtail snapper landed by a fisher on the day/night of sampling;
  - FD-nonrandom were collected by haphazardly selecting a subsample of yellowtail snapper from a fisher at market which meant that catch may have been combined from multiple trips and an unknown portion of fish may have been sold prior to our sampling
- Fisheries-independent: Fish/Fisheries Conservation Lab collections for 2013-2023 from USVI and Puerto Rico
  - Collaborative efforts to fill in temporal, spatial, and size gaps with the help of fishers using hook gear
  - Castnet, spear, and hook gear sampling by PIs to ensure collection of small juvenile yellowtail snapper samples
- Fisheries-independent (FI): SEAMAP –C samples collected 2009-2020 and processed by the PR DNER lab
  - PR SEAMAP-C project objective is to collect information on abundance and distribution of reef fishes using randomized stratified sampling designs and hook gear
  - One of the benefits of this monitoring is to establish a long-term database from different regions of Puerto Rico
  - Starting in 2009 we started taking gonad tissue from a subset of samples

Processing

- For each sample we noted date of collection, gear of capture, collection location, depth (if available)
- Obtained length (SL/FL/TL mm) and whole weight (g) of samples
- Gonads weighed (0.01 g) and preserved for reproductive histology
- Otoliths obtained for age estimation for all FD and FI samples processed by the Fish/Fisheries Conservation Lab

- Collected genetic tissue sample, muscle sample, stomach, and eyes for additional research

Length-Length and Length-Weight Conversions

- IMPORTANCE: Long-term, consistent, and widespread fish length data are limited for Caribbean reef fish species like yellowtail snapper. Conversions of length-type (i.e., SL, FL, TL) serve as a helpful tool to bridge gaps in scientific sampling and measuring between studies (Jones et al. 2021)
- Due to logistical or physical reasons, different studies may utilize differing measurement methods; for example, one study may report SL, while another primarily utilizes FL. The creation of accurate conversions of length improves upon the amount of available data for Caribbean fisheries species and promotes the sharing of data across different researchers and managers who had previously used differing measurement methodologies.
- Regression equations based on a large sample size of yellowtail snapper were calculated to create length-length and length-weight conversions
- The length-weight regressions were in the form of $W = a L^b$; where W = weight (g), L = length (mm), and *a* and *b* are the intercept and slope parameters, respectively

Evaluation of trends related to fish length

- A two factor ANOVA was used to test for significant differences in mean fish length between sexes (female versus male) and between sample source (FD versus FI)
- Separate Kolmogorov-Smirnov (K-S) tests were used to determine if significant differences occurred in length frequency distributions between males and females and between FD and FI samples

Age estimation and evaluation of trends related to fish age

- To obtain age estimates for understanding population demographics and computing growth estimates, two independent readers with 10+ years of experience assessed increment counts for each yellowtail snapper otolith without knowledge of fish size or date of collection
- In cases of between-reader increment count disagreements, the two readers concurrently evaluated the otolith section together and reached a consensus age estimate
- Average percent error (APE) between age estimates obtained by readers using the equation of Beamish and Fournier (1981)

- For each otolith, readers evaluated if the last opaque zone occurred on the otolith edge; the monthly proportion of otoliths with opaque zones on the edge was calculated using age-3 to age-20 fish and then all monthly proportions were plotted to evaluate the time of year that the opaque zone forms on the otolith margin (Jones et al. 2021, Shervette and Rivera Hernández 2022b, a) Separate pairwise K-S tests were used to compare the age frequency distributions between sexes and sample sources
- A two-factor ANOVA was used to determine if mean age differed significantly between sexes and between sample sources.

Growth parameter estimation

- Using all yellowtail snapper FL-at-age data, von Bertalanffy growth functions (VBGF) were fit with the least squares method
- We also computed VBGF using a fixed t_0 value of -0.96 to compare results with Manooch and Drennon (1987) and again using a fixed t_0 value of -1.93 to compare results with the most resent yellowtail snapper assessment for Florida (SEDAR 2020)
- A two-factor ANOVA was used to test the effect of sample source on estimated size at age for ages 2-7 y, the most prevalent age classes present in the data; the dependent variable for this was FL. The independent variables were age class and sample source (FD versus FI)

Gonad histology

- Gonads removed from each yellowtail snapper sample; either the whole gonad or the posterior portion of each gonad was fixed in 11% seawater-buffered formalin, Davidson's fixative, or polyethylene glycol–ethyl alcohol–glycerol–acetic acid (PAGA) fixative for up to 2 weeks and then transferred to 70% alcohol
- Gonad samples were processed using standard histological procedures for gonochoristic fish species (Kelly-Stormer et al. 2017, Rivera Hernández et al. 2019)
- Tissue samples were vacuum-infiltrated and embedded in paraffin wax; at least three transverse sections (~7 µm thick) were cut using a rotary microtome, mounted on glass slides, stained with double strength Gill hematoxylin, and counter-stained with eosin-y
- Stained sections were viewed using a compound microscope to determine sex and reproductive phase, assessed according to the histological criteria described in Rivera Hernandez et al. (2019) for tropical gonochoristic fish species
- Two readers examined each of the gonad histology slides for FD samples and non-SEMAP-C FI samples independently assigned sex and reproductive phase without knowledge of the capture date, specimen length, or specimen age; if differences in the assignment of reproductive phases occurred, readers examined the slide

simultaneously to obtain a consensus phase assignment; if no consensus was reached, then that specimen was eliminated from the analyses

- For SEAMAP-C yellowtail snapper samples gonad histology slides were read as described above by a single reader

Spawning season and spawning frequency

- The proportion of spawning-capable females relative to the total number of mature females in developing, regressing, and regenerating reproductive phases for each month was plotted to document overall spawning season and peak spawning period for the U.S. Caribbean region
- Spawning fraction, the proportion of actively spawning females relative to the total number of mature females, was calculated.
- Spawning interval was calculated using the early postovulatory follicle method (Rivera Hernández et al. 2019); to estimate spawning interval (number of days between spawning events) for mature yellowtail snapper samples overall, by length class, and by age class, the following equation was used: spawning interval = 1/spawning fraction.
- Spawning frequency was computed to estimate the number of times females could spawn within a year by dividing 365 days (the number of days within the spawning season of U.S. Caribbean yellowtail snapper females; Rivera Hernández et al. 2019) by spawning frequency.

Sexual maturity

- Size (L_{50}) and age (A_{50}) at median sexual maturity of males, females, and all individuals combined from the U.S. Caribbean were calculated using separate logistic regressions.
- Additional size and age at maturity values were also computed for sizes and ages at which 90% (L_{90} and A_{90}) and 95% (L_{95} and A_{95}) of individuals were sexually mature.
- For logistic regression analyses, maturity was treated as a binomial response variable. Logistic regressions were conducted using the logit function transformation and the generalized linear model procedure in R (Ogle, 2013).

RESULTS

General overview of sample collections/Trends related to fish length

Fisheries-dependent and -independent samples processed by Fish/Fisheries Conservation Lab for population demographics, growth, and reproductive biology: A total of 1554 samples were collected and measured for 2013-2023 from across the U.S. Caribbean. Age estimates were obtained for 1437 samples. Gonad histology was obtained for 765 females and 675 males.

Table 2. Yellowtail snapper collections by the Fisheries Conservation lab. FD = Fisheries-Dependent; FI = Fisheries-Independent.

Group	Number collected/ measured	Number aged	Length (mm FL) range (mean)	Age (y) Range (mean)
All Islands				
FD + FI	1554	1437	28-572 (291)	0-26 (5)
FD	979	885	202-572 (320)	2-26 (6)
FI	575	552	28-541 (242)	0-15 (4)
Female	765	706	28-570 (294)	0-19 (5)
Male	675	623	29-572 (294)	0-19 (5)
Unknown	114	108	72-541 (254)	0-26 (5)
USVI				
FD + FI	539	532	28-572 (328)	0-19 (6)
FD	491	484	235-572 (339)	3-19 (6)
FI	48	48	28-378 (222)	0-12 (3)
Female	277	274	28-570 (328)	0-19 (6)
Male	258	254	29-572 (330)	0-19 (7)
Unknown	4	4	109-318 (224)	1-5 (3)
Puerto Rico				
FD + FI	1015	905	72-541 (271)	0-26 (4)
FD	488	401	202-536 (300)	2-26 (5)
FI	527	504	72-541 (244)	0-15 (4)
Female	488	432	120-536 (275)	1-18 (4)
Male	417	369	96-502 (271)	0-16 (4)
Unknown	110	104	72-541 (255)	0-26 (5)

- Mean length did not significantly differ between males and females but did differ significantly between FD and FI samples (Tables 2 and 3)
- Length frequency distributions did not differ significantly between female and male yellowtail snapper (Fig 1; Table 4)
- Size frequency distributions did differ significantly between FD and FI samples; FD samples had a higher proportion of larger fish compared to FI samples (Fig. 1; Table 4)

Table 3. ANOVA results for mean length and mean age between sexes (male and female) and between sample sources (FD and FI).

Source	df	Sum of Squares	Mean Square	*F*	*P*
Length (FL mm)					
Sex	1	3721	3721	0.78	0.378
Source	1	2721327	2721327	569.19	< 0.001
Sex x Source	1	7431	7431	1.55	0.213
Error	1325	6334937	4781		
Age (y)					
Sex	1	0.6	0.6	0.07	0.797
Source	1	2432	2432	261.67	< 0.001
Sex x Source	1	35	35	3.81	0.51
Error	1325	12313	9		

Table 4. Results from Kolmogorov-Smirnov tests.

Comparison	D	*P*
Length (FL mm)		
Female versus male	0.690	0.728
FD versus FI	11.575	< 0.001
Age (y)		
Female versus male	0.401	0.997
FD versus FI	8.602	< 0.001

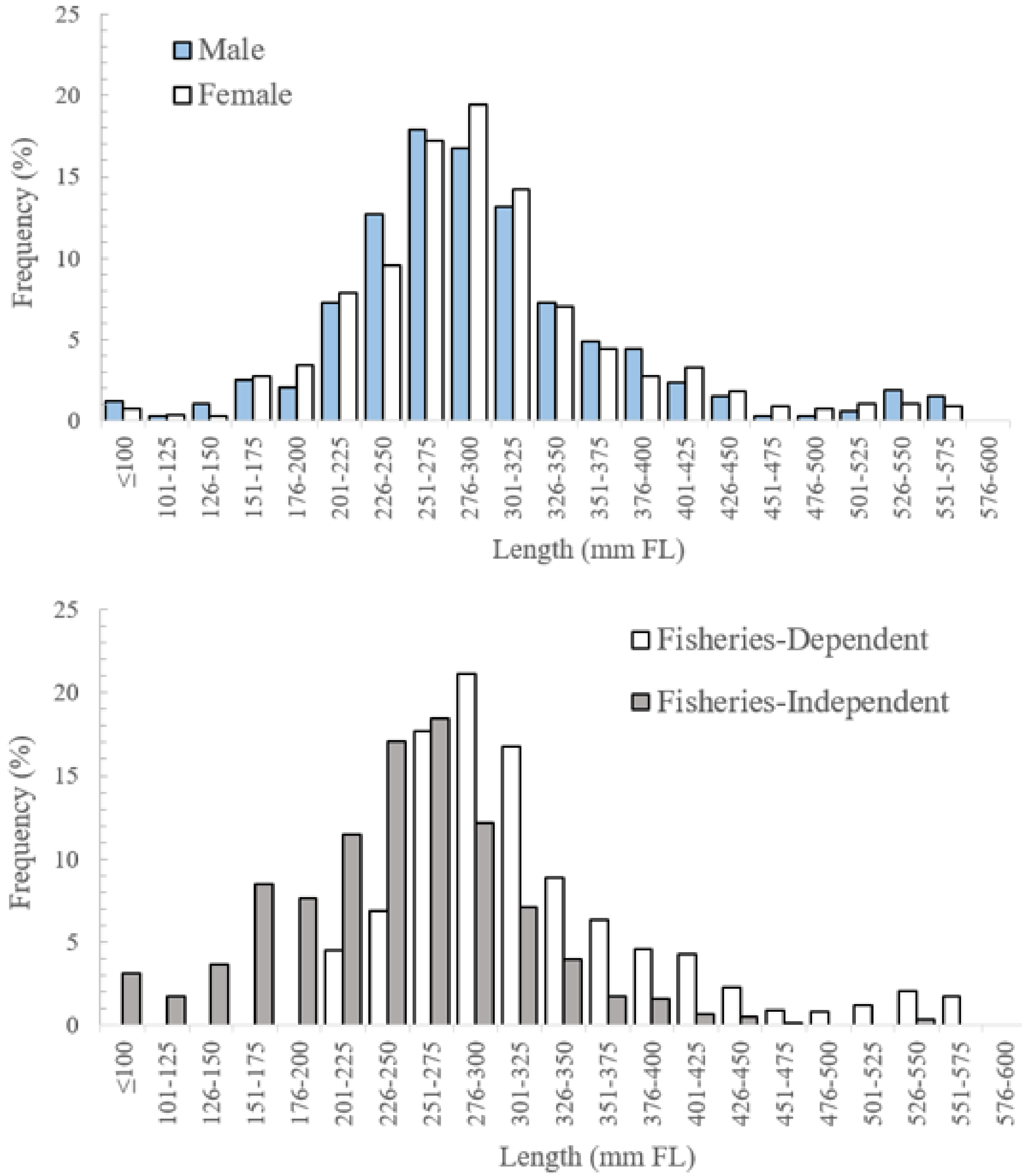

Figure 1. Length frequency distributions for U.S. Caribbean yellowtail snapper.

Puerto Rico SEAMAP-C samples processed by DNER for reproductive biology

A total of 1094 yellowtail snapper samples were measured from Puerto Rico SEAMAP-C fisheries-independent efforts. Of those, 437 females and 485 males were processed for gonad histology (Table 5; Fig 2).

Table 5. Puerto Rico SEAMAP-C yellowtail snapper collections analyzed for reproductive biology by the PR DNER Lab

Group	Number collected/ measured	Number processed for histology	Length (mm FL) range (mean)
All PR SEAMAP-C	1094	922	98-501 (261)
Female	437	437	185-501 (282)
Male	485	485	118-441 (262)

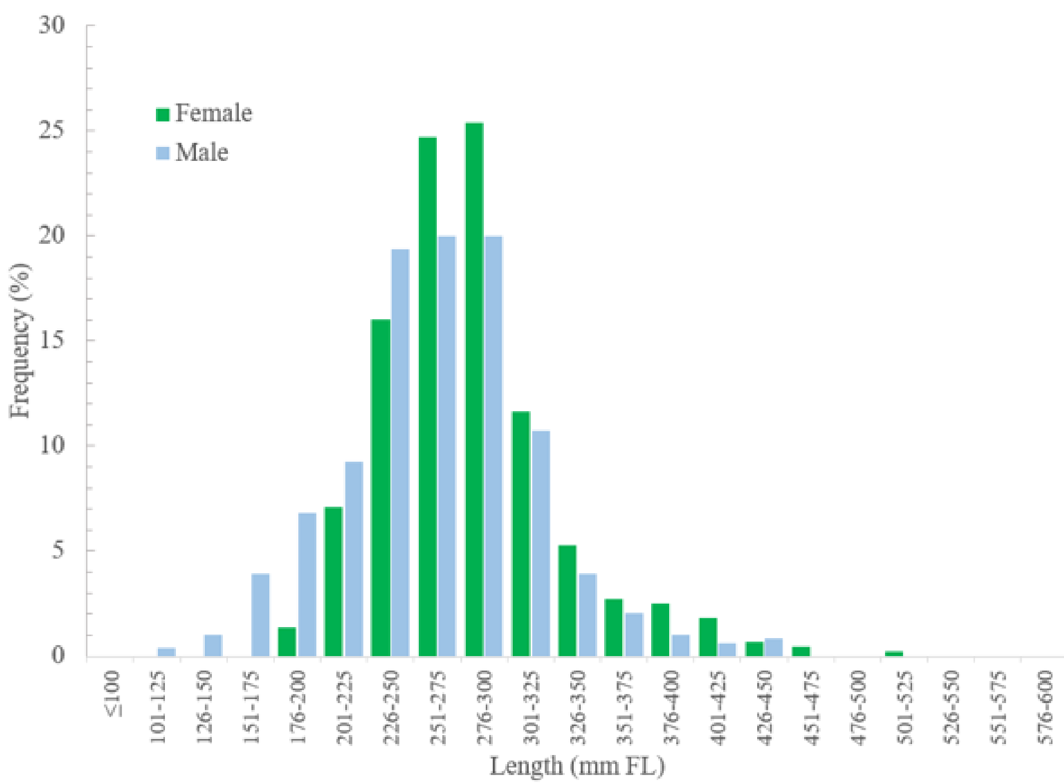

Figure 2. Length frequency distributions for SEAMAP-C Puerto Rico yellowtail snapper samples.

Length-Length and Length-Weight Conversions

- Represents fish collected from 2013-2023 and from every month of the year across full size rage documented in the U.S. Caribbean including small juveniles (Table 6)
- Includes variability related to stomach fullness, gonadal development, time of year, time of day/night, habitats, gears

Table 5. Regression results for U.S. Caribbean yellowtail snapper length and weight relationships

Variables				
x	y	n	Equation	R^2
SL	FL	1538	$y = 1.1156x + 7.9985$	0.9974
SL	TL	1520	$y = 1.4435x - 69857$	0.9917
SL	Wt	1532	$y = 0.00008x^{2.7772}$	0.9842
FL	SL	1538	$y = 0.8694x – 6.4783$	0.9974
FL	TL	1530	$y = 1.2937x – 17.299$	0.9944
FL	Wt	1542	$y = 0.00004x^{2.8642}$	0.9882
TL	SL	1520	$y = 0.687x – 6.92$	0.9917
TL	FL	1530	$y = 0.7686x + 14.945$	0.9944
TL	Wt	1524	$y = 0.00005x^{2.7185}$	0.9839

Evaluation of trends related to fish age

- Using the bomb radiocarbon validated age estimation method, ages were estimated for 1437 yellowtail snapper: 905 from PR and 532 from the USVI (Table 2). Of these fish, 885 were from FD sources and 557 from FI sources.

- APE between the two expert readers was 4.9%.

- Results from the otolith edge analysis indicated that opaque zones formed in the otoliths from March – July with a peak in April (Fig 3).

- The ages of PR samples ranged from 0 – 26 y with a mean age of 4 y; USVI samples ranged in age from 0 – 19 y with a mean of 6 y (Table 2).

- Mean age did not significantly differ between males and females but did differ significantly between FD and FI samples, with the mean age of FD fish (6 y) significantly older than FI fish (3 y) (Tables 2 and 3).

- Age frequency distributions did not differ significantly between females versus males; but did differ between FD versus FI samples (Table 4); Samples from FD collections had a higher proportion of older fish compared to FI samples.

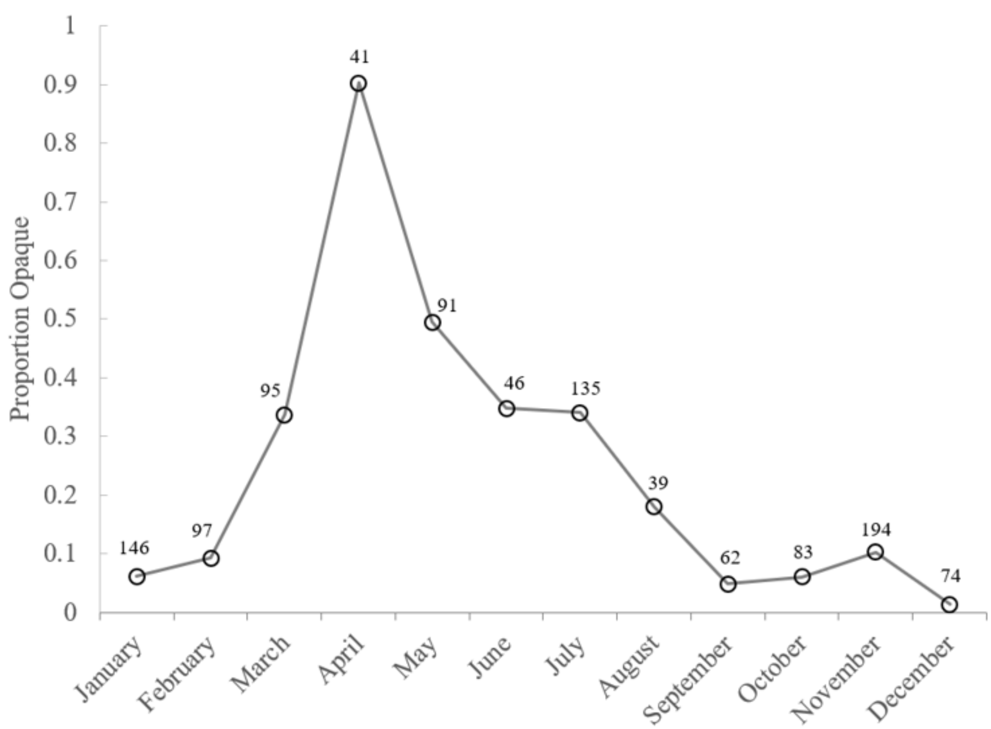

Figure 3. Monthly proportion of U.S. Caribbean yellowtail snapper otoliths with final opaque zone on the otolith edge.

Growth parameter estimates

- Fork length-at-age data fit to a von Bertalanffy growth curve for all samples combined from across the U.S. Caribbean and with t_0 fixed to equal -0.96 resulted in the following model: $FL_t = 424[1 - e^{-0.23(t + 0.960)}]$ (Table 6; Fig 4)

- Fork length data fit to the growth curve with t_0 freely calculated resulted in the following equation: $FL_t = 508[1 - e^{-0.12(t + 2.733)}]$ (Table 6).

- Total length data fit to the growth curve with t_0 freely calculated resulted in the following equation: $TL_t = 653[1 - e^{-0.11(t + 2.699)}]$ (Table 6).

- The two factor ANOVA indicated that mean size varied significantly among the age groups (2-7) and between FD and FI samples (Table 7; Fig 5).

Table 6. U.S. Caribbean yellowtail snapper VBGF results. Parameter estimates are provided using FL and TL. We also computed parameter estimates using t_0 = -0.96 for comparison with the Caribbean study by Manooch and Drennon (1987) and using t_0 = -1.93 for comparison with growth parameter estimates for Florida yellowtail snapper as reported in SEDAR 2020.

Model	**L_∞ (mm)**	**K**	**t_0**	**R^2**
FL mm	508 (479-547)	0.12 (0.10-0.14)	-2.73 (-3.29- -2.26)	0.70
TL mm	653 (635-648)	0.11 (0.10-0.13)	-2.67 (-3.18- -2.18)	0.70
FL mm **t_0**-fixed Carib	424 (415-434)	0.23 (0.22-0.24)	-0.96	0.68
FL mm **t_0**-fixed Fla	467 (454-481)	0.16 (0.15-0.18)	-1.93	0.70

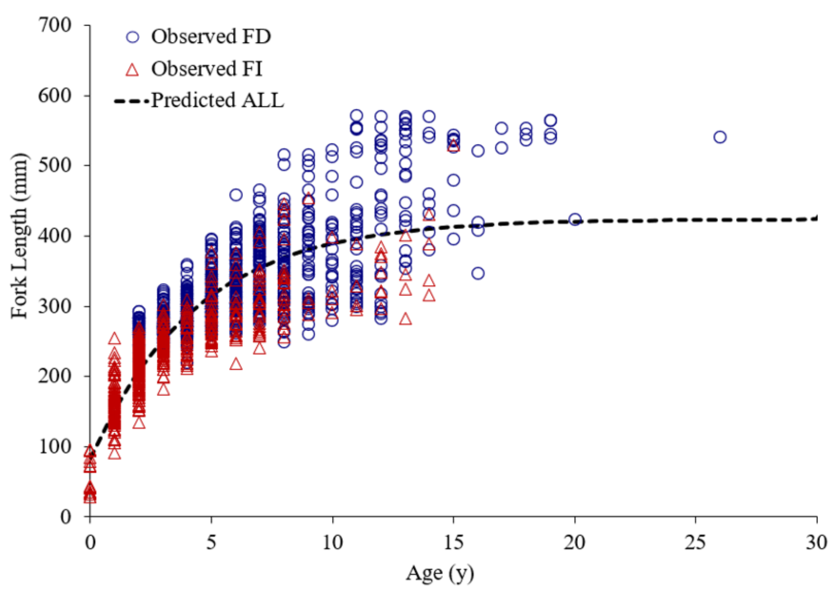

Figure 4. U.S. Caribbean yellowtail snapper length-at-age for FD and FI samples and von Bertalanffy growth curve based on t_0 = -0.93.

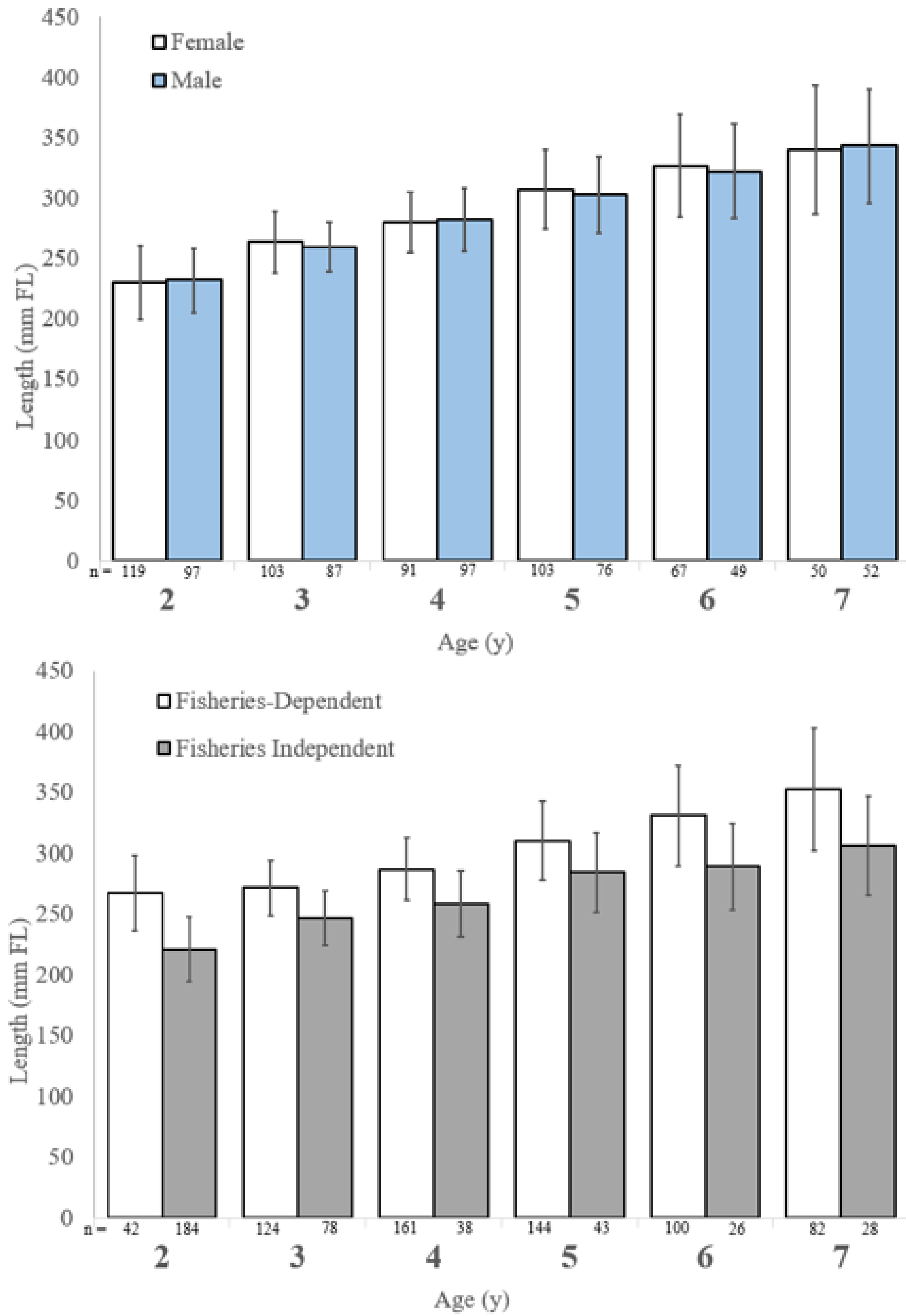

Figure 5. U.S. Caribbean yellowtail snapper mean length at age comparison between females and males (left) and between FD and FI samples (right) for age classes 2 through 7 y. Error bars represent standard error.

Table 7. Results for two-factor ANOVAs testing for significant differences in mean size-at-age between males and females and in mean size-at-age between FD and FI.

Variables	df	Sum of Squares	Mean Square	*F*	*P*
Female v Male					
Age (2-7 y)	5	1287953	257591	245.42	< 0.001
Sex	1	268	268	0.26	0.614
Age x Sex	5	2918	584	0.57	0.734
Error	979	1027647	1050		
FD v FI					
Age (2-7 y)	5	493410	98682	177.12	< 0.001
Fish Source	1	189234	189234	224.57	< 0.001
Age x Source	5	12204	2441	2.90	0.053
Error	979	824966	843		

Sex ratio, spawning season, and spawning frequency

- Using the combined data for sex from the two labs, the overall M:F sex ratio was 1:1.04

- To examine the monthly trends in spawning for yellowtail snapper in the U.S. Caribbean, we combined the gonad histology information obtained from both labs.

- A total of 892 mature female yellowtail snapper had reproductive phase information for the combined datasets; females with ovaries in the spawning capable phase occurred in all months of the year; the months with the greatest proportion of spawning capable females were March and April (Fig 6)

- A total of 856 mature male yellowtail snapper had reproductive phase information for the combined datasets; males with testes in the spawning capable phase occurred in all months of the year (Fig 7)

- Yellowtail snapper from the U.S. Caribbean exhibit year-round spawning with peak spawning from March-April

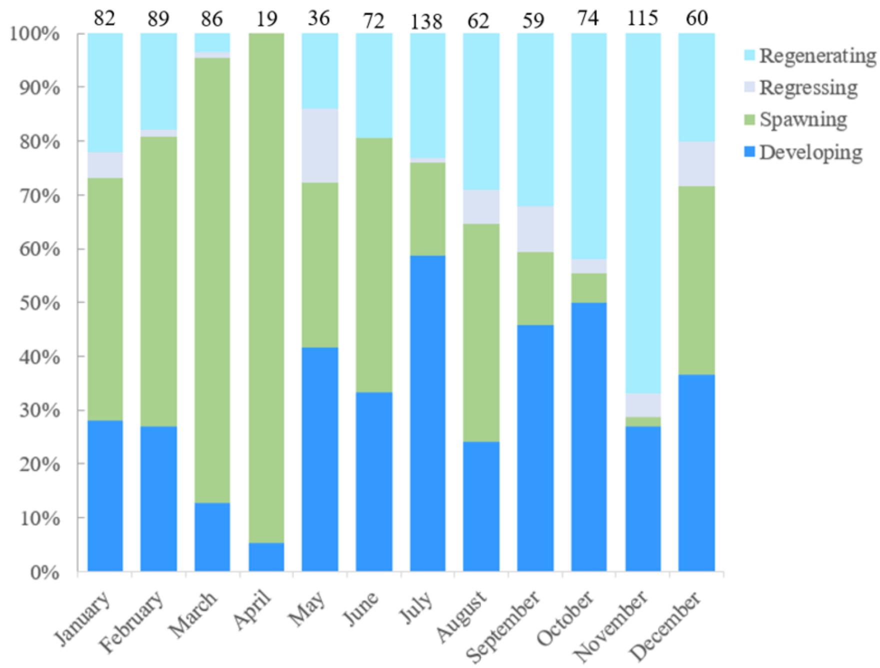

Figure 6. Female yellowtail snapper reproductive seasonality for the U.S. Caribbean. Monthly percentages of individuals in each reproductive phase are presented. Number of samples included for each month are provided above the bars.

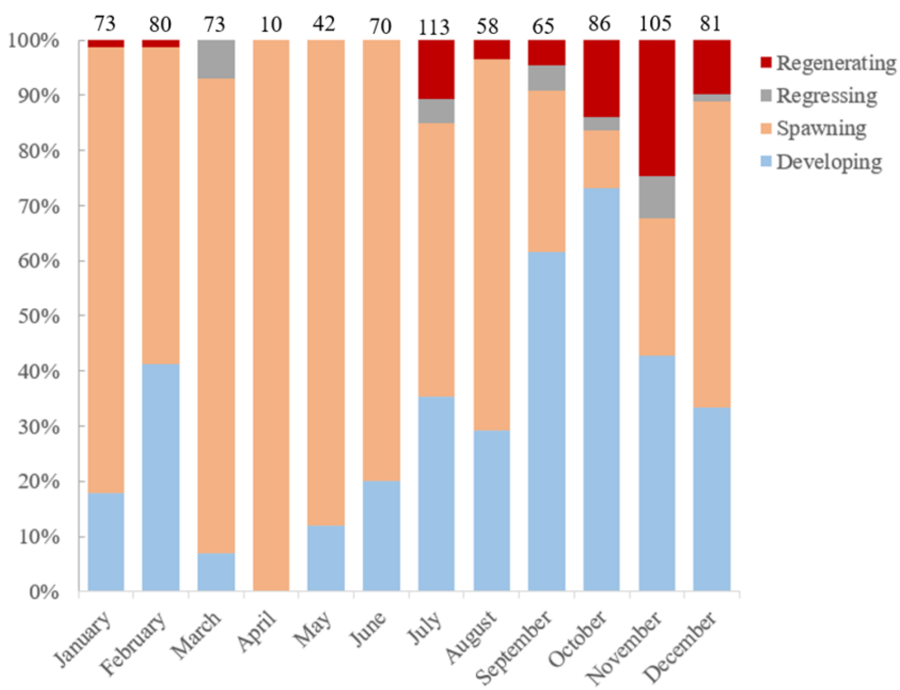

Figure 7. Male yellowtail snapper reproductive seasonality for the U.S. Caribbean. Monthly percentages of individuals in each reproductive phase are presented. Number of samples included for each month are provided above the bars.

- A total of 454 female yellowtail snapper samples from the Fish/Fisheries Conservation Lab FD and FI U.S. Caribbean collections were evaluated for maturity and indicators of active spawning to use in estimating spawning fraction, spawning interval, and spawning frequency

- U.S. Caribbean female yellowtail snapper spawning fraction overall was 0.13 (Table 8); overall spawning interval, defined as the number of days between spawning events in a female, was 7 d, indicating that a female spawns around 49 times over the estimated ~365-day spawning season

- When examining trends in spawning fraction, interval and frequency by length, spawning frequency increased with increasing length class; females in the smallest FL class had an estimated spawing frequency of six times over the spawning season, while females in the largest FL class had an estimated spawning frequency of 69 times over the spawning season (Table 8)

- Similar increases in spawning frequency occurred when examined by age classes; females in the oldest age class (13+ y) spawned approximately 85 times a year (Table 8)

Table 8. U.S. Caribbean female yellowtail snapper estimates for spawning fraction, spawning interval, and spawning frequency summarized overall, by size classes, and by age classes.

	Number of mature females in grouping	Spawning fraction (# actively spawning/ total mature)	Spawning interval (days between spawning)	Spawning frequency (# of spawns/y)
Overall	454	0.13	7	49
Size class (mm FL)				
201 – 250	57	0.02	57.0	6
251 – 300	185	0.12	8.4	43
301 – 350	117	0.17	5.9	62
351 – 400	37	0.19	5.3	69
401+	58	0.19	5.3	69
Age class (y)				
3-5	210	0.16	6.4	57
6-8	93	0.18	5.5	67
9-11	42	0.19	5.3	70
12+	30	0.23	4.3	85

Sexual maturity

- U.S. Caribbean yellowtail snapper gonad histology results for assessment of sexual maturity were combined from the two labs to provide overall estimates related to size-at-sexual maturity (Table 9)

- A total of 949 U.S. Caribbean yellowtail snapper samples with age and sexual maturity information were used to obtain estimates of age at maturity (Table 10)

Table 9. U.S. Caribbean yellowtail snapper length (mm FL) at sexual maturity (95% prediction intervals).

Variable	Sexes Combined	Female	Male
Number of samples	1876	922	954
L_{50}	194 (189 - 199)	207 (202 - 211)	182 (174 - 190)
L_{90}	238 (233 - 242)	244 (238 - 249)	229 (221 - 235)
L_{95}	253 (246 - 258)	256 (248 - 264)	245 (235 - 253)

Table 10. U.S. Caribbean yellowtail snapper age (y) at sexual maturity (95% prediction intervals).

Variable	Sexes Combined	Female	Male
Number of samples	949	482	464
A_{50}	1.5 (1.4 - 1.6)	1.5 (1.3 - 1.9)	1.6 (1.4 - 1.7)
A_{90}	2.2 (2.0 - 2.3)	2.1 (1.9 - 2.3)	2.3 (2.0 - 2.6)
A_{95}	2.4 (2.2 - 2.6)	2.3 (2.0 - 2.6)	2.5 (2.2 - 2.9)

Discussion/Conclusion

First report to provide comprehensive life history information (age, growth, and reproductive biology) for yellowtail snapper in the U.S. Caribbean.

We documented that U.S. Caribbean yellowtail snapper are characterized by a unique suite of parameter estimates when compared to data from other regions and time periods which emphasizes the importance of utilizing current and region-specific information to obtain parameter estimates for U.S. Caribbean stock assessments (Table 11).

We also showed the importance of combining gear-specific catches across a broad range of depths and fishing practices for reef fishes when seeking to document a comprehensive understanding of population life history trends for a region – our largest samples were obtained from fishers targeting schooling yellowtail snapper during night time pelagic foraging; our smallest fish were caught using castnets and spearfishing.

Population Demographics and Growth

The male to female sex ratio documented in the current study was slightly skewed to more females than males but was within range of sex ratios reported from other studies on yellowtail snapper (Figuerola et al. 1998, Trejo-Martínez et al. 2011). Minor deviations from 1:1 sex ratios are common for gonochoristic fish species and was observed in other yellowtail snapper populations. Male to female sex ratios from previous studies range from 1:0.8 – 1:1.4.

Several studies that examined age and growth in yellowtail snapper have reported on periodicity of opaque zone formation in sagittal otoliths (Johnson 1983, Manooch and Drennon 1987, Garcia et al. 2003, Allman et al. 2005). One study from the Caribbean reported that opaque zones formed from March – May (Manooch and Drennon, 1987) Another study from Florida reported increment formation from May – July (Johnson, 1983). Garcia et al. (2003) found that opaque zone formation occurred once annually in the spring with a peak in April which is consistent with our observations for the U.S. Caribbean. Caribbean yellowtail snapper peak opaque zone formation coincides with peak spawning in the region (Zajovits 2021). Previous studies on white grunt *Haemulon plumieri* (Potts and Manooch 2001), gray triggerfish *Balistes capriscus* (Shervette and Rivera Hernández 2022a) and queen triggerfish *B. vetula* (Rivera Hernández et al. 2019, Shervette and Rivera Hernández 2022b) also have noted a similar relationship between the timing of otolith opaque zone formation and peak spawning period.

In the current study, no significant difference in yellowtail snapper mean length between male and female was observed. Previous studies on yellowtail snapper from the GOM, Southeast Florida, and Cuba have also reported that mean size did not differ between male and female yellowtail snapper (Claro 1983, Figuerola et al. 1998, Allman et al. 2005, Trejo-Martínez et al. 2011). The current study documented differences in mean size and size frequency distributions between FD and FI samples. This difference is partially explained by the minimum size limit for commercially caught yellowtail snapper in the U.S. Caribbean. Previous studies utilizing FI and FD samples have also noted differences in mean length between FD and FI samples (Allman et al. 2005, Allman et al. 2018). Additionally, gear selectivity can impact size trends among fish samples caught utilizing different collection methods. Sampling programs that utilize randomized sampling designs to obtain FI samples of reef fishes require the use of a standard series of hook sizes while commercial fishers utilize larger hook sizes to target larger fish. Allman et al. (2018) noted that in their study on age and growth of gray triggerfish, sample source (FI versus FD) impacted size trends; the larger hook size used by commercial fishers in the GOM resulted in significantly larger FD samples.

Maximum size of yellowtail snapper from the current study was 572 mm FL which was within the range of maximum size reported from other life history studies on this species. The maximum reported sizes from Florida studies were 605 mm FL (Allman et al. 2005), 567 mm FL (Johnson 1983), and 561 mm FL (Garcia et al. 2003; Table 1). A study from the north Caribbean reported a maximum size for yellowtail of 590 mm FL (Manooch and Drennon 1987). A study on yellowtail snapper from the Yucatan Peninsula reported the smallest maximum size (455 mm FL; Trejo-Martinez et al., 2011).

The average maximum size of U.S. Caribbean yellowtail snapper (L_∞ = 424 mm FL) and the growth coefficient (K = 0.23) fell within the ranges for L_∞ and K reported from other yellowtail snapper growth studies (Table 1). Most studies reporting on yellowtail snapper growth have mainly utilized FD samples (Johnson 1983, Manooch and Drennon 1987, Garcia et al. 2003) A study from the north Caribbean examined yellowtail snapper growth for FD samples collected from 1983-1984 and reported an average maximum length (L_∞) of 503 mm FL and a growth coefficient of 0.14 (Manooch and Drennon 1987). A Florida study that examined growth of yellowtail snapper from FD collections for the years of 1994-1999 reported an L_∞ of 484 mm FL and a growth coefficient of 0.17 (Garcia et al. 2003). Another study from Florida that focused on age and growth of yellowtail snapper from FD sources collected in 1979-1980 reported an L_∞ of 451 mm FL and a growth coefficient of 0.28. Allman et al. (2005) utilized a combination of FD and FI samples to estimate growth for east Florida yellowtail snapper collected from 1980-2001 and reported a more moderate L_∞ of 410 mm FL and a growth coefficient of 0.27.

Previous studies on yellowtail snapper life history noted that large variations in length at age occurred for most age classes (Johnson 1983, Garcia et al. 2003, Allman et al. 2005); the same is true for yellowtail snapper in the U.S. Caribbean. Consequently, length is not an ideal predictor of age for this species.

In the current study, spawning capable female yellowtail snapper were observed in every month of the year. Our results support the general findings that yellowtail snapper exhibit year-round spawning in Caribbean waters. Other studies reporting on yellowtail snapper spawning seasonality have also observed year-round spawning (Munro et al. 1973, Trejo-Martínez et al. 2011). Caribbean yellowtail snapper in the current study had a peak in spawning from March – April which is consistent with peak spawning period for the species documented in waters of the Yucatan Peninsula (Trejo-Martínez et al. 2011), Cuba (Claro 1983), and Jamaica (Munro et al. 1973). As previously noted, yellowtail snapper populations from regions at higher latitudes may exhibit a shorter spawning season compared to populations at lower latitudes. Spawning season in Florida is shorter than that observed in the Caribbean and extends from spring to summer with a peak from May – July (Muller et al. 2003). The signal which yellowtail snapper utilizes to initiate spawning aggregations within peak months is not fully known. Trejo-Martinez et al. (2011) speculated that the new moon phase may play a role in igniting aggregations, but further study is necessary to determine if the monthly spawning pattern of yellowtail snapper correlates with moon phase.

Table 11. Comparisons with and corrections of parameter estimates summarized in Stevens et al. 2019 for yellowtail snapper, stoplight parrotfish, and queen triggerfish

Species and Study	**Maximum Age (y)**	**$L_\infty/K/t_0$**	**LM_{50}/AM_{50}**	**LT_{50}/AT_{50}**
Yellowtail snapper				
Summarized in Stevens et al. 2019; original source SEDAR 27A: Yellowtail snapper stock assessment report for SA and GOM; samples used for growth parameters were collected from 1980-2010	23	618 mm TL (~490 FL)/ 0.13/-3.13	232 mm FL** 1.7 y	Not Applicable
SEDAR 2020 provided updated yellowtail snapper information focused mainly on Florida management needs; growth parameter samples were collected from 1980-2017; maturity parameters based on samples collected prior to 2003	28 (SC/NC) 20 Florida	426 mm FL/0.20/-1.93; used size-truncated growth model with constant CV	192 mm FL 1.7 y	Not Applicable
U.S. Caribbean current study 2010-2023	26	508 mm FL/0.12/-2.73 424/0.23/-0.96(fixed) 467/0.16/-1.93(fixed)	194 mm FL 1.5 y	Not Applicable
Stoplight parrotfish				
Summarized in Stevens et al. 2019; original sources for parameter estimates were Choat et al 2003 for age/growth using fish collected in 1990s from Bahamas; and Figuerola et al 1998	9	357 mm SL (~412 FL)/ 0.45/-0.06; t_0 was fixed value based on length at hatch of a Pacific parrotfish species	205 mm FL (based on only fisheries-dependent samples)/not reported	Stevens et al. 2019 did not provide summary information on size and age at sexual transition

Species and Study	Maximum Age (y)	$L_\infty/K/t_0$	LM_{50}/AM_{50}	LT_{50}/AT_{50}
Rivera Hernandez and Shervette 2024 U.S. Caribbean 2015-2023 (SEDAR84)	20 (overall) 14 (validated)	338 mm FL/0.33/-0.52 332/0.39/-0.06(fixed)	153 mm FL 1.6 y	279 mm FL 4.5 y
Queen triggerfish				
Summarized in Stevens et al. 2019; original sources for parameter estimates were: Albuquerque et al. 2011 for age/growth – samples from Brazil collected in 1990s; Aiken 1975 maturity – samples from Jamaica collected in early 1970s and used macroscopic gonad assessment	14 based on dorsal spine	441 mm FL/0.14/-1.8	215 mm FL 2.97 y	Not Applicable
Shervette and Rivera Hernandez 2022a U.S. Caribbean samples collected from 2013-2021 for SEDAR80	23 (overall) 21 (validated) based on otoliths	430 mm FL/0.15/-0.585	212 mm FL 3.5 y	Not Applicable
Shervette and Rivera Hernandez 2022b Using samples from NC/SC collected 2012-2020	40 based on otoliths	520 mm FL/0.14/-0.585; t_0 was fixed value based on study from U.S. Caribbean	Not Reported	Not Applicable

**** Stevens et al. 2019 reported this value as "c. length type was converted to fork length" but this statement was in error. The original source of the value indicates that the length type for 232 mm was TOTAL LENGTH; that original source reported that LM_{50} = 192 mm FL which was the same maturity parameter estimate used for 2020 assessment.**

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